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Food and Agriculture Organization of the United Nations

INBAR
INTERNATIONAL BAMBOO AND RATTAN ORGANISATION

Policy Synthesis Report

Bamboo for land restoration

Drawing recommendations and best practices from case studies where bamboo has been used for land restoration: China, Colombia, Ghana, India, Nepal, South Africa, Tanzania and Thailand.

Bamboo is a versatile plant that can provide climate-smart solutions to millions of rural communities – if its benefits are recognised by decision makers and planners and if national sustainable development policies address the benefits that bamboo can offer.

NEPAD TRANSFORMING AFRICA

TERRAFRICA REGIONAL SUSTAINABLE LAND MANAGEMENT

INBAR Policy Synthesis Reports

INBAR Policy Synthesis reports aim to inform decision makers in government and international development partners of the benefits that bamboo and rattan can bring to their efforts to build sustainable development and green economies that improve peoples' livelihoods. INBAR, The International Bamboo and Rattan Organisation, is an intergovernmental organisation bringing together some 40 countries for the promotion of the ecosystem benefits and values of bamboo and rattan.

Key Words

Bamboo, land restoration, land degradation, INBAR, forestry, sustainable development.

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Forewords

Food and Agriculture Organization of the United Nations

We are pleased to have collaborated with the International Bamboo and Rattan Organization (INBAR) and the New Partnership for Africa's Development (NEPAD) on an assessment on bamboo for land restoration. The report explores a variety of case studies from Asia, Africa, and Latin America in assessing the ecological and socio-economic viability of using bamboo for land restoration, and provides key lessons learned and recommendations for using bamboo for land restoration initiatives. Bamboo is not only a versatile and hardy species with many traditional and non-traditional uses. As the report outlines, its exceptional environmental and biophysical properties make it an efficient and cost-effective approach to addressing some of the complex challenges of land degradation we are currently facing, particularly in areas of severe degradation.

The Food and Agriculture Organization of the United Nations (FAO) has long been at the forefront of efforts to develop new techniques in support of sustainable agriculture, and has championed the role of agriculture in sustainable development. The strategic focus of FAO balances the imperatives of food security, elimination of poverty, and sustainable management and use of natural resources. Our vision is that of a world free from hunger and malnutrition, where food and agriculture contribute to improving the living standards of all, especially the poorest, in an economically, socially, and environmentally sustainable manner. Bamboo and rattan have an important role to plan in realising this vision.

It is for this reason that FAO welcomed, and embraced, the opportunity to collaborate with INBAR in this global assessment. We believe that bamboo and rattan provide numerous pathways to support sustainable green growth, and we look forward to working with member countries of INBAR and the Secretariat in further developing and applying the findings this report has provided. Moreover, this report provides an excellent opportunity to further develop the nascent initiatives for south-south cooperation that exist in many countries in the use of bamboo and rattan in support of national sustainable development strategies within the context of the Sustainable Development Goals.

FAO, in partnership with member countries, has developed a comprehensive, global strategy for sustainable food and agriculture which is well aligned with the Sustainable Development Goals. The progressive use of bamboo and rattan can play an important, and perhaps even pivotal, role in implementing both national and global sustainable development strategies in many countries around the world. We look forward to working with INBAR on this effort, and with country partners in developing transformative investments in this area.

- Mr. Eduardo Mansur
Director, Land and Water Division,
Food and Agriculture Organization of the United Nations

International Bamboo and Rattan Organisation

The International Bamboo and Rattan Organisation (INBAR) takes land degradation very seriously. In fact, the United Nations' Sustainable Development Goal 15 – 'Protecting life on land' – is one of our core focus areas.

With a network of 43 Member states, almost all of which are from bamboo-producing countries, INBAR has considerable experience in using bamboo for land restoration. We work in a number of countries whose ecosystems, watersheds and rural livelihoods are affected by land degradation and desertification. Over the years, we have supported a number of projects to restore land across our Member states, and the results have been inspiring. Soil quality improves, biodiversity recovers and crucial ecosystem services are restored.

Poverty alleviation is also a core focus of INBAR's work, and we realise the benefits that local bamboo stands can have for rural populations. Fast growing and easily replenishable, with no need for replanting, bamboo can be used to create an inexhaustible supply of commodities for sale, as well as disaster-resilient construction and bio-based energy. Using bamboo to restore land, then, has important co-benefits for rural communities.

Our Members' support speaks for itself. In 2014, at the ninth meeting of our INBAR Council, our Member states pledged to restore 5 million hectares (ha) of degraded lands using bamboo – an important contribution to the Bonn Challenge, which aims to bring 150 million ha of the world's deforested and degraded land into restoration by 2020.

We are delighted to publish this important new report on land restoration, and we hope that it inspires concerted efforts among our Member states and other countries to make more use of this incredible plant. When you think of land restoration and poverty alleviation, we urge you to 'think bamboo'.

- Dr. Hans Friederich
Director General, International Bamboo and Rattan Organisation

New Partnership for Africa's Development

This joint Policy Synthesis Report on Bamboo for Land Restoration was made possible by the close collaboration between the International Bamboo and Rattan Organization (INBAR), the United Nations Food and Agriculture Organization (FAO), and the New Partnership for Africa's Development - NEPAD - Planning and Coordinating Agency (NPCA). The NEPAD Agency, with a footprint in 52 African Union Member States, leads its actions through the following four thematic programmes: Natural Resources Governance and Food Security; Regional Integration Infrastructure and Trade; Human Capital Development (Skills and Employment) and Industrialisation Science Technology and Innovation.

The NEPAD Agency supports African Union Member States on two major continental initiatives to improve natural resource-based livelihoods and ecosystem functions with the TerrAfrica Partnership and the African Forest Landscape Restoration (AFR100) initiative. It was through the active contributions of INBAR and FAO as key strategic partners and African countries, particularly Ghana, South Africa and Tanzania, as active TerrAfrica Member countries, that this report was put together. The highlighted case studies showcase how bamboo restoration provides environmental (improved soil quality, water regulation, combat erosion…), social (regulations in place, increased local involvement, local knowledge…) and economic (bamboo enterprises development, job creation…) benefits to countries. For instance, in Ghana, a rule that 20 per cent of profit of bamboo plantations should be given to the workers encouraged more participation by local communities to restore land with bamboo. In that sense the invaluable support of INBAR and FAO strengthen the role of bamboo for land restoration, which is a key to the development of African economies. Indeed the dedication and sustained efforts of these partners alongside the NEPAD Agency in providing leadership and guidance in the implementation of bamboo for land restoration was critical and strategic to the successful preparation of this report, especially in the perspective of improving land restoration in the continent.

I am confident that this synthesis report will inspire more discussions and will lead to relevant actions at national, regional and continental levels to move towards a more sustained management of land resources.

Wishing you all an excellent read.

- Dr. Ibrahim Assane Mayaki
CEO, NEPAD Agency

Introduction

Land degradation occurs in every country as a result of biodiversity loss, soil erosion and depletion, soil pollution and water shortage. Degraded land has serious adverse impacts on the environment, including soil quality degradation, local water loss and threats to biodiversity. This in turn has a knock-on effect on economic and social services derived from the ecosystem by reducing the productive capacity of agricultural land, threatening food security (Nachtergaele et al. 2008) and even increasing the risk of disease (World Health Organisation 2018). According to one estimate, between 2001 and 2009, land degradation cost about USD 11 billion in Kenya, USD 18 billion in Tanzania and USD 35 billion in Ethiopia (Kirui and Mirzabaev 2015).

Bamboo possesses qualities that make it ideal for restoring degraded lands. It is able to thrive on degraded soils and steep slopes where many plants cannot grow. Being a perennial monocot plant, it has extensive fibrous roots that make it capable of stabilising loose soil to prevent soil erosion. Multiple studies have shown that the underground rhizomes and fibrous roots of bamboo can measure up to 100 kilometres (km) per ha of bamboo stand, grow to a depth of 60 centimetres (cm) and live for a century (Acharya et al. 2016). This underground biomass makes bamboo capable of surviving and regenerating when the biomass above ground is destroyed, for example, by fire. As well as its extensive root system, bamboo is one of the fastest growing woody plants able to grow up to one metre in a day (Zhou et al. 2005). It is therefore able to re-vegetate and restore productivity to bare land over a short period. In fact, sustainable harvesting of bamboo, at between a sixth and a third of the stand per year, encourages thicker growth of the stand in subsequent years.

For these reasons, an increasing number of countries have begun to identify and explicitly include bamboo as a high priority species for use in landscape restoration. Cameroon, China, Ethiopia, Kenya, Ghana, India, Madagascar, the Philippines and Vietnam are examples of just some countries that now specifically include bamboo in their sustainable land management (SLM) programmes. Indeed, in 2014 Members of INBAR committed to support the global Bonn Challenge for land restoration using bamboo and agreed to work towards a plan for reclaiming million ha of degraded land (INBAR 2018).

As well as its land restoration credentials, bamboo provides important additional benefits as a commodity. Fast growing and easy to harvest, bamboo can be used to earn income within as little as three years, making it a sustainable alternative to several types of wood (FAO 2005). For this reason, bamboo has been used for millennia by rural communities across the world, to create a wide range of products. In recent decades, bamboo has also played an increasing role in poverty alleviation across many countries – a change partly enabled by the shift from 'low-end' crafts to 'high-end' value-added commodities, and from an increasing recognition of bamboo's usefulness as a source of high-strength construction and bioenergy. By creating bamboo products, individuals can now participate in a sector with an estimated annual trade value of USD 60 billion. [1]

Even though bamboos have already been extensively used in many national and sub-national restoration programmes, public information about bamboo-based landscape restoration initiatives and the reasons for their success or failure is limited. This is important because restoring degraded land requires a careful balance of scientific research and community input. The selection of planting species, for example, is a crucial step, and the species chosen should be not only ecologically suitable for the soil and climatic conditions but also socially and politically supported. This synthesis report aims to address these knowledge gaps.

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1 INBAR estimates this based on its annual trade analysis reports,

collected using data from UN Comtrade.

1. Key findings

The case studies presented in Chapter 2 offer a wide range of projects from across Africa, Asia and Latin America. Diversity aside, there are several particularly clear findings from the case studies. It is apparent that bamboo can be a very important tool for land restoration. It is equally clear that bamboo offers an important co-benefit and can increase incomes for local residents. The case studies also make clear that, to be successful in the long term, bamboo land restoration projects require social acceptance and local buy-in, which can largely be achieved by clearly outlining the environmental and economic benefits of bamboo.

Environmental benefits

Several of our case studies support previous research and local knowledge about bamboo: when properly selected and well managed, bamboo species can help improve the soil quality of degraded land and raise the groundwater table level. Our study in India shows how severely degraded soil – the result of an intensive brickmaking industry – staged a remarkable recovery after planting with bamboo. Within 20 years, the groundwater table had increased by 10 metres (m), and agricultural crops and tree species had been incorporated into a bamboo landscape. As a result of its success, the project was scaled up to cover 100,000 ha of degraded land in 600 villages, to the economic and social benefit of over one million people.

Similarly, in Colombia, planting *guadua* bamboo in degraded soil improved soil quality, decreasing soil compaction by more than half. This more porous soil, with a lower bulk density, quickly restored several crucial ecological functions, including water regulation and nutrient recycling. In Nepal, a similar plantation helped reduce soil erosion and flood damage.

Improved water regulation was also a key feature of the study in Chishui, China. A comparison of soil conditions between a bamboo plantation and sweet potato farm found that bamboo plantations had 25 per cent less water runoff. The bamboo plantation also helped to reduce the average soil erosion by 80 per cent, and the established bamboo plantation significantly reduced soil erosion up to 27 t soil/ha/year.

As well as restoring degraded lands, harvested bamboo can be used to reduce coastal erosion. In Thailand, a fence of bamboo poles was erected to protect a growing area of mangroves. The bamboo wall bore the full brunt of the waves, reducing the force of each wave by up to 70 per cent and the height by 87 per cent. Over three years, the bamboo fence had also increased sediment accumulation by 56 cm, clearly showing that bamboo's resilience as a 'woody' grass product also contributes to land restoration and watershed protection.

What these studies also make clear, however, is that bamboo species must be selected carefully. Unsurprisingly for a plant which boasts over 1600 species, some species of bamboo can grow under dry conditions, while others cannot. The case in South Africa shows that planting *Bambusa balcooa* in a place with low annual precipitation (650-700 mm/year) resulted in a low survival rate, and planted bamboos were susceptible to pest and disease; projects would do better to use *Oxytenanthera abyssinica*, which grow well under the same conditions.

Livelihood gains and social acceptance

In most of the case studies, the acceptance and involvement of local people was regarded as an essential component of the project's success. The project organisers for these studies used a participatory approach in the planning, implementation and management of the plantations to encourage locals to participate in land restoration, which was largely successful. In China, local farmers were actively involved in using bamboo for land restoration, under combined approaches from local governments that included awareness raising, subsidies and legal obligations. In Ghana, the rule that 20 per cent of the profit of bamboo plantations was given to workers encouraged participation. In Tanzania, meanwhile, awareness raising about the link between bamboo plantation programmes and bamboo enterprise development led to increased local involvement.

As most of the case studies show, land restoration with bamboo creates many jobs for local people, especially women.

In Anji county, China, the bamboo sector provided jobs for about 100,000 people; in Tanzania, a number of bamboo enterprises were established, creating jobs for almost a thousand villagers.

Awareness raising is a crucial part of securing the support and participation of locals. Local people took an active role in these bamboo plantation programmes once they were made aware of adverse effects of land degradation and the benefits and products that bamboo can sustainably provide after only a few years. The links between bamboo plantations and product development were particularly important in this regard.

Economic viability

Just as important as bamboo's ability to rehabilitate degraded soil is its attractiveness as a commodity. Following the establishment of bamboo in Anji, China, several lucrative markets developed. By 2012, the value of Anji bamboo shoots alone reached about USD 2 billion. In addition, Anji's abundant bamboo forests have become a lucrative tourist destination. In 2011, 7.74 million tourists visited Anji, spending USD 850 million. As a direct result of bamboo land restoration efforts, farmers' annual income from bamboo has increased by around 1000 RMB – over half the value of the farmers' income before the project began. Bamboo enterprise development has also proven very successful in Tanzania, where bamboo-related enterprises have generated an estimated extra USD 200 every month per household.

Key lessons learned and recommendations

The key lesson from these case studies is simple. Bamboo can play an important role in reclaiming degraded land and contributing to poverty alleviation in rural areas. That said, a lot depends on the careful implementation of these projects. The long-term success of bamboo land restoration requires the consideration of a number of factors.

First, programme developers should actively encourage and plan for local participation. Participatory decision-making and planning processes are particularly crucial for the long-term management of the reclaimed land, after the project has ended. Furthermore, a land restoration approach that incorporates local knowledge and wisdom when developing restoration models with bamboo can result in improved outcomes.

Raising awareness – through local media or via awareness campaigns – is a key element to actively involve local people in projects. Awareness campaigns should make clear the benefits of bamboo plantations for erosion control and

The case studies show that a combination of attractive subsidies and regulatory policies can speed up the land restoration process and encourage people to take land management responsibilities seriously.

environmental protection, as well as the tangible benefits which bamboo culms provide.

Given the huge income potential of bamboo products, bamboo land restoration projects should also consider integrating bamboo product development into their plans and providing appropriate support and training. Projects should also encourage the establishment of community-driven enterprises, which create employment opportunities, generate income and provide locally available renewable products. Finally, training and capacity building are key to ensuring an intervention's long-term sustainability.

Site-species matching selection is therefore a critical requirement to identify suitable species and appropriate management options. The existing literature on bamboo species and soil matching, planting density, pests and diseases, and plant nutrition is yet to reach some project implementers who are using bamboo for land restoration.

Once a suitable species has been chosen, the establishment of local nurseries can help produce a number of high-quality offset bamboo seedlings for small-scale projects. For larger projects, more research is needed regarding the most cost-effective way to produce a large quantity of planting materials, including bamboo tissue culture and seedlings.

From a regulatory perspective, the case studies show that a combination of attractive subsidies and regulatory policies can speed up the land restoration process and encourage local people to take land management responsibilities seriously. More complicated is the situation regarding land rights. Local people do not want to restore degraded land when land tenure and ownership rights are not clear. Therefore, restoring degraded land in unclear land ownership and land use conflict situations should first settle the land tenure and ownership rights.

2. Bamboo for land reclamation: case studies

Africa

Ghana

Compiled by Dr Nana Afranaa Kwapong

Introduction

In Ghana, there is great potential for bamboo to be used for restoring degraded areas. Soils and lands in Ghana are vulnerable to degradation as a result of human and natural factors. Human activities associated with the pressures of increasing population growth and urbanisation, unsustainable agricultural practices, deforestation, overgrazing, mining and other industrialisation activities all contributed to land degradation. In addition, natural factors have contributed to soil erosion, compaction, depletion of soil nutrients, salinity, acidification and loss of organic matter. About 69 per cent of total land surface area in Ghana is prone to soil erosion, particularly prevalent in the Upper East, Upper West, Northern and Ashanti Regions (PROFOR 2011). Soil erosion is estimated to cost between 1.1 to 2.4 per cent of the country's GDP, corresponding to between 2.9 to 6.3 per cent of agricultural GDP or USD 166 million. Deforestation in Ghana is one of the highest in the world; it is estimated at an annual rate of 2 per cent and accounts for 1,075,000 ha of forest land degraded (FIP and MLNR 2012). Peprah et al. (2014) demonstrated the ability of bamboo to restore degraded lands in Ghana, reporting overall survival rates of 95 per cent and rapid foliage growth converting degraded sites into green landscapes.

The Government of Ghana (GoG) is committed to finding innovative ways to restore degraded lands. The GoG recognises the environmental and socio-economic importance of bamboo and has enacted policies and programmes that promote the bamboo industry to restore degraded lands. In 2001, the GoC launched the National Forest Plantation Development Program (NFPDP) to restore landscapes through large-scale tree planting across the country to recover degraded forest areas, improve environmental quality, generate employment and enhance food production (Forestry Commission 2002, 2016). The implementation of the NFPDP is guided by the Ghana Forest and Wildlife Policy, which emphasises, as part of its objective, the rehabilitation and restoration of degraded landscapes through forest plantation development, enrichment planting and community forestry (MLNR 2012). This policy directive is to be achieved through government and private sector capital investments and community engagement in reforestation and forest plantation development. The Ghana Forest Plantation Strategy sets a target of establishing 625,000 ha forest plantation, of which 50,000 ha of bamboo plantation is to be planted by the year 2040, with an annual plantation rate of 2,000 ha per year (Forestry Commission and MLNR 2016). As a complement to the NFPDP, the government in collaboration with INBAR, the United Nations Industrial Development Organization among other stakeholders in 2012 established the Bamboo and Rattan Development Programme (BARADEP). BARADEP's aim was to promote the bamboo and rattan industry development as an alternative raw material to timber, thereby reducing the pressure on natural forest for timber to restore landscapes and create jobs (Ghana Forestry Commission 2012). Since its establishment, BARADEP has facilitated awareness raising and education on the socio-economic and environmental benefits of bamboo and supported the development of bamboo plantations nationwide together with the Ghana Forestry Commission, private sector and local communities (information available on request). In addition, BARADEP promotes the processing and utilisation of bamboo resources for many products including furniture, craft, construction, charcoal, bicycles and floor mats. The Ghana SLM programme promotes bamboo as a strategic resource to reduce land degradation and improve productivity, wildfire management, watershed management, forest plantation development, biodiversity conservation and ecosystem stability (EPA and MESTI 2011).

The bamboo industry in Ghana is in its infant stages, hindered by major constraints including limited knowledge on the importance and benefits of bamboo and a lack of technical knowledge of bamboo species, nurseries establishment, plantation and management (J. Osiakwan, personal interview, 2018). There is also a lack of interest in growing bamboo due to the perception that, when established, bamboo takes over arable land and such land cannot be put to any alternative use (M. Kwaku, personal interview, 2018). These challenges prompt the need to intensify education and awareness raising on the environmental and socio-economic importance of bamboo. Another challenge facing the bamboo industry is insufficient financial investment to support the bamboo sector, from both the public and private sectors (Osiakwan 2018; Acquah 2018). However, the GoG, in partnership with the Chinese government, is in the process of setting up a bamboo and rattan processing, demonstration and equipment centre to create demand for bamboo and to motivate the private sector to invest in bamboo plantation.

Case Study Approach

This case study highlights the potential of bamboo to restore degraded lands in Ghana. Three case examples on how bamboo has successfully been used to restore degraded land through forest conservation, reclaiming mined-out land for riparian re-vegetation are presented in this report. The studies were conducted in three regions of Ghana – the Upper East, the Western and the Ashanti regions, with the respective agro-ecological zones – guinea savannah zone, evergreen forest and forest savannah transition zone (Figure 1). In all zones, the natural vegetation has undergone considerable changes due to human activities. The case study sites were purposively selected to explore the wide adaptability of bamboo to various agro-ecological conditions, identify suitable bamboo species under these conditions and assess the suitability of bamboo for restoring degraded landscapes. Field visits were made to the selected sites to observe the bamboo plantation impact on the environment and assess the socio-economic benefits. Informal and key informant interviews were conducted with project managers, community members, farmers and policymakers. The fieldwork was conducted in December 2017 and January 2018 with support of the TerrAfrica Secretariat hosted by the NEPAD Planning and Coordinating Agency.

Figure 1. Site for case study on bamboo for land restoration in Ghana: 1-North Bandai Hills forest reserve Ashanti Akyem South District, Ashanti Region; 2- Pawlugu- Bolgatanga , Upper East Region; 3-Nsuta, Tarkwa, Western Region.

CASE 1: North Bandai Hills Forest Reserve Bamboo Plantation for Forest Conservation

(a) *(b)*

Figure 2. (a) Forest destroyed by bushfires and (b) forest vegetation cover after planting bamboo.

Since the 1970s, the forest vegetation in the North Bandai Hills forest reserve located in the Ashanti Akyem North district in Ashanti region has been destroyed because of logging activities, cutting and burning of wood for charcoal and from activities of migrant nomadic herdsmen who set bushfires to regenerate new grass for feeding their cattle. Owing to these human activities, the forest vegetation cover was rapidly being lost and turning into grassland. The Ghana Forestry Commission in 2014 signed a pubic private partnership agreement with Ecoplanet Bamboo, an innovative forestry company that develops integrated bamboo plantations as an alternative raw material resource to timber, to reduce deforestation. Under this partnership, a 2818 ha commercial bamboo plantation was to be established within the North Bandai hills forest to reverse deforestation and provide a long-term sustainable source of bamboo fibre for the production of toilet paper, packaging materials and textiles. Ecoplanet Bamboo Company established nurseries on site for the multiplication of three species of bamboo – *Oxytenanthera abyssinica*, *Dendrocalamus asper* and *Bambusa Textilis*. A land area of 923.4 ha has been planted with bamboo within the forest reserve, which will be sustainably harvested as raw material for the production of textiles and for other usages, including construction, crafts and charcoal. Communities along the fringes of the forest reserve who depended on the forest for their livelihood were involved in the project, creating employment for over five hundred local inhabitants. They worked at the nurseries raising seedlings and on the plantation undertaking land preparation, weeding, transplanting bamboo plantlets, watering and farm maintenance.

The bamboo species were planted between trees and remnants of forest patches. With the introduction of bamboo, the gaps in the vegetation cover are gradually closing. The bamboo replaced the trees that had been destroyed by bushfires or cut for charcoal burning. The bamboo developed shoots and foliage which have closed the gap between the remaining tree stands, changing the entire vegetation cover to forest. Wildlife and other plant species growth in the forest are gradually being restored. Birds and bush animals that previously lived in the forest are returning to the forest reserve.

One major threat to the success of the project is bushfires, which are an annual occurrence, often set off by migrant Fulani herdsmen from Mali and Burkina Faso who trespass into the forest reserve in search of fodder for their livestock. They deliberately set off the bushfires to burn the vegetation to get new grass for their livestock. The bushfires destroy the young bamboo plants and retard the growth of the established bamboo plants. However, unlike many other tree species that are completely destroyed by the fires leaving the land bare, the established bamboo is able to withstand the bushfires; the bamboo shoots stay on the land and rejuvenate when they receive some water. This unique characteristic of the plant compared to the other tree plants makes bamboo useful for maintaining cover in areas with rampant bushfires that destroy vegetation cover. Weed maintenance and the establishment of fire belts around the bamboo is essential but costly. To address this threat and to upscale the project, the Ghana Forestry Commission in collaboration with the local community is adapting the 'taungya' system, where community members in groups of five are allocated land on which to plant and maintain bamboo and plant plantain in-between. These arrangements reduce the cost of weeding and provide land for community members to plant crops to not only supply food for household consumption but also gain income from sales of surplus produce. Access to land and ownership of crops is an incentive for community members to protect the plantation from bushfires. Under the partnership agreement, Ecoplanet Bamboo Company is entitled to 80 per cent of the standing tree value of the bamboo plantation. The remaining 20 per cent is allocated to the GFC, landowners and forest fringe communities. The first batch of bamboo planted is ready for harvest after two years, and planting is ongoing under the 'taungya' system to increase the land area planted with bamboo.

CASE 2: Bamboo for riparian re-vegetation in Northern Savannah Zone

The Northern Savannah ecological zone, made up of the northern region, the upper east and the upper west regions, experiences prolonged periods of dry season (7-8 months) that reduces the vegetation cover. The soils are prone to risk of erosion and have limited capacity to retain and drain water and hold nutrients. Farming practices along the streams and river banks pollute water bodies with agrochemicals and erode river banks. Illegal mining activities, charcoal burning and bushfires have resulted in severe degradation of vegetation and water bodies. The Ghana Sustainable Land and Water Management Program was initiated in 2016 with the goal of reducing land degradation and enhancing biodiversity in the northern savannah ecological zone (EPA and MESTI 2011). The department of agriculture is the lead institution in the implementation of the project with the EPA, Ghana Forestry Commission and local communities. An aspect of this project focuses on water catchment area protection to protect three river bodies – White Volta, Sissila river and Kulpawn river – to reduce soil erosion, siltation and the harmful effects of agricultural activities along river banks and from illegal mining activities (Osmani L., personal interview, 2018; E. Yeboah, personal interview, 2018). The policy on buffer zone protection indicates recommended buffer zone widths of 15 to 60 m along major rivers and streams; however, farmers plant crops within the buffer zone (EPA and MESTI 2011).

The Sustainable Land and Water Management Program, using bamboo for riparian re-vegetation, started mid-2017. The project is implemented in twelve districts. Bamboo is planted along the river catchments to restore the vegetation cover, reduce soil erosion and stop farmers from farming close to the river banks (Osmani L., personal interview, 2018; E. Yeboah, personal interview, 2018). Community members farming along the river bed were sensitised to the need for river buffer zone protection. Community watershed management committees were formed and interested community members, mostly farmers who farm along river beds were given bamboo saplings and other tree seedlings to plant along the river buffer zone. Farmers were trained on land preparation, planting, mulching, fertiliser application and tree maintenance. Agricultural extension agents and technical experts provided technical advice on the environmental and economic benefits of planting bamboo. About 7000 bamboo saplings were supplied to 48 farmers whose farms were located close to the river banks, covering over 50 ha (Osmani L., personal interview, 2018; E. Yeboah, personal interview, 2018). Bamboo grows

faster than other trees planted for catchment area protection such as cassia and eucalyptus. Within six months of planting the bamboo along the river banks, stands about 5 m developed. Other conservation trees would take longer to grow to this height (Osmani L., personal interview, 2018; E. Yeboah, personal interview, 2018).

(a) (b)

Figure 3. (a) Farmlands along the White Volta river bed, river polluted by illegal mining activities and (b) bamboo (6 months) planted along the White Volta river banks.

Farmers participating in the riparian re-vegetation programme were optimistic the bamboo would help protect against soil erosion. Moses Atubga Akunbila, a farmer who had planted bamboo describes the benefits as helping to reduce soil erosion and protect the land. When the culms are matured, the bamboo could be sold to craftsmen who use it for furniture. The bamboo can also be intercropped with other crops such as yellow melon and calabash (Akunbila, personal interview, 2018). Farmers have also mentioned ruminants (grasscutter) feeding on the bamboo leaves and shoots as another co-benefit.

A major challenge is the dry weather conditions in the area, which requires farmers to water the bamboo, especially in the initial stages. Farmers along the river catchment area have pump machines to draw water from the river and irrigate their farmlands. This water is also used for watering the bamboo: farmers' mulch around the bamboo to reduce water evaporation from the soil after watering. Community members have embraced the project due to its foreseen benefits, even though the planting of bamboo started only six months ago, and they are interested in planting bamboo for its environmental and economic benefits. The government policy on buffer zone protection needs to be enforced and promote the planting of bamboo along the river catchment area. Monitoring and data collection on the growth and impact of bamboo should be done to measure outcomes of the intervention.

CASE 3: Bamboo Land Reclamation and Renewable Energy Project

Ghana Manganese Company (GMC) owns and operates the Nsuta manganese mine in the Western region of Ghana, a mining concession over an area of 175 km². The company, which has been mining manganese since 1916, explored innovative sustainable ways of reclaiming mined-out land. In 2013, GMC signed a partnership agreement with Darlow Enterprise, a company specialising in the establishment of commercial bamboo plantation on marginal and degraded land for environmental services, for a renewable energy crop to supplement the high energy demand of the company for its mining operations.

According to Darlow Enterprise, after four years, bamboo will yield in excess of 100 tons of bamboo wood chips per ha with a 50-year lifespan (Darlow 2013). Bamboo has a high calorific value of 4200, low ash and sulphur content; as such, it is a good source for generating renewable energy (Darlow 2013). Darlow Enterprise imported 20,000 bamboo saplings for the plantation. Three bamboo species – *Bambusa vulgaris, Beema bamboo* and *Bambusa pervariabilis* – were

The case studies show that using bamboo for land restoration is a promising practical option for restoring degraded land through forest conservation, reclaiming mined-out land, rejuvenating riparian re-vegetation and reducing soil erosion.

planted on 10 ha of mined-out land as a trial before upscaling. The project created jobs for community members who worked at the nursery, preparing land for planting and initial maintenance of the bamboo plantation.

(a) *(b)* *(c)*

Figure 4. (a) Mined-out land covered with soil, (b) bamboo established on mined-out land and (c) vegetation cover on reclaimed mined site at GMC.

The project is in its fourth year since the establishment of the bamboo plantation. At the site, the bamboo has formed a thick canopy covering, developed many culms and completely colonised the land, turning the land cover at the site into a forest. The fallen leaves have covered the soil surface and enriched the soils, improving the soil properties, and the extensive root system of the bamboo has bound the gravel and soil, helping to reduce soil erosion on the land. The bamboo plantation has improved the biodiversity and serves as a habitat for many bird species. Even though it is evident the bamboo had successfully restored the mined-out land, the project after establishment did not collect data on the growth and impact of the intervention on the environment to measure, for instance, the amount of humus added to the soil, the average number of culms, carbon capture, carbon emissions or wildlife numbers. The culms are currently ready for sustainable harvesting. GMC and Darlow Enterprise are collaborating to move forward with sustainable harvesting for production of bioenergy and other alternative uses. This pilot project has demonstrated the potential of bamboo to restore degraded mined-out land. The project could potentially be upscaled to cover other mined-out land, especially in restoration areas where illegal mining of gold has destroyed the land in Ghana.

Conclusion and Recommendations

In addition to the environmental benefits of establishing bamboo plantation, economic benefits include employment creation, income from the sales of processed products, and the potential to produce biomass-based products such as textiles, paper and renewable energy.

The GoG has enacted policies to rehabilitate and restore degraded landscapes through forest plantation development. Bamboo has a potential role in achieving this goal. The Ghana Forest Plantation Strategy set a target of establishing 625,000 ha of forest plantation, of which 50,000 ha of bamboo plantation is projected to be planted by the year 2040, with an annual plantation rate of 2,000 ha per year (FC and MLNR 2016). The bamboo industry in Ghana is in its infant stages, hindered by major constraints including limited knowledge of the importance and benefits of bamboo; a lack of technical knowledge of bamboo species, nurseries establishment, plantation and management; insufficient financial investment in resources to support the bamboo sector both from the public and private sector; and a lack of a bamboo processing industry.

There is a need to intensify education on the importance of bamboo and provide technical support towards establishing and managing bamboo plantations. There is also a need to increase investment in establishing bamboo plantations and in setting up bamboo processing centres, demonstration and equipment centres to create demand for bamboo and thus motivate the private sector to invest in establishing bamboo plantations.

For established bamboo plantations, there is the need for proper plantation management, including weed control and bush fire prevention; the provision of adequate nutrients, sustainable harvesting monitoring; and data collection on the stages of growth and impact on the environment. Close supervision of public-private-partnership arrangements and the involvement of government agencies, such as EPA, GFC, INBAR and other key strategic partners and local communities for bamboo project sustainability, is also needed.

South Africa

Compiled by Camille Rebelo

Introduction

With more than 0.7 million ha of extremely degraded agricultural land (Republic of South Africa 2016), South Africa has a high potential for bamboo as a tool for restoration and economic regeneration. Between 2000 and 2010, the country lost 1.2 million ha of commercial crop production due to low productivity and/ or economically unviable yields (Tilahun et al. 2015). This trend resulted in an increasing land base for which few opportunities currently exist; therefore, identifying a use for this land that can provide both economic development and rural jobs is becoming a priority concern.

Despite a low occurrence of native bamboo species, the potential of bamboo for the country was recognised as far back as the 1900s, when the government considered utilising sympodial timber bamboo for developing what later became an extremely successful, but tree (pine and eucalyptus)-focused, forestry and pulp industry (Ohrnberger 1999). The targeted bamboo species was *Bambusa balcooa*, a dense and high-yielding bamboo whose distribution specialists at Kew Gardens describe as follows: Africa: south, Asia-tropical: India and Indo-China, Australasia: Australia, and Pacific: north-western and north-central (Clayton et al. 2006). As a result, *Bambusa balcooa* became established across the Eastern Cape, and today enjoys a classification as 'naturalised'. More recently, a number of public entities in South Africa, including the Eastern Cape Development Corporation, have attempted to re-initiate the development of a commercial bamboo industry, indicating a positive political will towards the plant's potential. With a well-developed forest products sector and both primary and secondary domestic manufacturing of wood and fibre products in existence, the potential for bamboo to be a valuable solution that contributes towards South Africa's national development strategy is significant.

Case study approach

In 2012, US-based EcoPlanet Bamboo Group purchased a highly degraded, century old pineapple farm in the Ndlambe Municipality of South Africa's Eastern Cape with the aim of restoring it into a sustainable and certified bamboo plantation.

Although representing the largest bamboo initiative in Southern Africa, the project was undertaken as a small-scale pilot initiative with the following key objectives:

- Analyse the feasibility of utilising tissue culture bamboo plantlets for bamboo farming at commercial scale and, if viable, gain the necessary experience in management of tissue culture plantlets for larger scale operations;
- Determine whether bamboo can be successfully utilised to restore ex agricultural land that has suffered from extreme degradation including a depletion of nutrients and the destruction of the soil's physical properties and other issues associated with high intensity mechanised agriculture over an extended period;
- Determine the viability of bamboo as a tool for economic empowerment for South Africa and, if positive viability is determined, set the stage for increased interest and support, leading to larger scale commercialisation of bamboo.

The project implementers, including the author of this case study, designed and carried out the project with the ultimate goal of determining whether South Africa as a country provided a positive location for further private sector development of bamboo as a commercial crop. Although evidence exists as to bamboo's ability to survive and be productive on degraded lands, little tangible information is available regarding its ability to regenerate soils that have been stripped bare due to over-intensive chemical-based agriculture. The successes, challenges and lessons learned from this project contributed to the determination of the potential for bamboo as a tool towards regeneration of such agriculturally degraded land both for South Africa and beyond, while still being economically viable for the private sector.

Today, the Kowie Bamboo Farm, with a land area of 485 ha, represents the largest productive bamboo farm in Southern Africa, and on 12th October 2015 became the only bamboo entity in Africa to have achieved forest management sustainability certification through the Forest Stewardship Council.[2]

This particular project has been chosen as a case study for bamboo as a tool for Forest Landscape Restoration (FLR) because the successes and barriers overcome within the six years of operation of this farm have led to a renewed interest in the potential contribution of bamboo towards the local development and restoration of old agricultural lands across South Africa, with larger scale bamboo planting projects now underway.

Project Implementation

Forest and landscape restoration aims to recognise a matrix of landscape options across forestry and agriculture.[3] The Kowie Bamboo Farm is an interesting case study for FLR representing more than five years of intensive research and development targeting the commercial growing of bamboo on denuded and degraded agricultural lands. Furthermore, the farm sits in the midst of two widespread but degrading forms of land management, intensive pineapple agriculture and cattle farming.

The Eastern Cape has a complex climate, and the project is located at the confluence of several climatic regimes, the most important of which are temperate and subtropical. There are wide variations in temperature, rainfall and wind patterns, largely as a result of movements of air masses, altitude, mountain orientation and distance from the Indian Ocean.[4] Average annual rainfall is between 650 and 700 millimetres (mm) per year. Exceptionally high temperatures may be experienced during berg wind conditions, which occur frequently during winter, with maximums of well over 30°C. Extreme temperatures also occur during summer, with little accompanying wind.

The project experimented first with tissue culture plantlets of *Bambusa balcooa*, sourced from two different sources:

- *Hortus capensis* plantlets produced in laboratories in Indonesia and shipped to the Hortus capensis nursery in South Africa, where they underwent a period of hardening off prior to delivery to the project. At the stage the plantlets arrived (20-30 cm in height), they were frequently under significant stress and required a minimum 2-3-month period of recuperation and further root development within the project's own nursery, followed by an additional hardening off period prior to transplanting in the field.

[2] The Kowie Bamboo Farm is certified under the RA Interim Standard for Assessing Forest Management in South Africa - FM - 32- South Africa, Version 03-15, March 2015 with FSC® License Code: FSC-C-125434.

[3] Laestadius, L., Maginnis, S., Minnemayer, S., Patapov, P., Saint-Laurent, C., Sizer, N. 2011. Mapping opportunities for forest landscape restoration. Unasylva, 238(62).

[4] Stone, A.W. 1988. Climate and weather. In: R.A. Lubke, F.W. Gess, M. Bruton eds. A Field Guide to the eastern Cape Coast. The Grahamstown Centre of the Wildlife Society of Southern Africa.

Growmore biotech plantlets arrived directly from a tissue culture laboratory in India as 4-8 cm plugs and required an extended 6-8-month period of care within the nursery prior to being hardened off and ready for transplanting. These plantlets showed considerable signs of stress on arrival after extended transportation periods.

The first small-scale field trial with Bambusa balcooa tissue culture seedlings occurred in 2012, while the farm itself was planted in 2013 and 2014, at a density of 400 clumps per ha or a 5 x 5 m spacing. Mortality of *Bambusa balcooa* from both plantlet sources in the early stages of the farm's development were high, reaching levels of up to 40 per cent. As a result, a large number of trials and silvicultural research work was undertaken to determine the best treatment for the plantlets, including ideal stage of growth at out planting, exact timing of out planting, post planting care and the maintenance and management regimes during the first 2-3 years of growth, during which time these seedlings remain fragile and easily susceptible to pests, fungi, drought and other stress factors.

In 2013, a combination of factors made EcoPlanet Bamboo decide to add a second species to the project's planting matrix. These factors included an unreliable supply of *Bambusa balcooa* tissue culture plantlets and poor quality and consistency of these plantlets, which resulted in a challenge from a management perspective when implementing a project at scale. The high mortality rates and the high costs – between USD 1.20 and USD 1.50 per tissue culture plug – associated with purchasing tissue culture plantlets from third party sellers were made significantly higher due to the mortality experienced in the nursery and upon field planting.

Oxytenanthera abyssinica[5] was chosen because it is a drought resistant species that occurs in non-humid and semi-arid areas. The relatively low rainfall of the project area, combined with low levels of humidity and high evapotranspiration caused by the high prevailing winds made this climatic context ideal for trials to determine the drought resistant extent of this species.

Following the establishment of areas to be planted with bamboo, as well as an integrated network of conservation areas of native vegetation, the farm entered a phase of maintenance. During this period, carefully targeted treatments were prescribed, including the use of mulch to increase water retention. Bi-annual soil testing was carried out to determine the physical and chemical properties of different areas of the farm, with significant differences found based on historical treatments of different ex-agricultural fields. The farm's management plan incorporated such differences from field to field to prescribe the best possible treatments for the newly planted bamboo.

In 2017, portions of the farm transitioned into a state of nearing maturity, with the emergence of larger diameter woody culms. A manufacturing facility for the conversion of the bamboo biomass into a range of carbonised products was initiated in preparation for the first thinning, currently underway, and markets for these bamboo products secured.

Achievements:

- Hectares successfully planted: 350 (72 per cent)
- Total conservation area: 135 (27 per cent)
- Job creation (full time positions): 120 during years 1-4, decreasing during years 5-6 and expected to average at around 65-80 once harvesting begins in 2019
- Female employment: >25 per cent
- Certification: FSC
- First thinning: 2018
- First harvest: 2019

[5] http://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:410276-1

In 2016, EcoPlanet Bamboo hosted the former Deputy Minister of The Department of Forestry and Fisheries (DAFF) (now the Police Minister for South Africa). As a result of this visit, DAFF has undertaken to develop a national scale programme utilising bamboo as a tool for community enterprise development, targeting timber markets. If successful, this programme will provide not only national level scalability, but also the chance for other nations to follow suit and target bamboo as a potential tool for FLR of degraded agricultural lands combined with the economic enhancement of rural towns and communities.

Challenges

EcoPlanet Bamboo has had to overcome a large number of challenges[6] to ensure the longevity and success of this project.

Management of Tissue Culture Plantlets: Although significant R&D had gone into the development of the young plantlets within each laboratory facility and into the early stages of transitioning into a controlled nursery environment, neither supplier had adequate experience or knowledge of the management required post this stage of plantlet development. These young plantlets undergo extreme levels of stress during their transportation, and any activity that causes movement between the fragile root system and the surrounding soil can lead to mortality of the plant. These fragile plantlets are also highly susceptible to fungi and need to be maintained within a temperature and humidity-controlled environment to develop a healthy root system.

No expertise existed on the specific climatic conditions of the Eastern Cape or elsewhere, nor on the utilisation of these fragile plantlets within soils that are nutritionally depleted and physically poor. As a result, significant investment into multi-year trial and error combined with results-based studies was required to determine the best prescriptions and management regimes to ensure the successful transition of tissue culture plantlets from laboratory to nursery to a healthy bamboo farm.

Degraded Soils Requires Further Research: Much information exists on bamboo's ability to grow and be productive with minimal inputs. However, little peer reviewed data exists, with regards to the growth of bamboo, on soils in which the type and level of degradation has been classified. In the case of restoring degraded lands, regardless of the cause of degradation, it is important to be realistic about the efforts required behind simple planting. Depleted soils require inputs and management regimes that are carefully designed based upon the specific properties of soils, which in turn requires careful analysis and investigation combined with managers who exhibit a deep agrarian understanding.

Furthermore, landscape degradation often goes far deeper than what the eye can see. Within the Kowie Bamboo Farm, there exist small areas of soil where bamboo simply cannot grow. Yet extensive soil tests (chemical and physical), research and trials indicate no difference in soil properties from one field to the next. It is therefore critical for any project to have a solid understanding of the historical treatments that occurred on the soils as well as the different crops and crop cycles that the soil has previously hosted.

Fertilisation, Pests and Disease: Despite common literature suggesting that bamboo does not require fertilisation and is not frequently attacked by pests and/or disease, EcoPlanet Bamboo's experience on the Kowie Bamboo Farm is very different. Under the context of degraded land, and therefore for the consideration of bamboo as a tool for FLR, carefully designed fertilisation of bamboo is necessary. If adequate nutrition is not available, both species of bamboo have shown a high increase in susceptibility to multiple strains of

[6] Debunking the myths and misinformation for bamboo farming. Available at: https://www.ecoplanetbamboo plantations.com [Accessed 20 Mar. 2018].

fungus. Fungus attacks can lead to a lower shooting capacity, a reduction in the number of shoots that achieve maturity, an increase in culm rot and eventually to the death of the bamboo clump.

In addition, both *Bambusa balcooa* and *Oxytenanthera abyssinica* are extensively attacked by a vast variety of pests, resulting in mortality if such attacks occur during the early months of establishment, and significant stunting often leading to death of the clump if such attacks occur during shooting season of the growth and development phase.

Conversations with Green Grid Energy (June 2017) who operate *Bambusa balcooa* plantations in KwaZulu Natal as well as with the Green Belt Movement (May 2017) who are involved in the planting of *Oxytenanthera abyssinica* in Kenya, confirm the same experience with high mortality rates and a high occurrence of pest attacks. At the Kowie Bamboo Farm, an integrated pest management (IPM) system was introduced in 2013, in concurrence with ongoing research trials on the effects of a range of natural pesticides, including combinations of chili, garlic and other natural repellents. Furthermore, the farm has a balanced approach to naturally occurring predators, such as snakes, which serve a vital purpose of keeping rat and other bamboo pest populations under control. Today, this IPM incorporates a range of techniques aimed at achieving a balance between preventing populations of known pests from becoming significant enough to pose economic damage to the plantation and maintaining such populations within the many conservation areas within the farm's boundaries.

Lack of Technical Data: Each bamboo species is unique, and although interest in the plant's potential as a tool for FLR is increasing in momentum, a gap remains in the science and understanding behind this plant's growth patterns and productivity, particularly in the context of highly degraded landscapes.

The lack of a rigorous knowledge base is extended beyond the ecological aspects of lesser-known species and growing contexts to the technology for value addition of bamboo. While ample information exists on the use and marketing of bamboo for handicrafts, EcoPlanet Bamboo has had to invest heavily within the development of technologies that not only maximise the unique properties of a bamboo feedstock, but that can also meet increasingly rigid global standards on green supply chains, closed loop and zero waste systems, and low environmental footprints to prepare for the volumes of fibre that the farm will yield beginning in 2019.

Plant Spacing: Although a 5 m x 5 m spacing was highly recommended during the early stages of this project, the growth and development of both *Bambusa balcooa* and *Oxytenanthera abyssinica* under the conditions of degraded land and lower rainfall indicate that such spacing is not ideal. As EcoPlanet Bamboo undertakes an expansion of the Kowie Bamboo Farm, a higher density of clumps will be used, varying between 500 and 625 clumps per ha, with the specific density being determined by factors including soil degradation, slope and surrounding vegetation.

Conclusions

Despite the challenges faced, this degraded landscape has been successfully restored from a barren and abandoned farm with few opportunities for productive use into a healthy ecosystem that combines a sustainable and certified bamboo resource with areas of healthy and protected native vegetation.

Several factors contributed to the project proponents' ability to overcome the challenges detailed within this case study. These include the ability to carry out cross cutting research, a multi-sectorial team, determination and perseverance where trials proved unsuccessful, and access to networks and experience spanning different sectors, from forestry and agriculture, to business, finance and on to manufacturing and technology. This diversity and tenacity enabled the project to gain invaluable inputs from a wide range of expertise and to overcome each challenge as it appeared.

As a result, the positive growth and health of both species of bamboo trialled on the pilot Kowie Bamboo Farm indicates that, if managed correctly, bamboo has the potential to be a valuable tool for the restoration of land that has been severely degraded by decades of intensive agriculture, while creating a valuable source of employment for surrounding rural communities. The farm represents a case study that provides policymakers, decision-makers and financiers with a clear visual and tangible experience of the 'before', 'after' and 'business as usual' scenarios, as well as the transition of what was considered worthless land back into productivity. Meanwhile, the invaluable lessons learned and accumulated knowledge provides a scientific basis for bamboo to receive the support necessary for it to become a tool for landscape scale restoration across South Africa, with particular application to lands previously used for commercial agriculture that are no longer viable due to high levels of degradation.

This knowledge base and the associated management framework have resulted in an expansion of the Kowie Bamboo Farm through the acquisition of additional pieces of degraded farmland within the vicinity being well underway. However, the experiences of this project can also provide valuable lessons to a wider context of bamboo's potential to restore land, whether at a smallholder, community or commercial scale, that is no longer viable for agriculture in South Africa and beyond.

Recommendations

From this experience, a number of recommendations can be drawn in the context of scaling the development of planted bamboo as a tool for FLR, under community, government or private sector frameworks.

(1) Lessons learned from the commercialisation of other plants and the rapid manner in which certain species have gone from representing a positive new opportunity towards contributing towards large-scale negative land use change drove the choice of highly degraded agricultural land for this pilot project. Under the context of such areas, the threat to the clearance of native ecosystems and vegetation is minimised, and bamboo can maintain its positive attributes without becoming a threat to remaining standing forests. Careful consideration to the commercialisation of bamboo in any country should be given to avoid a similar occurrence.

(2) For the industrialisation of bamboo in the context of South Africa, only highly degraded ex agricultural land should be targeted. The success of the conversion of this degraded pilot farm into a healthy ecosystem with numerous associated benefits provides a solid case study to ensure that the planting and associated industrialisation of bamboo for South Africa is limited to agricultural land designated as highly degraded.

(3) Tissue culture plantlets are a costly mechanism for the planting of bamboo at scale. Where large-scale commercial projects are to be developed and seed of the chosen species to be planted is not an option, consideration should be given to the development of on-site tissue culture facilities to (a) reduce costs per ha, (b) reduce transportation of fragile bamboo plugs and (c) reduce waiting times and therefore enable more timely planting of project areas.

(4) Site-species selection is a critical requirement to identify suitable species and suitable management options, particularly in the context of achieving bamboo-based FLR.

(5) Bamboo, as any other plant desired to be managed for production purposes or at scale, requires detailed and carefully targeted management practices to reduce mortality and develop a healthy, productive and sustainable ecosystem. The existing literature base on bamboo might not be applicable to degraded soil conditions, particularly within areas of planting density, pest and disease, and plant nutrition. As a result, further research should be conducted to understand the suitable conditions for bamboo species under degraded soils, particularly under the context of a landscape scale.

(6) The many uncertainties described above result in a need for investment in ongoing and long-term research trials and for new projects to have the ability and capacity to be adaptable as new data and learning becomes available.

(7) The Kowie Bamboo Farm should be utilised as a case study on the suitability of bamboo planting on highly degraded ex-agricultural land to gain the political, policy and financial support necessary for scaling to occur.

Tanzania

Compiled by Selim Reza

Introduction

Degraded land has serious adverse effects on community livelihoods and the environment in Tanzania. It was estimated that between 2001 and 2009, the cost of land degradation was approximately USD 18 billion (Kirui and Mirzabaev 2016). To reduce deforestation, the Tanzanian government imposed a heavy tax on charcoal, one of the main drivers of land degradation. The inter-regional charcoal trade was also restricted. Given this initiative, bamboo could play an important role in replacing tree charcoal to meet bioenergy demand. Since 2009, INBAR has worked with the Tanzanian government to promote a community-driven bamboo enterprise approach to enhance land restoration and realise sustainable livelihoods in the Mbaya District in Tanzania.

Bamboo is a pioneer planting crop that is useful for improving rural livelihoods, controlling soil erosion, sequestering carbon and restoring degraded land rapidly. The growth dynamics and the underground rooting network system make bamboo a perfect species for preventing soil erosion and land degradation. Bamboo's natural propagation, fast growth, short rotation and soil binding properties, make it ideal for afforestation, soil conservation and social forestry programmes (Singh et al. 2013).

This is a case study of the Mbeya District in Tanzania where INBAR has supported land restoration with bamboos since 2009. The case study was conducted by reviewing project documents and technical reports. Mbeya is in the south-western corner of the southern highlands of Tanzania. The geo-coordinates are 8°54′00″ S and 33°27′00″ E (see Figures 5 and 6). In Mbeya, women and girls commonly collect firewood and make charcoal for cooking and selling. Men also collect firewood; however, this often includes the illegal practice of felling trees. Other men have migrated to neighbouring districts to find employment.

Figure 5. Degraded land in Mbaya (source: INBAR project).

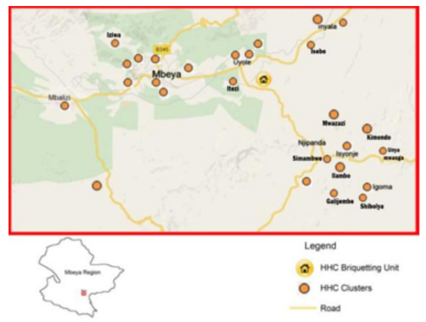

Figure 6. Plantation sites in Mbeya Region, Tanzania Tanzania (source: INBAR project).

Project Implementation

To begin the project, INBAR's implementation team conducted Participatory Rural Appraisal (PRA) exercises to capture the community dynamics and determine how they could be employed to address land degradation issues in the Mbaya District (see Figure 8). The PRA exercises helped to identify the target village and households to involve in the project.

Project activities were designed to focus on land restoration by promoting cluster-based bamboo micro enterprise development (see Figure 7).

Key features drawn from PRA exercises:

- Abundant degraded land due to mining and deforestation.
- The local community were felling trees for making wood charcoal and construction of housing.
- Bamboo resources were available in community forest and homestead plantation.
- Lack of fodder for household animal resources.
- Limited livelihood options and people willingness to work on bamboo.
- Livelihoods were wage labour in mining, collecting firewood, charcoal, cultivating maize, rice, bananas, beans, potatoes (Irish and sweet), soya nuts, wheat, rearing animals and bamboo crafts and migration in urban locations for wage employment.

The bamboo micro enterprises contributed significantly to economic growth, social security and greater equity. The interventions on the ground took place step-by-step, building up a community demand-driven approach, which helped to achieve land restoration and empower the local community, especially women.

Figure 7. Land restoration approach.

Figure 8. PRA exercises with villagers (source: INBAR project).

From the outset, the project faced a number of challenges, which the project team addressed using a range of approaches (see Table 1).

Critical challenges	Applied solutions
Governmental officials and local communities resistance to using bamboo for land restoration due to a lack of experience.	Frequent visits made by team members to coordinate with leading department's key officials to organise training and film showings to demonstrate bamboo's potential for land restoration. The team conducted awareness raising campaigns and distributed materials, including leaflets and posters in the local language.
Unclear land tenure and ownership rights in the region.	The project targeted only community and homestead farm land where clear ownership rights existed
Low motivation of community in establishment of plantation forest as economic value of plantation forest.	The project team set up a bamboo production unit to work with the local community to highlight the potential economic and income generating activities.
Developing good quality and larger quantity planting materials needs time and investment	The project team promoted homestead micro nurseries
Non-cooperation from the side of the mining company to trial and participate in land restoration.	Provide bamboo planting materials and setting-up a demonstration plot. Invite the mining company to different events on bamboo related activities, i.e. training and exposure.
Community expectations – people expected to receive economic benefits quickly.	The project team worked to educate the community about the bamboo cycles. The bamboo crop could be harvested after 3-4 years. The project facilitated several livelihood activities on bamboo, i.e. furniture making, bamboo crafts through using existing resources to help the community gain economic benefits in the interim period

Table 1. Critical Challenges and Applied Solutions

Engagement of communities

The project organisation and management aspects comprised mobilising the local community, networking and building partnerships with leading government departments. The project was also designed to ensure that community ownership was built into every step of the implementation process by ensuring active community participation. To achieve this, the community leader was appointed as a 'key person'. Participation activities included the development of a community bamboo nursery to produce high-quality plants for land restoration (see Figure 9), which helped to establish a sustainable long-term supply of good quality planting materials. The project also supported the establishment of a Farmers Field School (FSS), which played a key role as a 'bamboo knowledge centre' for other farmers from the adjoining villages and districts where knowledge and techniques were shared. Both male and female community farmers were selected as members of the FFS. The members played an important role in nursery development and management, and capacity development on bamboo plantations. The lead bamboo farmers from two FFSs in the village of Ivumwe and Isongole in Mbaya region performed a catalytic role for other farmers in the region. They coordinated different events at socio-cultural ceremonies, i.e. birthdays, marriage days and national events, to promote bamboo plantations to restore degraded land. Bamboo species such as *Bambusa balcooa*, *Bambusa tulda* and *Bambusa vulgaris* were planted. Scientifically, these species have a high tolerance to drought and show excellent clump forming qualities, with a secure internal rooting network system to protect soil siltation. They also develop a thick canopy to protect moisture to increase water levels. Finally, they are adaptable and provide a source of heavy biomass for making bamboo charcoal. Through this approach, 39.00 ha of degraded land was restored in the Mbaya region between September 2014 and October 2017.

Figure 9. Bamboo nursery and bamboo plantation (source: INBAR project).

Homestead bamboo approach

Apart from a large-scale bamboo plantation of 39.00 ha being grown on degraded land, the project also promoted micro-level bamboo plantations on homesteads and along farm boundaries. The micro-level plantations provided households with biofuel and feed for homestead cattle. The micro-level bamboo plantation system increased community self-dependence on their resources, thus building confidence amongst the people.

Case Result Highlights:

- 834 rural households involved in land restoration
- 39.00 ha of bamboo planted in degraded land for land restoration
- 22.5 ha of bamboo planted in homestead
- Five bamboo species planted
- Two Bamboo Farmers Field Schools (FFS) established
- Two Community Bamboo Nurseries established
- 419 rural women trained on bamboo plantation and management for land restoration

The farm homestead bamboo plantation is an alternative way to promote land restoration initiatives within the project villages. Around 843 households are involved in homestead bamboo plantations. Collectively, they have planted 9000-10,000 bamboo plants on their farm boundaries, covering 22.5-25.00 ha of degraded land. Householders have planted bamboo for many purposes including for feed, fodder and biomass. The households collect bamboo leaf from the farm boundary and homestead bamboo plantation on a regular basis as feed and fodder for their household animals. Previously they were dependent on forest feed and felling trees, at times illegally. Owing to a scarcity of water and the savannah forest biome, the community was facing problems sourcing sufficient fodder for their animals. The farm boundary restoration initiative has reignited householders' interests in rearing animals among the community as an alternative livelihood option. The farm boundary land restoration initiative is being extended to adjoining villages and other projects in the region, including Madagascar and Ethiopia.

Linking bamboo for land restoration with enterprise development

As identified during the PRA exercise, one of the main drivers of deforestation and land degradation was the large-scale of felling trees in primary and secondary forests to make charcoal. Bamboo has important properties that can stop this activity in the community. One of the great advantages of bamboo is that culms can be collected at three years old, or older, without negatively affecting the health of the bamboo clump. In fact, collecting culms stimulates the growth of new culms. To take advantage of this property, the project promotes the local community to use bamboo instead of trees for

biomass energy, handicrafts and other products. This approach aims to meet to two targets at the same time: (1) reduce deforestation and degradation and (2) create job opportunities and income for the community.

Bamboo charcoal enterprises: Women's Organization for Donald Grace and Rama Bamboo Briquetting Company Limited (WODGRA)

The project successfully empowered the local community to scale up pro-poor bamboo household charcoal and biomass enterprises and link them with land restoration. One approach was the establishment of bamboo enterprises, such as WODGRA (vide registration No. 98179), to transfer technology and skills.

WODGRA is a bamboo charcoal and briquetting enterprise supported by the project, which includes the necessary infrastructure, technologies and coaching to promote bamboo charcoal briquetting in the region. WODGRA has mobilised around 783 rural households to collect bamboo and agricultural waste to produce charcoal. Three commercial bamboo charcoal-making clusters have been developed to establish a bamboo charcoal dome for making and supplying charcoal to WODGRA for further processing into bamboo briquette. This development has helped to increase the income among rural households and other project beneficiaries. The monthly collection of bamboo charcoal and agricultural waste, approximately 10 tons, raises USD 10,000. By processing the charcoal into briquettes, the added value rises to approximately USD 25,000-30,000 (INBAR's project monthly progress report 30th September 2017). The WODGRA enterprise has also helped to protect trees from being felled for making wood charcoal, thereby contributing to land restoration. WODGRA has also motivated households to plant bamboo in their respective homesteads and remnants patches of degraded land or farm boundaries specifically to make charcoal. WODGRA is operating in 12 villages and has mobilised another 701 women in the Rungwe district.

Bamboo product development

The project enhanced capacity building and knowledge transfer to set up viable bamboo community-driven micro and small enterprises. Community training culm production centres (CPTC) were set up to develop skills and transfer technology for bamboo treatment and processing. One such centre was the Isongole bamboo treatment CPTC, which employed 20 young people directly, and provides employment for around 89 entrepreneurs, including bamboo farmers throughout the supply chain (see Figure 10). The Isongole bamboo treatment CPTC generated approximately USD 200 per month extra income to those households involved. Bamboo furniture, diversified bamboo craft and honeycomb bamboo briquette enterprises have provided jobs earning USD 112-205 per month for a further 254 project beneficiaries (see Table 2).

Sl.No.	Bamboo Micro Enterprise	No of unit	No of HH involved	Monthly Income (App.)
1	Bamboo Treatment and processing unit	1	20	USD 200
2	Bamboo Furniture	2	23	USD 205
3	Bamboo Crafts	2	93	USD 112
4	Honeycomb briquette	3	138	USD 150

Table 2. Employment and Income Figures from Community-driven Bamboo Micro and Small Enterprises

(a) *(b)* *(c)*

Figure 10. (a,b) Making bamboo handicrafts and (c) bamboo charcoal briquettes (source: INBAR project).

Conclusions and recommendations

Setting-up community-driven enterprises was a driving force to promote land restoration with bamboo plantation. Community-driven bamboo enterprise initiatives can create employment opportunities, generate income and provide locally available renewable energy while reducing the felling of trees, thus reducing land degradation. The initiatives involve the local community directly in the land restoration process and provides them with economic benefits.

The Tanzanian Government imposed a heavy tax on wood charcoal to prevent further deforestation, limit the inter-regional supply of wood charcoal and encourage briquettes for alternative biomass.

Awareness raising was essential for the successful implementation of the project. At the start of the project, government officials and local people showed limited interest in using bamboo for land restoration or increasing economic opportunities. Raising awareness of the potential of bamboo was coordinated by the lead department, which conducted training showcases on the capacity of bamboo for land restoration using local language leaflets and posters.

The project attempted to engage local people in every step of the land restoration process from the establishment of community nursery to creation of the FFSs. Especially significant to the process was linking land restoration with economic and income generation activities such as bamboo handicraft and bamboo charcoal enterprises.

Developing homestead micro nurseries helped to produce good quality seedlings and a sufficient quantity for the local community. Production of large quantity and good quality bamboo seedlings in a short period is not an easy task, especially when bamboo seedlings are propagated by vegetative technique from bamboo rhizomes. More research is needed for the production of large quantity planting materials such as bamboo tissue culture for large-scale bamboo plantations.

Land restoration should be carried out under clear land tenure and ownership rights. Land tenure and ownership rights are critical in the region. Planting activities should not be conducted in places where there is land use conflict or unclear tenure rights. Local people do not want to plant trees where there are unclear land use rights because they might risk benefitting from any future arrangements. Additionally, if trees were planted on contested land, there would be no clarity over who should take responsibility for their maintenance. Therefore, the project focused on community land and homestead farmland.

Asia
Anji, China

Compiled by Li Yanxia and Lou Yiping

Introduction

Anji county is located at the centre of the Yangtze River Delta, 200 km from Shanghai and 60 km from Hangzhou (see Figure 11). The county, which has a population of 457,100, spans 1886 km^2 of territory and contains eight cities, three towns and one economic development zone. It is also a popular seasonal tourist destination, with a humid sub-tropical maritime monsoon climate, temperatures ranging from -17.4 °C to 40.8 °C and an average annual rainfall of 1,350 mm. The Xitiao River is the primary source of water, and the dominant soil is of the red earth variety composed of acidic magmatic and sedimentary rocks.

Figure 11. Anji county.

Bamboo covers 69,000 ha or 1.08 million mu (15 mu = 1 hectare) of Anji county's territory. Annually, more than 600,000 tons and 40,000 shoots of bamboo are produced, worth in excess of 12 billion RMB (USD 1=about 6.2 RMB). It is no wonder that Anji county is ranked first among the ten most significant bamboo producers and manufacturers in China, generating 18 per cent of the national output in terms of value, with less than 2 per cent of country's total bamboo resources. By 2010, some 2800 bamboo manufacturers were operating in the county. Of these, 153 generated more than 5 million RMB each, while 8 of them exceeded 100 million RMB. Anji county's many enterprises create enormous demand for raw materials that are often in short supply locally. Planting bamboo increases resource availability and contributes to the county's increasing economic development, including the creation of nearly 100,000 jobs in the sector.

Despite the presence of bamboo in the mountains, the hills and lowlands that cover most of Anji county are degraded by decades of unsustainable agricultural practices and deforestation. In the 1980s, many chestnut trees were planted as part of a programme to reclaim barren hills and wasteland. Farmers benefitted from an increase in income, especially in the upper area of the Fushi Reservoir. Approximately 10,000 ha of coniferous forests including the species *Cunninghamia* (China fir) *Pinus massoniana* (Masson Pine) and 5,000 ha of economic deciduous forests were planted. However, this led to soil erosion, thus weakening the soil's water retention function, polluting the water, degrading the environment and reducing biodiversity. The unsustainable planting and cultivation of economic trees such as chestnut and tea have exacerbated land degradation, and the programme to plant chestnut trees failed to reduce nutrient loss and control soil erosion. The capacity of chestnut trees to minimise nitrogen and phosphorus loss from the soil is far lower than that of bamboo or coniferous forests.

With a degraded complex soil-forming rocky terrain, both water erosion and gravitational erosion have resulted in significant topsoil degradation. The situation leads to water loss, landslides and debris flow occurring during the rainy seasons (May/June and August/September). For example, soil erosion stemming from the Xitiao River flowing into Lake Tai reduced water quality and thus threatened the ecology. Pollutants originating upstream and flowing into Lake Tai exacerbated this situation. The soil erosion and related land degradation have profound ecological, social and economic implications.

Case study approach

In 2008, a collaborative project was launched to restore forest cover in Anji county and reverse soil erosion. Bamboo was a crucial element in the land restoration project design.

Process and Implementation

In 2008, Anji county's Forest Bureau, in collaboration with the Environmental Protection Bureau, the Finance Bureau and the Water Conservancy Bureau began pilot projects to restore degraded lands using bamboo. The project converted 1800 ha of walnut forests and 537 ha of coniferous forests into broadleaf mixed with bamboo forests.

The Anji county government set up a committee to oversee project implementation. The committee included all the coordinating Bureaus plus the Agriculture Bureau and the Land and Resource Bureau. The townships of Hanggai, Kuntong and Xiaofeng also established committees to assist with implementation at the local level.

In October 2008, the committee issued guidelines to regulate the project's strategy, principles, objectives, priorities, standards, management and logistical support for ecological restoration. The government incorporated ecological restoration into its assessment of the Chinese Beautiful Countryside programme. Stakeholders rights and obligations were also clarified. The leader at the township level (economic development area) had overall responsibility for restoration initiatives, while others were charged with direct responsibility for work in their assigned areas, e.g. water conservation. Under this system, duties were clear, resulting in improved overall supervision and outcomes of the project.

Six models with technical specifications for interplanting deciduous broadleaf forests and tea plantations with bamboo (Table 3) were designed specifically for the project.

No.		Interplanting model of Forest species(a+b)	Planting density (sapling/mu)	Interplanting patternsA	lternative species
1	a	Bamboo	30	Row - row or row—strip	Deciduous broadleaf trees such as Eucommia Bark, Liquidambar, and Tulip tree
	b	Ginkgo	5		
2	a	Bamboo	25-30	Row - row or row—strip	Deciduous trees such as thin-shelled walnut
	b	Walnut	5-10		
3	a	Red Bamboo	60	Row - row or row—strip	Deciduous broadleaf trees such as Eucommia Bark, Liquidambar, and Tulip tree
	b	Ginkgo	5		

Table 3. Ecological Restoration by Interplanting Economic Deciduous Trees and Bamboo

The approaches were based on experiments, best practices and ecological and economic benefits. A list was also compiled for the project that outlined standards for seedling selection and planting techniques for interplanting dominant forest species (Table 4). The list was based on the species biological characteristics, requirements of afforestation in the project area, ecological-economic benefits and the capacity to conserve water and prevent soil erosion. The information empowered farmers to make their own decisions about species selection based on the range of potential benefits available.

Species	Growth features and functions	Growth condition	Site preparation	Planting season & method	Seedling selection
***Phyllostachys pubescens* (Moso bamboo)**	Retains soil and stores water; grows well in sunny, warm and humid climate; prefers to be fertilized; is water sensitive and fast-growing	15-20℃ average annual temperature but can resist up to -15℃; annual precipitation of 1000-1900mm; prefers sun and deep, fertile sand soil; 1000 meters above sea level; soil of over-dry gravel, saline-alkali or bog should be avoided	Extensive site preparation in holes of 100cm×60cm ×40cm	Transplant mother bamboo with rhizome in early winter or early spring (Nov-Feb)	Healthy with normal shape; turgid bamboo rhizome; 3-5 cm in diameter; 1 to 2 year-old mother bamboo
Phyllostachys iridescent	Retains soil and stores water; grows well in sunny, warm and humid climate; prefers to be fertilized; is water sensitive and fast-growing	Strong adaptive capacity to site conditions; suitable for almost any soil, except heavy alkali and bog	Extensive site preparation in holes of 60cm×40cm ×40cm	Transplant mother bamboo with rhizome in early winter or early spring (Nov-Feb)	Healthy with normal shape; turgid bamboo rhizome; 3-5 cm in diameter; 1 to 2 year-old mother bamboo
Phyllostachys nigra	Retains soil and stores water; grows well in sunny, warm and humid climate; prefers to be fertilized; is water sensitive and fast-growing	Resistant to temperatures as low as -20℃ and to overcast skies; adapts to many soils but prefers fertile, loose and slightly acidic	Extensive site preparation in holes of 60cm×40cm ×40cm	Transplant mother bamboo with rhizome in early winter or early spring (Nov-Feb)	Healthy with normal shape; turgid bamboo rhizome; 3-5 cm in diameter; 1 to 2 year-old mother bamboo Healthy with normal shape; turgid bamboo rhizome; 2-3 cm diameter; 1 to 2-year-old mother bamboo

Table continued on next page

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Red bayberry	Prefers warm and humid climate; resists infertile soil and drought; strong adaptability; nodule bacteria in roots make it good for nitrogen fixation	15-21 ℃ average annual temperature but can resist up to -15 ℃ ; annual precipitation above 1000mm; prefers loose, moist and well-drained red soil with gravel ph 4-5	Extensive site preparation in holes of 60cm×40cm ×40cm	Plant grafted seedlings in the first days of spring	3-year old healthy seedlings, grafted with improved varieties
Chinese torre	Prefers warm and humid climate; resists infertile soil and drought; long life	200-800 meters above sea level; adapts to most soil but prefers deep, fertile, moist, well ventilated and moderately acidic ph 4.5-8.3.	Extensive site preparation in holes of 60cm×40cm ×40cm	Plant grafted seedlings in late fall, early winter or early spring	Healthy seedlings of more than 3 years old for grafting; 3-5% from pollination trees
Gingko	Deep and wide lateral roots which grow quickly after cutting; strong adaptability; long life; good at soil-fixation and pollution control	Adapts to most soil but prefers deep, fertile, moist and well ventilated sandy soil ph 6.5-7.5	Extensive site preparation in holes of 60cm×60cm ×40cm	Plant seedlings or grafted seedlings in spring	2-3 years old
Mangnolia officinalis	Prefers sun and moisture; shallow roots; strong sprouting ability; lateral roots; strong adaptability	Suitable for hillsides of 300-2000 meters above sea level in red, yellow or calcareous sol ph 4-8	Extensive site preparation in holes of 60cm×60cm ×40cm	Plant seedlings in spring	Seedlings with robust and intact roots
Eucommia Bark	Prefers sun; strong, distinct taproot and lateral root system, good at soil fixation and water conservation; drought resistant; strong sprouting ability	Prefers deep, fertile, and loose yellow sand soil with good drainage	Extensive site preparation in holes of 60cm×60cm ×40cm	Plant seedlings in spring	Improved variety seedlings more than 2 years old

Table 4. Planting Techniques for Ecological Restoration for Significant Forest Species (excerpt)

Technical and Financial Support

To improve the projects' effectiveness, the government provided support including funding, technical assistance and monitoring of activities to ensure compliance with annual work plans. At the beginning of the project, technical capacity amongst many stakeholders, especially the farmers, was limited. Between 2008 and 2011, technical experts from the Forestry Bureau ran 10 courses in which approximately 800 farmers were trained to undertake an assessment for ecological restoration, select appropriate species and apply afforestation techniques to their context. The management skills learned by the farmers helped to improve the value and quality of their interventions.

To incentivise participation by farmers, the government offered financial subsidies for using deciduous trees such as chestnut to restore areas greater than 50 mu. The subsidy rates provided were 500 RMB/mu for interplanting moso bamboo, 300 RMB/mu for red bamboo, 200 RMB/mu for economic trees such as red bayberry and Chinese torre, and 200 RMB/mu for other broadleaf trees. Some aspects of the restoration were based on the principle of 'those who destroyed should repair', where no subsidies were provided. Farmers who converted forests for agriculture without approval were ordered to complete restoration within a specified time and pay the local government a deposit of 3 RMB/mu. The deposit was returned once the restored area passed an inspection by a government official. Regarding the restoration of mined areas, the local government supervised directly the measures taken by those who were given approval for planting.

Publicity and Awareness Raising

Publicity campaigns to prevent deforestation and reclaim previously forested farmland were launched. Full use was made of mass media, including television and newspapers, to advocate the importance of, and need for, ecological restoration in Anji county. Campaigns to raise awareness targeted township government officials, forestry farmers and the general public. It was believed that farmers were more likely to support the project and work collaboratively to achieve restoration goals if they understood the rationale for using bamboo. These awareness-raising measures of the negative effects of deforestation and related impacts are now being scaled back due to their effectiveness in improving knowledge about the issues.

Conclusions and recommendations

The bamboo restoration project in Anji county resulted in environmental, social and economic benefits. Soil erosion was significantly reduced in the region. For example, the unique underground root and rhizome systems of *Phylloslachys pubescens* (moso bamboo) form a dense web to stabilise slopes and areas with thin layers of topsoil. As a result, the capacity of walnut forests to prevent the loss of soil nutrients due to precipitation was significantly enhanced. In 2010, 7.8 per cent (147.05 km^2) of Anji county was affected by soil erosion. The annual loss of soil dropped to 561,000 tons in 2010, a reduction of 49.2 per cent compared to that in 1999. The interplanting techniques employed in the project resulted in increased stand biomass and improved carbon sequestration capacity. Bamboo is a fast-growing crop and has a higher carbon sequestration capacity than Chinese fir trees grown in the region. In addition, the commercial plant species such as *Phylloslachys pubescens* enriched the stand structure of the predominantly walnut forest and increased biodiversity levels. As a result, both the stability of the stand system and resistance to pests were enhanced.

The local communities enjoyed significant economic benefits from the project, including improved opportunities to benefit from tourism. Prior to the project, when chestnut trees shed their leaves in winter, the landscape became desolate and adversely affected forest-based tourism. The restored landscapes reinvigorated ecotourism in Anji county. In 2011, 7.74 million tourists spent 5.3 billion RMB in Anji county raising the average local farmers' income to 14,152 RMB. The local community also benefitted from the stable jobs created in the expanded bamboo processing industry.

Capacity building and technical assistant component was crucial to the success of the restoration programme. The set of technical guidelines on selection of species, species composition, quality of seedlings, planting and tending techniques combined with training and regular technical support in the field improved the quality of the plantation.

The subsidy policy and the principle of 'those who destroyed should repair' encouraged farmers to actively participate in restoration activities and ensured a timely establishment of forest plantation.

Awareness raising on combating land degradation via diverse channels and targeting various levels from local people to governmental officials has led to mass-social political support for landscape restoration activities.

Chishui, China

Compiled by Li Yanxia, Oliver Frith, Lou Yiping and Saurabh Upadhyay

Introduction

In response to a succession of ecological crises – the Yangtze floods (1998) and a severe drought in the Yellow River basin (1997) – in 1999, the Chinese government launched the world's largest landscape restoration programme. The Conversion of Cropland into Forest Programme (CCFP) aimed to restore degraded farmland into forests and provide a number of ecosystem services, particularly soil and water conservation. By 2014, the programme had invested some RMB 450 million and involved more than 32 million farming households from around 2300 counties in 25 provinces.

Beyond its ecological aspects, the CCFP has had a real impact on land use systems, small holders' livelihoods and socio-economic development. The experiences and lessons gained from the CCFP serve as a valuable reference point for other countries with similar initiatives.

Bamboo has been used in the CCFP because of its extraordinary potential to bind degraded soil, store carbon and protect biodiversity.

In Guizhou Province, 5.35 million people live below the poverty line. This is particularly true of those living in the remote mountainous Chishui municipality, in northwest Guizhou. Located in the upper reaches of the Yangtze River, Chishui is a focus area for China's national poverty alleviation programme and a site of real ecological importance: it is one of the ecological protection demonstration project areas in China.

Chishui's ecosystems are particularly vulnerable to climate change. Its steep slopes, light soils and heavy rainfall in the summer months all increase the likelihood of erosion and landslides, and the area is highly susceptible to environmental shocks, such as heavy rains and droughts. These challenges are particularly severe in the face of increasingly unprofitable agriculture. Unsustainable cultivation practices such as the promotion of monoculture, heavy use of tilling and overuse of chemical fertilisers have contributed to long-term land degradation and subsequent reductions in productivity and farmer income (Du 1996).

Chishui boasts over 300 species of bamboo, and this plant has been an integral part of the municipality's reforestation initiative since it first joined the CCFP in 2001. From 2001 to 2014, the local Chishui government invested RMB 40 million into restoring about 54,000 ha of slopping and unproductive land with bamboo. Targeting a massive area, the afforestation programme covered 14 townships and two districts, which subsequently involved almost 51,000 households and 189,000 farmers from 99 villages.

Project implementation

Land reforested

This study conducted desk research and personal interviews of key stakeholders between 2015 and 2016 and found the following results.

By 2015, Chishui boasted over 78,000 ha of bamboo forest. Moso (*Phyllostachys pubescens*) bamboo alone covered 35,000 ha of land by 2014, a substantial increase from its previous coverage of 24,000 ha. Currently, Chishui has almost 87,300 ha of bamboo forest and ranks number one in China for its per capita bamboo forest.

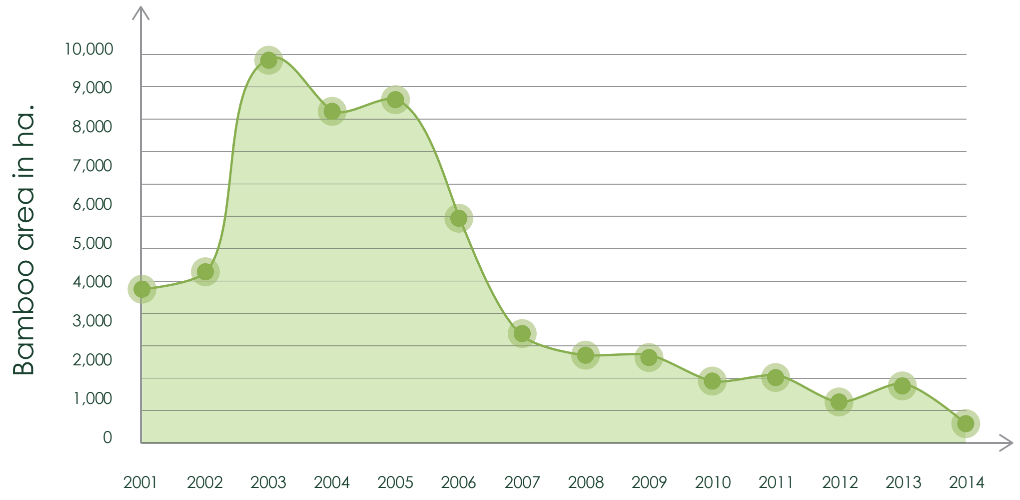


Figure 12. Restored land with bamboo from 2001 to 2014 (unit: ha.)

Research shows that Chishui's afforestation effort has had an important impact on reducing soil erosion, conserving water resources and increasing carbon sequestration.

- Compared to sweet potato farming lands, the average water runoff for bamboo plantations is 25 per cent less, and the average soil erosion quantity is reduced by 80 per cent.
- One 13,000-ha bamboo plantation in Chishui was shown to reduce over 350,000 tons of soil erosion that used to flow into the Chishui River annually and conserved some 6 000 m^3/ha water resources annually (internal report from the Chishui government) (see Figure 13).
- The increased bamboo stocks sequestered almost 200,000 tons of carbon annually (INBAR internal project report).

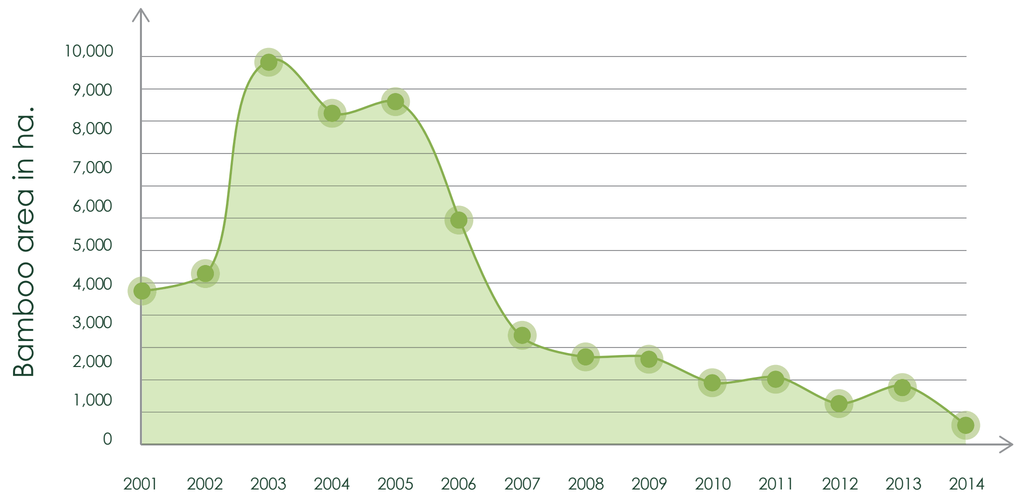


Figure 13. Sediment concentration in Chishui River from 2001 to 2007 (kg/m^3) (Data source: He 2009).

Socio-Economic impacts

As well as its environmental benefits, bamboo has played a key role in supporting the economy of Chishui. The annual per-capita income for farmers involved in Chishui's land restoration project was 1888 RMB in 2001, with an additional income from bamboo of under 600 yuan (Zhang 2006). By joining the afforestation programme, the annual per-capita income from bamboo increased to 2 900 RMB.

This increase can partly be attributed to the development of Chishui's bamboo sector as a result of the increased bamboo stocks. Chishui has seen a rise from 180 small and micro-sized bamboo processing enterprises in 2000 to 375 in 2015; almost 200,000 farmers are involved in the bamboo supply chain, up from 10,000 people in the value chain in 2000. According to data accumulated from the bamboo sector, by 2015, the total value of the sector was 6 billion RMB in 2015, almost 20 times more than that in 2000.

As a result of continuous support and training initiatives, more than 30,000 farmers have shifted from primary industries to secondary industries in the bamboo sector, which has contributed to a 42 per cent boost in the number of people employed in the service sector between 2000 and 2015.

An eco-tourism industry is also emerging and is attracting more and more investment in infrastructure and capacity building for service provision. Five out of six famous tourist spots in Chishui feature bamboo which together have a value of RMB 10 billion.

One fascinating result of the project is the return of migrant workers to Chishui. Since the project began, about 40 per cent of migrant workers have returned home from Guangdong, 30 per cent of whom are dealing with bamboo supply chain. This result is testament to the increase in opportunities afforded by a robust bamboo supply chain.

Strategy and Policies for the Future

As a part of the new phase of CCFP, which started in 2014, the Chishui government has planned to restore another 7000 ha of farmland by 2020 and increase the value of bamboo sector to RMB 10 to 20 billion.

As a part of its policy to strengthen the bamboo sector, the Chishui government is encouraging the transfer of bamboo forest management rights from individual farmers to cooperatives and companies. It is hoped this transfer will improve the management and utilisation of these forests. Individual farmers who transfer these rights will be able to earn income from the rent generated and become involved as labourers in the bamboo value chain. In the past five years, Chishui farmers received more than RMB 70 million in loans.

A healthy bamboo sector also needs to have good road accessibility. The government plans to upgrade around 600 km of existing roads and build an additional 600 km.

The government has also pledged to build a standard enterprise cluster, which will be fully equipped with facilities to help people set up small- to medium enterprises (SMEs) – another crucial part of encouraging more participation in the bamboo value chain and part of the government's plan to establish 600 SMEs in Chishui by 2020.

Conclusions and recommendations

Although no two areas are the same, future initiatives can learn from the success of the CCFP bamboo project in Chishui.

Several factors contributed to the success of this restoration programme:

- **Flexible and efficient incentives and governance to encourage participatory engagement of farmers.** The programme established a mechanism to encourage the active engagement of farmers in the initiative, which included the provision of technical and financial support (Figure 14).The Chishui Forestry Bureau provided technical guidance and support to local communities, including field investigation, planning, technical training, purchase support for seedlings, fertilisers and other necessary materials, and production monitoring. However, farmers were encouraged to make their own decisions about whether to join the programme, the amount of their farmlands to be restored and the bamboo species they wanted to plant. Because of bamboos' short rotation and quick return on investment, some three years after planting, most farmers were interested in the scheme. Farmers were offered annual subsidies amounting to almost RMB 1500 per ha – money provided through the central government's CCFP funds, as well as contributions from the Chishui local government and private sector contributions.
- **Localised bamboo solutions.** Planting is the just the starting point. A healthy and promising industrial system is the key to ensuring sustainability of the afforestation programme. Because of its quick growth, ability to regrow without replanting and selective harvesting technology, bamboo has a low opportunity cost for farmers and local authorities who wish to engage in the bamboo sector. Specific bamboo species – mainly sympodial species – were chosen to ensure the maximum industry potential for harvested bamboo.
- **Strategic planning for bamboo value chain development in the long run.** Setting up and enhancing local bamboo value chains, particularly in terms of developing the production line downstream, was an essential component of the project that ensured a demand for raw harvested bamboo. A bamboo paper pulp factory, Chitianhua Bamboo Paper Pulp Co. Ltd, which was established in 2003 makes 20,000 tons of pulp per year using 80,000 tons raw bamboo. It has created an industry with an annual value of over RMB 760 million annually. Chitianhua Bamboo Paper Pulp offers direct employment to more than 500 people and creates a value chain of bamboo farmers, who supply the raw material to the factory. Indirectly, the factory supports thousands of people involved in the value chain, including lumberjacks, bamboo chip makers and drivers.

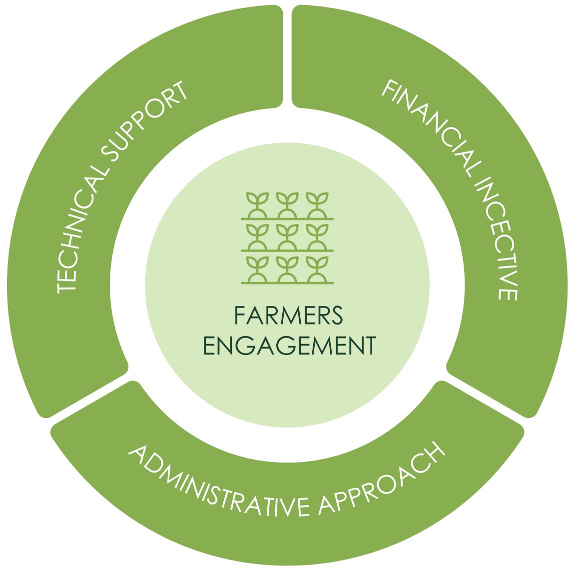


Figure 14. Governance strategy of the afforestation programme.

India

Compiled by K.P. Eashwar

Introduction

In 1997, Utthan (the Centre for Sustainable Development and Poverty Alleviation) in Allahabad in Uttar Pradesh, North India began working on a project with INBAR[7] to restore degraded land and reverse the decline in local farmers' livelihoods. Since the 1960s, Allahabad had seen, like many regions in India, an increase in demand for topsoil to make bricks. Increased demand within the construction sector drove the demand for bricks. Given that topsoil is a key material for brickmaking, this growth impacted India's agricultural landscape.

(a) (b)

Figure 15. (a) The extent of topsoil excavation and (b) dust storm in village (INBAR 2003).

In the early 1960s, land-owning farmers in the 96 villages of Kotwa and Rahimabad in Allahabad, Uttar Pradesh leased out their fertile agricultural lands to brickmakers to mine the topsoil. Before long, about 5000 ha of land were dotted with 156 brick kilns. Digging for soil ranged from between three and 10 feet in many areas. Once the top soil was removed, farmers were unable to grow crops (Figure 15a), which negatively impacted the livelihoods of 0.88 million people in the region. Environmental impacts from topsoil removal were also severe. Frequent dust and cyclonic storms in the region affected nearby areas (Figure 15b), air pollution levels reached new highs and water became an issue as the water table dropped. The social, environmental and economic degradation resulting from the topsoil removal in the region needed to be reversed.

Project implementation

In 1997, Utthan, an Allahabad-based local action-oriented non-governmental organisation (NGO) working on sustainable development and poverty alleviation approached INBAR to undertake an initial survey to research and analyse the potential for bamboo cultivation to revive and restore the degraded land. The INBAR technical mission led to a decision to establish a pilot project on approximately 5000 ha of land working in partnership with Utthan who would execute the work. INBAR agreed to provide all the funding and technical know-how.

Selecting a Pilot Area

After surveying the region, an initial 106 ha in the Kotwa-Rahimabad area was selected to be the most suitable for a pilot project (see Figure 16). Kotwa-Rahimabad is at the head of a catchment area of five micro watersheds. The micro-ecosystem would deliver the greatest beneficial impacts from the pilot project.

[7] In 1997, INBAR was part of the International Development Research Centre, Canada.

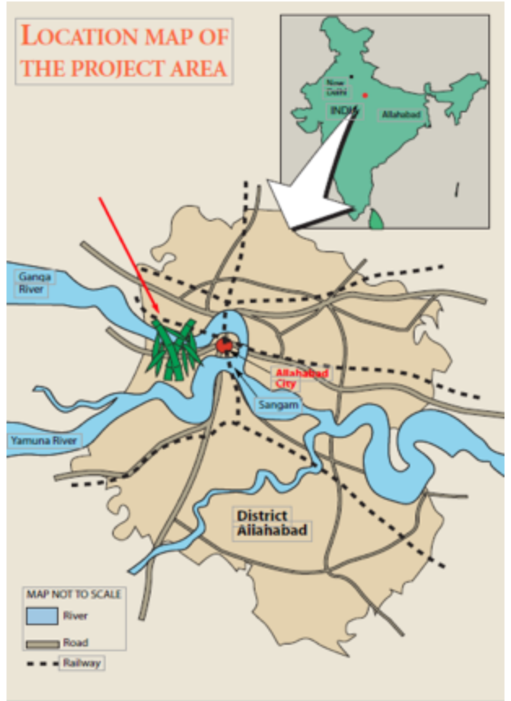


Figure 16. Kotwa-Rahimabad, Uttar Pradesh (INBAR 2003).

In 1997, Kotwa-Rahimabad had high levels of poverty amongst the villagers due to the unsustainable land use practices (see Table 5). Topsoil extraction for brickmaking had affected the water supply and the land due to deep mining practices. Not only did the water table fall but the potable water was also polluted.

ParameterU	nit
Area of the micro-watershed	106 ha
Area mined up to a depth of 3 metres	60 ha
Common degraded land available	12 ha
Population of the villages	2340 (as per 1991 census)
Number of households	311
Number of landless families	125
Number of people living below poverty line	1872

Table 5. Profile of the Kotwa-Rahimabad Project Area

When identifying pilot sites for agroforestry restoration projects, it is important that the people in the catchment area are engaged in the process because they will be integral to the project's success or failure. Utthan's local knowledge and expertise was an important element in selecting the most suitable project area. The stakeholders included members from civil society groups, farmers' groups, a women's group and the panchayat (village councils of both Kotwa and Rahimabad). INBAR and Utthan held discussions with these groups to raise awareness of the project and the potential benefits for them and the community. After getting buy-in from all stakeholders, Canada's International Development Research Centre and INBAR released the funds to Utthan implement the project. In this four-year project, INBAR provided the financial seed capital and technical expertise to Utthan. The main challenge for the project proponents was to showcase a development model for restoring degraded land with bamboo in a sustainable manner.

Commencing work

Effective project implementation involves overcoming different challenges on the ground. In the Kotwa-Rahimabad project, INBAR and Utthan identified three specific challenges: ecological, socio-cultural, and economic and developmental. The challenges are interlinked; thus, for the Kotwa-Rahimabad project to succeed, it was imperative that they be addressed in a holistic manner. This section examines how participation and training were incorporated into the project to ensure that all the stakeholders understood all issues equally.

Participation and Training

Participation is key to the successful implementation of any project. In cases involving multiple interlinked challenges, it is necessary to have community buy-in not only at the initial stage but also throughout the life-time of the project and beyond. To build awareness, meetings held with stakeholders INBAR and Utthan used PRA techniques as a strategy to involve the local community in the project and have them take part-ownership of it. Using PRA, INBAR and Utthan were able to foster an 'enabling environment' in which the stakeholders, especially the villagers, could identify themselves with the Kotwa-Rahimabad project process and objectives. The people's participation helped INBAR and Utthan overcome the multilevel interlinked challenges that the project faced on the ground.

Throughout the project, training was provided for villagers (see Figure 17). In the initial phases of the project, it was necessary to address negative perspectives that villagers had towards bamboo and give training in basic literacy and numeracy. A series of initiatives taken by the project leaders in this regard brought about a definitive change in the mindset of people, which helped them understand the process and objectives better. Small-group meetings were held with villagers to create awareness of the benefits of bamboo cultivation and debunk the myths farmers had about it. Following this, the farmers received training in bamboo, soil health and productivity, agroforestry models, climate-smart agriculture, fodder for cattle and nutrition-sensitive agriculture.

Training programmes especially designed to empower the female members of the households were also offered. After years of land degradation, women were often the main householder in the village due to male migration out of the region in search of paid employment. All these development-oriented activities helped the project overcome the socio-cultural and economic challenges that INBAR and UTTHAN faced.

Figure 17. A training session with farmers (INBAR 2003).

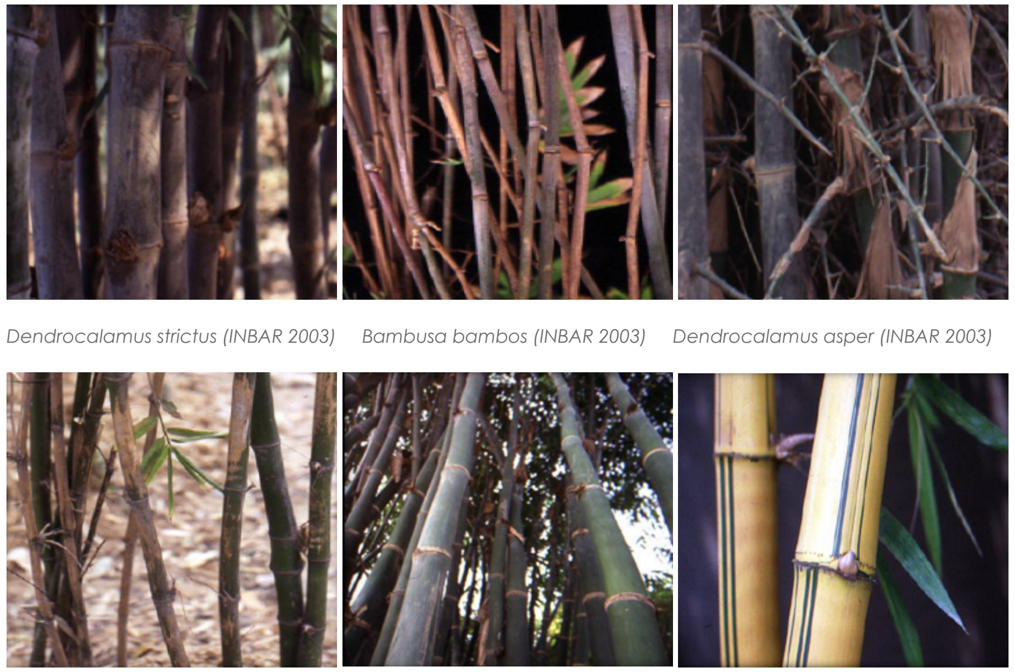
Ecological issues

The Kotwa-Rahimabad restoration project required decisions to be made about the most suitable bamboo species and agroforestry models to apply to reverse the degradation of the soil and water quality. Soil tests from different areas in the pilot area revealed that the pH value ranged from 4 to 11.[8]

Taking a bioremediation route to restore the soil stability, it was decided that the bamboo would be planted in areas where the soil was acidic in nature and jatropha in areas of alkaline soil. Selecting the bamboo species entailed the following key considerations:

- Fast growing on degraded lands;
- Able to prevent soil erosion;
- Useful and have potential market value for local people; and
- Fit with alternative agroforestry models that were being developed.

After conducting soil-species matching studies for 16 bamboo species, INBAR technical experts selected six species that met the criteria for the project site. The species were *Dendrocalamus strictus, Bambusa bambos, Dendrocalamus asper, Bambusa nutans, Dendrocalamus giganteus* and *Bambusa vulgaris cv striata* (see Figure 18).



Dendrocalamus strictus (INBAR 2003) *Bambusa bambos (INBAR 2003)* *Dendrocalamus asper (INBAR 2003)*

Bambusa nutans (INBAR 2003) *Dendrocalamus giganteus (INBAR 2003)* *Bambusa vulgaris cv striata (INBAR 2003)*

Figure 18. Kotwa-Rahimabad project bamboo species.

Once the six bamboo species were selected, the challenge that followed was to grow large quantities of the seedlings sustainably. For *Bambusa bambos* and *Dendrocalamus strictus*, the germplasm was prepared from seeds. Utthan procured 14 acres of degraded land for running the project office, building a nursery and organising training programmes. In the nursery, experiments involving sexual, vegetative and tissue culture methods were conducted for mass propagation. For species such as *Bambusa nutans*, *Dendrocalamus giganteus* and *Bambusa vulgaris cv striata*, vegetative propagation on the planting material procured worked well under the controlled conditions of a mist chamber that was developed for the purpose. The success rate of seedlings developed by the nursery was 92 per cent, even reaching 99 per cent in some cases (INBAR 2003). Propagation of *Dendrocalamus asper* was done through an innovative method known as 'Flute Technology' amongst the local villagers[9], which proved to be a successful example of incorporating traditional knowledge into the restoration project.

Once the nursery started producing the seedlings in enough numbers, Utthan started distributing them to the villagers for planting in their lands. In the initial

[8] A pH value of 7 is neutral. A pH value of less than 7 means the soil is acidic in nature and more than 7 means the soil is alkaline in nature.

[9] In Flute Technology the culm is cut in the shape of a flute, with holes neatly drilled into it. Small wooden pipes are fitted into these holes and the culm placed under the earth, with only the pipes jutting out of the earth. After every seven days water is poured into the pipe. Within 23 days or so, shoots begin to emerge from the nodes.

stages, only seedlings of those species that could grow fast and check soil erosion were distributed by Utthan. From the second year onwards (1998), Utthan started distributing saplings of these species so that their growth was more or less assured because of established rhizomes. Utthan offered training and guidance to the local farmers, which helped to achieve successful proliferation of all six bamboo species in a short period.

(a) *(b)*

Figure 19. (a) Bamboo and tree nursery and (b) bamboo and agricultural crop (INBAR 2003).

The agro-forestry models chosen by farmers included a bamboo + medicinal plants model (for example, with *Aloe vera*), bamboo + jatropha and a bamboo + agricultural crop model. In some areas where the topsoil mining had left deep craters, the chosen bamboo + fishery model also worked well.

Economic and developmental opportunities

Reversing the decline in villagers' livelihoods that had resulted from the degradation of agricultural lands due to the unsustainable topsoil extraction for brickmaking since the 1960s was a key objective of the Kotwa-Rahimabad project. The objective of doubling the farmers' incomes undoubtedly played a role in raising the general awareness and knowledge of the villagers. The challenge for INBAR and Utthan was to identify the best agroforestry models for income-generating opportunities with the minimum turnaround time. Whichever model was selected also needed to be sustainable over the longer term, maintaining the progress made initially and improving upon it season after season, even during off-seasons.

INBAR and Utthan's strategy to deliver economic benefits through the project was to train people in the community about the various bamboo-based enterprises they could use to improve their livelihoods. The training programmes helped villagers to develop the necessary skills to produce various products out of bamboo including scaffolding, baskets and agricultural implements. Some products such as incense sticks, matchsticks and pencils were made and sold via the Utthan Sustainable Development and Poverty Alleviation Centre in Allahabad. Utthan also connected bamboo consumers such as estate developers and enterprises that use bamboo as raw material (e.g. pulp and paper industry) with the producers. Attention was also given to activities which could improve the resilience in farming techniques such as using bamboo leaves to make compost to save money on fertiliser purchases.

Conclusions and recommendations

The outcomes of the Kotwa-Rahimabad project demonstrate what a remarkable success it has been (see Table 6). Between 1997 and 2000, the project exceeded all its social, ecological and economic goals. Even more important is the ongoing sustained improvement up to 2016. This case study shows a real turnaround story in terms of land degradation and poverty alleviation through the strategic incorporation of bamboo into agroforestry models for communities.

Sl.No.	Indicator	1996: facts and figures	2000: facts and figures	2016: facts and figures*
1	Water table in 5 wells	40 metres deep	33.7 metres deep	30.15 metres deep
2	Water in tanks	Dry tanks by January end	Water remained till June	Water remained all the year round
3	Greenery	Only 19 trees in 106 hectares	The total area is lush green	The total area is lush green
4	Production and economy	Practically no production	Each family earns a minimum of Rs 30,000/- a year from its holdings	Each family earns a minimum of Rs 70,000/- a year from its holdings
5	Poverty level1	872 out of 2340 people below poverty line	All families above poverty line	All families above poverty line
6	Migration of male members in search of jobs	All youths and adults used to migrate to other places in search of jobs	About 70% of male members have returned to their villages	About 95% of male members have returned to their villages
7	Micro-climateF	requent dust and cyclonic winds	Practically no stormsA	rea is free of pollution

Table 6. Kotwa-Rahimabad Area Project Facts and Figures
Source: 2016 Facts and figures provided by Utthan through an email to INBAR India, dated 24 August 2017.

In a field visit by an INBAR team in August 2017, the cascading effect of the project was seen in the entire belt of the Kotwa-Rahimabad area. The fact that the entire area of approximately 5000 ha looks green with improved livelihood opportunities and economic security is a standing proof of the tangible outcome of the project. With greenery all round, the whole area continues to brim with activities, keeping the hopes and aspirations of people living there alive and kicking. Through the sustained efforts of the project team over the years, the activities were replicated in 96 villages in the Kotwa-Rahimabad area.

Utthan has become an active champion of afforestation in the region. In 2014, it was producing over 10 million quality seedlings of various plants, including bamboo, from its 25 high-tech nurseries spread over its project locations. The organisation now has a dedicated staff of about 600 people. Utthan initiated similar projects using knowledge learned from the Kotwa-Rahimabad project. As a result, about 100,000 ha of degraded land in 600 villages in the states of Uttar Pradesh, Madhya Pradesh, Chhattisgarh, Bihar, and Jharkand has been reclaimed, benefitting over one million people economically and socially (INBAR 2017a, 2017b).

The Kotwa-Rahimabad project illustrates that:

- Development projects can become extremely successful if 'effective' and 'lasting' partnerships are forged with local governments, NGOs, the stakeholder community/ies and especially the farmers;
- Secure funding is provided at the first stages of a project before the benefits can be realised commercially;
- Local partners are empowered – 'leading/guiding them from behind' is key to ensuring interventions are sustainable;
- Incorporating local knowledge and wisdom when developing agroforestry models with bamboo can result in improved outcomes;
- Training is a prerequisite for the local community to benefit from sustainable income-generation opportunities;
- With effective promotion and marketing, the trading potential for bamboo and bamboo-based products can expand significantly, not only in the domestic market (India), but also in the whole of South Asia.

Nepal

Compiled by Bijaya Raj Paudyal

Introduction

Nepal is situated along the southern slopes of the Himalayan Mountain ranges in Asia. There are five physiographic regions in Nepal based on geology and geomorphology (LRMP 1986) (Figure 20). The Terai region consists of recent and post Pleistocene alluvial deposits that form a piedmont plain (Carson et al. 1986). The lower Chure is largely composed of very fine-grained sediments such as variegated mudstone, siltstone and shale with smaller amounts of fine-grained sandstone (Upreti 1999). The middle Chure has thick beds of multi-storied sandstones alternating with subordinate beds of mudstone. Very coarse sediments such as loose boulder conglomerates characterise the upper Chure. The dominant soil texture found in the Middle Mountains region ranges from fragmented sandy to loamy/boulder, loamy and loamy skeletal as per the diverse landforms. High mountains soils are rocky mostly derived from Phyllite, schist, gneiss and quartzite of different ages. The high Himal physiographic region is characterised by rocky soils originated from gneiss, schist, limestone and shale of different ages (Pariyar 2008).

The vegetation differs with the different land geology in Nepal; as such, it is important to adapt the various land restoration techniques with suitable planting methods and materials. Regarding the planting material, *Pinus roxburghii* (Chirpine), *Pinus patula* (Patte Salla), *Dalbergia sisoo* (Sisoo), *Tectona grandis* (Teak) and *Alnus nepalensis* (Uttis) are the major seedlings being planted in production forestry. Similarly, Bamboo (*Bambusa tulda*), Ketuke (*Agave sisalana*) and Simali (*Vitex nigundo*) are the major vegetative planting materials for land restoration in Nepal.

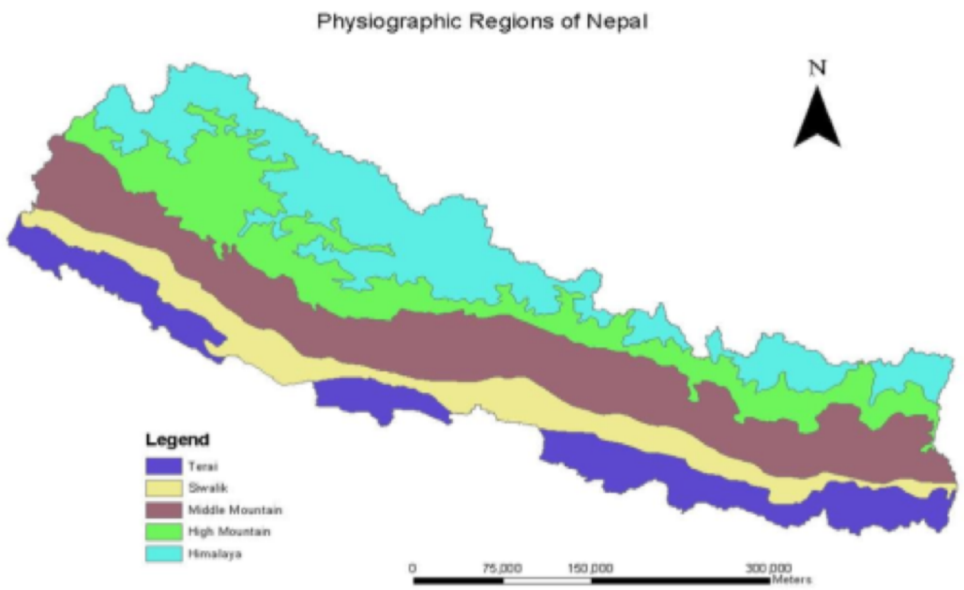


Figure 20. Map showing the five physiographic regions of Nepal.

Figure 21. Typical bamboo plantation for land rehabilitation in Nepal.

The Government of Nepal included a plantation programme in its first five-year plan (1956-1961) to rehabilitate the country's degraded land. A number of environmental protection programmes and projects have invested funds into plantations with different species of trees and non-timber forest products, including the Sagarnath and Ratuwa Mai Plantation Project, the Nepal Australia Forestry Project, the Tamagadhi Taungya plantation, the Hill Forest Development Project and the Terai Community Forestry Program. National and international agencies, including the Department of Forests, the Department of Soil Conservation and Watershed Management, the Department of Water Induced Disaster Management, the World Wildlife Fund (WWF) Nepal and the United Nations Development Program (UNDP) Nepal office, have initiated plantation and rehabilitation work using various bamboo species and contributing multiple benefits from aesthetic to livelihoods improvement and disaster mitigation for the population.

Although a number of projects have used bamboo as a bioengineering tool, information and knowledge-sharing about the interventions and land restoration outcomes in Nepal is lacking. Further, there are only a few detailed case studies from a peoples' perspective of using bamboo to successfully restore land sustainability in the long run.

In sum, previous projects on bamboo have the following limitations:

- Knowledge gaps from the bamboo plantation land restoration interventions and the outcomes due to a lack of research;
- Many acres of degraded land in Nepal are unused due to a failure to replicate and upscale plantation benefits from pilot interventions;
- Few peoples' perspectives are documented on bamboo utilisation for livelihood and economic growth along with the successful conservation of bamboo plantation;
- Limited research of watershed management and its sustainability at critical catchment places for better livelihood activities (Figure 22).

(a) (b)

Figure 22. (a) Watershed Management using bamboo in Bardias Mahottari, Nepal and (b) bamboo plantation along Giru Bari river in Nawalparasi, Nepal.

Case study approach

The methodology used in the case studies focused on gathering primary information by:

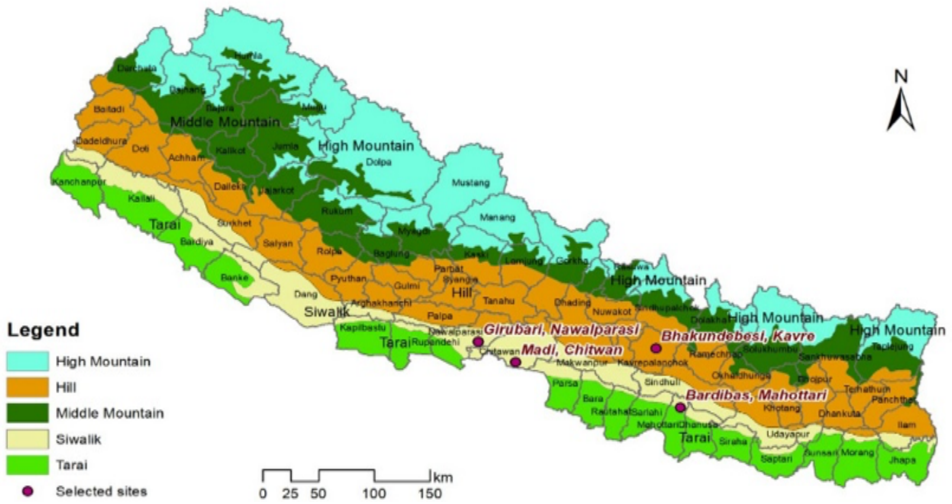
1. Identifying the existing major projects applying bamboo land restoration projects in Nepal through a literature review and expert consultation;

2. Conducting case studies by collecting information and interviewing local people and institutions such as forest users' groups and watershed protection committees involved in bamboo plantation;

3. Analysing the information to find out the factors determining the success of land restoration interventions using bamboo; and

4. Proposing recommendations based on the lessons learned for the better use of bamboo for land restoration in Nepal.

Different methodologies were used while conducting field visits and during the proposal writing, and key informant information, personal interviews and literature reviews were gathered. The chosen sites for the field visits were identified at four different physiographic regions in the Terai, the Chure, and Middle hills regions. All four have different geographical territories and textures, being a source of important information about the land restoration through bamboo plantations (Table 7 and Figure 23).



Description	Site 1. Bardibas	2. Madi	3. Girubari	4. Bhakunde besi
Site name	Pani KholsiG	Rui khola	irubari khola	Bakunde besi
Address	Bardibas Municipality -1, Bardibas, Mahottarai district	Madi Municipality Chitwan district	Hopsekot Municipality	Namobudhha Municipality, Ward no 2, Kavre Palanchok District, Nepal
Aspect	Southern slope and foothills of Chure ridge	Norther slope-foot hills of Chure	Sourthern slope - foothills of Mahabharat	Valley in Southern slope
Physiographic region	Terai	Inner Terai - Chure	Inner Terai - Chure	Middle Hills - Valley
Watershed	Pani kholsi Micro watershed	Riyu Sub - watershed	Girubari sub watershed	Dapcha Khola micro watershed /Roshi sub watershed
Implementing agency	Chure Watershed Management Project, Bardibas	Adobe Bamboo & Earth Initiative Pvt. Ltd.	Disaster Mitigation and Support Program project	Nepal-Australia Forestry Project, District Forest Office, Kavre Palanchok
Executing agency	Department of Soil Conservation and Watershed Manage-ment, District Soil Conservation Office, Mahottari	Department of National Parks and Wildlife Conservation, World Wildlife Fund, Chitwan National Park	Department of Water Induced Disaster Management	District Forest Officer Kavre Palanchowk, Department of Forests
Local community	Pani Kholsi Micro watershed Conservation Committee	Buffer Zone Committee	Girubari Khola (River) Sedimentation Protection Coordination Committee	Bhakunde Chaur Community Forest User Group

Figure 23. Map showing four case study sites of bamboo plantation in Nepal.
Table 7. Details of Case Study Sites

Case Study 1: Pani Kholsi, Bardibas, Mahottari, Nepal

Bardibas is a small town located in the Chure ridge foothills situated along the East-West Highway sector in Mahottari district, Terai region. Pani Kholsi is located in the Bardibas Municipality, Ward No. 1, Mahhotari district. The study team communicated with the Pani Kholsi Micro Watershed Committee to prepare for the case study. The participants were Mr Kedar Koirala, Head Teacher of Deorali High School, Bardibas Ward No. 1; Mr Rishi Pokharel; the Chairperson of Bardibas Ward No. 1 municipality; and former Chairperson of the Pani Kholsi Micro Watershed Committee.

Over 27 years, continuous and intensive pressure to use and extract natural resources from Chure hills has caused heavy degrading to the catchment area. Mr Pokharel said 'he worked with 13 members and visited the Mauli area of Saptari District'. He was inspired by the successful conservation work done there, especially by the people of the Mauli areas who were able to stop soil erosion. He worked with the people and communities in this micro watershed from the beginning of 2006. The area now is restored and rich in plants. He stated that 'continuous efforts are necessary in the Chure hills, like conservation and bamboo plantation work, which played a vital role in this endeavour'.

Similarly, Mr Kedar Koirala stated that 'Pani Kholsi is a historical place and a 3.5-km-long water stream. Now, we share equal benefits with all the local households by providing bamboo, along with financial support. We stopped open grazing and illegal cutting of forest resources. We got the ideas by doing and learning through bamboo plantation for restoration of the deteriorated land of the Chure hills which needs regular protection measures and maintenance work. To fulfil this purpose, we are trying to collaborate with local NGOs and district institutions and hope to extend across the country' (Figure 24).

(a) *(b)*

Figure 24. (a) Critical stage of Pani Kholsi in 2006 and (b) Pani Kholsi in 2018 after restoration using bamboo.

To implement the programme, locals started the plantation work with 4000 bamboo (four species) seedlings and cuttings with the support of District Soil Conservation Office (DSCO). In the first year, the committee started conservation work in the micro catchment. However, the local people took little interest in their responsibility to conserve the natural resources in the upstream area and rather focused on protecting their land and houses in the downstream catchment area. To motivate the people to actively participate in the conservation programme of the deteriorated micro catchment, Bardibas, the Chure Watershed Management Project, the DSCO and the local community collaborated to design a benefit-sharing mechanism. A commitment was made with the local communities that after reestablishment of various natural resources under the greenery programme, the benefits of resources would be divided between each household in the communities and the micro watershed conservation committee at a 90:10 ratio, respectively.

The results from the interventions were easy to identify. The efforts successfully controlled and reduced the water-induced disaster from a 300 m span to 30-m-long section of Pani Kholsi (the stream). The Pani Kholsi micro watershed has more than 10,000 bamboos planted in it, and the local people living around and near this river would like to retain all the bamboo for environmental protection. The local forest resources are now regenerating naturally. Communities have planted *Bambusa nutans* (Taru Bans) and *Bambusa balcooa* (Dhanu Bans) bamboo. A total of 1,537 households were previously affected by water-induced disasters. The native conservation programme was a milestone for initiating President Chure Terai Madhes' Conservation and Development Programme in Nepal.

The case study team observed that the degraded site developed into a plant rich environment, combined with bamboos and other forest seedlings, turning it into Nepal's unique model for micro watershed conservation. In this fiscal year 2017/2018, USD 30,000.00 was allocated to conserve the Chure region by the Bardibas Municipality. Chairperson of the Pani Kholsi Watershed Conservation Committee, Mr Rishi Pokharel, is planning to carry out further conservation work by implementing structural measures and other bio-engineering work such as planting bamboo rhizomes to maintain existing interventions. The budget was allocated after the successful bamboo plantation to conserve the Chure region. In Pani Kholsi, one of the hotel proprietors from the Bardibas market, Mr Hira Lal Gautam has donated money and constructed a siltation check dam in Pani Kholsi to help minimise the high flood near the vicinity areas of Bardibas market during rainy season. He urged for a payment for ecosystem services (PES) system to be developed in the Pani Kholsi watershed. The committee is also planning to hire a forest watcher to patrol the site and standardise maintenance works to improve effectiveness. One of the local NGOs, Community Development and Advocacy Forum Nepal is also willing to contribute to the long-term protection and management of Pani Kholsi. The DSCO, established in 1996, is also supporting the sustainable management in this area of the Chure region.

Case study 2: Madi Municipality, Chitwan, Nepal

Flooding in 2010 completely inundated fields of four Village Development Committees in Madi, which lies inside the Chitwan National Park. The flood washed away banks causing significant property damage. It also deposited tons of silt and sand particles, making the land unproductive. The flood in the Rui Khola of Madi Village Development Committee also swept away land causing degradation in areas connected to the Chitwan National Park.

The Adoption of Bamboo and Rattan Initiatives (ABARI) and the WWF agreed on establishing the Hariyo Ban project in October 2014. The project commenced in November 2014. Major activities included setting up a nursery, community mobilisation, bamboo species plantation and capacity building for the community. ABARI worked in close collaboration with UNDP and community-based organisations such as Buffer Zone, Community Based Disaster and Risk Management Group, Someshwor Buffer zone Community Forest and Terai Arc Landscape for the implementation.

During the implementation period, local communities were consulted about the availability of their land. The communities were given 10,000 seedlings of commercially viable bamboo including the species *Bambusa balcoa, Bambusa nutans* and *Bambusa tulda*, which are native to the bioregion. In exchange, the community provided commitment of labour, water, land (trench of 1 m by 1 m and area of at least 100 m^2), manure and bamboo fencing against grazing. *Bamboos balcooa, Bambusa nutans* and *Bambusa tulda* are among the 24 species planted with the community of Gaurinagar, in Madi, Chitwan (Figure 25). ABARI also provided technical and capacity building on soil testing, land identification, the plantation and harvesting regime, nursery set up and intercropping. With their support, the local communities were able to plant bamboos at a greater scale.

(a) *(b)*

Figure 25. (a) Status of site in 2010 and (b) result of replication in 2018.

The following are the key results from the site:

- 10,000 bamboo clumps planted for biodiversity conservation and land restoration;
- 24 different species of bamboo for ecosystem management; and
- Two bamboo-based enterprises established to improve livelihood and income generation: one was a nursery and the other enterprise collected bamboo to sell for different household uses. The nursery was closed due to lack of funds from the donor, but the skilled worker continues to manage bamboo clumps on his own, and the other enterprise is still running and depends on orders received from the market.

Mitra Lal Chapai, Gaurinagar-09, Madi Municipality, Chitwan

Mitra Lal Chapai, a local Gaurinagar resident, emphasised the economic and conservation aspects of the bamboo plantation. He said if he had not participated in bamboo propagation training and planted bamboo on his own land along with the other community members on their respective lands in Gaurinagar village, at least 70 houses and approximately 600 to 700 ha of land could have been washed away by the Rui river. The plantation helped the river get back to its old route and helped with soil conservation. Mitra Lal Chapai was concerned about those community members who were not eager to be part of, or had not participated in, the plantation because this could threaten everyone (Figure 26).

Figure 26. Stream bank protection using bamboo in Gaurinagar.

Ram Krishna Thapa, Gaurinagar-09, Madi Municipality, Chitwan

As a local resident of Gaurinagar-09, Madi, Ram Krishna Thapa has been an active member of bamboo plantation project. Every year, the river torrents used to cross the boundaries of his residence, thus negatively affecting his land. As his residence is located near to the national park, he also faced the threat of wildlife entering his house. He started to grow the locally available bamboo species around his house as a fence. Later, the fence started working as a barrier to prevent water and wildlife from entering his house. The growing bamboo also worked as an embankment for his fence because its roots held on to the mud and prevented soil depletion. His realisation of the features and qualities of bamboo led him to work for the conservation of the Rui River (Figure 27).

Figure 27. Mr Thana explaining the success of the bamboo plantation.

Mr Thapa stated that 'before the plantation, the flood on Rui River wiped away the land even after the gabion wall fencing. Bamboo rhizomes are better at withstanding floods because they hold on to the mud, even if it contains silt, and they are better than a gabion wall in terms of preventing soil depletion and reducing the risk of the river flooding the land. After the plantation, the growth of the roots increased and intervened as a natural green gabion structure for protecting land from flooding and river bank cutting'. Based on these benefits, bamboo expert, Mr N. K. Ojha, argued that international and national institutions relating to bamboo should support further research and the upscaling of this particular programme.

Case study 3: Girubari, Nawalparasi

Girubari River (Khola) model site is located in the Western Development Region in the Nawalparasi district. The catchment area covers 154.5 km^2. Its primary tributary, the Peluka river, stretches 12.72 km from its origin to Jhyalbas. In 1998, the Girubari River (Khola) watershed was in a very poor condition. A team confirmed that the Girubari River system was a suitable project site to demonstrate the watershed management and disaster mitigation potential of bamboo using model intervention measures for a river system. The Disaster Mitigation and Support Programme project commenced in September 1999 in the Girubai river system.

Heavy deforestation of subtropical hardwood mixed forest was driven by shifting cultivation practices, continuous grazing, lopping and topping, forest fires and encroachment by the local community causing landslides in upstream and sedimentation in downstream areas of the case study site. Very scarce degraded shrubs and vegetation species such as Banmara (*Eupatorium adenophorum*), Titepati (*Artemisia vulgaris*) and Botdhairo (*Woodfordia fruticosa*) have newly regenerated on the site.

During the project implementation, bioengineering activities were prioritised at the different sites. *Bambusa nutans* and *Bambusa tulda* were the major species of bamboo planted during the upstream and downstream land restoration (Figure 28). Seedlings at least 0.3 to 0.5 m in height and 1.0 to 1.5 cm in diameter at the base were planted. These sizes were considered appropriate because they were more tolerant to the harsh climatic condition.

(a)

(b)

Figure 28. (a) Upstream greenery using bamboo in Girubari and (b) downstream river bank restoration in Girubari.

The study team met with several people during the field visit to the Girubari Khola site including Mr Yadu Nath Pandey, Mr Pruna Prakash Biswakarma and Mr Chandra Singh Rajali. The study team also met with Mr Dan Bahadur Raymajhi, Chairperson of the GirubariKhola Sediment Protection Coordination Committee, Girubari, Nawalparai (district level). Mr Raymajhi said that 'in the past, around 800 ha of agricultural land was affected by floods. We had flood fears in the past, but now we are sure that we can have three crops: paddy rice, wheat and mustard. The role of the bamboo plantations is significant in addressing landslides and flood control. Now we can protect more than 800 ha of paddy land from the flooding, replicating the bamboo plantation in the landslides and river banks. All landowners agreed to the project prior to starting the bamboo plantation on their own land so that we do not have any conflict now'. According to the local community, one of the project results was that 80 per cent of the bamboo survived after the plantation was established.

The pilot site has had a positive impact on the communities who hired a local plantation watcher from their fund (about USD 0.6 million from 115 households). Mr Kishor K. Karki, the bioengineering expert, employed during the project period stated, 'Analysis of the micro climate (soil texture, temperature, local grass or weed and plant sapling and run-off) of the plantation site, using mandatory techniques or tools, is required to be carried out before starting the plantation work. This helps to shape the decisions on planting bamboo materials and other protection measures'. In addition, 'careful inspection of the condition and factors affecting the site such as aspect, soil moisture, dryness, stoniness, wind direction, sun exposed hours, soil fertility and slope gradient in case of a landslide and gully control work has to be done during the plantation period'.

Case study 4: Bhakunde Besi, Kavre

Historically, the land had large forest areas with various species Chirpine and other broadleaves. By 1950, the forest landscape changed into an open and degraded forest land. Open grazing and the indiscriminate collection of firewood for cooking and timber for house construction placed an increasing pressure on the land. Ongoing pressure caused the degraded land to erode, beginning with rill erosion, and then sheet erosion and finally gully erosion. Owing to the erosion, huge landslides occurred in the upland affecting households and paddy fields downstream. The paddy land was covered by red soil, thus reducing the production of agricultural crops. As nearby households were in danger, some families shifted from the degraded areas to safer sites. Locals, however, took no action to address the problems. In addition, neither the government institution nor the community-based organisation responsible for action after the landslides and reclamation of degraded land acted to restore the forests.

In 1985, Mr Shashidhar Timilsina, a local leader, took the initiative to reclaim Bhakunde Besi's degraded land. The main aim was to stop landslides and soil erosion in Bhakunde Besi and the negative impacts these were having on its environment. With the support of the Nepal Australia Forestry Project, bamboo and other measures were used in Bhakunde Besi to address the landslides. The team carried out various activities such as bamboo watling (using Demdrocalamus strictus and other bamboo species), constructing a loose stone check dam, plantation of ketuke (*Agave sisalana*), simali (*Vitex nigundo*), banana (*Musa sapientum*) in the gullies and chirpine (*Pinus roxburghii*) on the degraded land.

During the project's implementation period, Forest Officer Bijaya Raj Paudyal provided technical know-how to the local communities. The technical and capacity-building programme provided skills on pitting, planting and low-cost soil conservation measures to local communities. The distribution of bamboo and other forest species seedlings, as well as planting costs, were covered by the District Forest Office Kavre Palanchowk (DFOK) and the Nepal Australia Forestry Project. Vegetative propagation methods were used to establish bamboo in the field. Major local materials used in the restoration period were bamboo clumps, bamboo watling, ketuke, simali, banana and stones. Bamboos were used for the check dam and watling to combat landslides and soil erosion.

Local people formed community forest user groups to protect the degraded land to combat the risks posed by landslides. They used bamboo materials and committed to stop open grazing and participate in conservation works. In addition, local communities took responsibility to manage the land as Panchayat Forest according to government rules.

The plantation programme with bamboo has become a notable demonstration or key entry point for treating landslides and reclaiming degraded land. Before the plantation, the government land had become a 'no man's land'. The successful result of the Bhakundebesi landslide was the community's realisation that land management is vital. The appointing of a local community leader was key to the project's success. According to Badri Timilsina, Buchakot, Bhakunde of Namo Buddha Municipality, 'Sustainability of any conservation work is vital. During the implementation of the programme, local people have taken responsibility of the area as a community forest. Since initiating the land reclamation programme, local communities are dedicated to protecting the forest and using bamboo materials in the gullies and plantation sites. Mr Shashidhar Timilsina also emphasised the importance of appointing a Forest Officer who visited the field to facilitate proper attention to the plantation. Although most of the reclaimed area is now under control of the Nepalese Army Complex, the conservation effort upstream has played a positive role for the downstream households and paddy field'. Local resident, Mr Bishnu Khanal noted 'The benefits from replicating the bamboo plantation can be observed in the area. With support of the DSCO, Kavre Palanchowk, a micro-watershed programme was launched in the adjoining area. There are huge opportunities to replicate the bamboo plantation along the roadsides in the area'.

Conclusions and recommendations

There are several lessons to be learned from these case studies:

- Local people have vital a role to play by participating in the management of degraded land once they realise the negative effects of existing land use patterns.
- Using the land for bamboo plantations has to be identified at the initial phase, along with proper consultation with the landholders to ensure their ownership and participation in the long run.
- Interaction with local people on the importance of bamboo's fast growth rates, usefulness, resilience, features and its overall added value leads to awareness raising in the communities.
- Sensitisation to the species used, farming and propagating techniques has to be highlighted from the beginning to foster bamboo survival and growth.
- Skill development, not only related to the propagation but also technical use, has to be fostered to develop bamboo products.
- The plantation programme with bamboo has become a key entry point for treating landslides and reclamation of degraded land.
- Using bamboo to reclaim areas where large-scale landslides occurred and providing trainings on technical matters could extend an important message about replication and upscaling to nearby and distant areas.
- Inspecting the site conditions carefully and evaluating the factors affecting the site such as aspect, soil moisture, dryness, stoniness, wind direction, sun

exposed hours, soil fertility and slope gradient in case of landslide and gully control work is essential.

- Regular and proper monitoring of planted species during rainy and winter seasons must be carried out with the user groups.

The following suggestions should enable replication and upscaling of this effort:

- Micro or Sub Watershed Conservation Committee should be linked with community forest user groups for a sense of ownership and participation in the long run.
- A PES system should be institutionalised for financial sustainability of maintenance and livelihood improvements.
- Bamboo plantation activities should be upscaled to reduce soil depletion, combat flooding and enhance biodiversity.
- Upscaling will help the community to understand the ecosystem better and enable them to increase water storage and land productivity.
- Bamboo plantations could improve the safety of human settlements by reducing conflicts with the animals.
- Bamboo plantations increase the number of the bamboo culms and products, which could directly support income-generating activities and job creation linked to the market economy for the community.
- Proper identification of the intervention is required because communities have different geographical and social contexts.
- Adapting or incorporating adjacent programmes related to bamboo plantations and engineering need to be coordinated.
- Local people must be made aware of the importance of bamboo species and plantations. The field staff must raise awareness amongst the people about the potential of bamboo to combat land degradation and generate valuable raw materials.
- Programmes helping communities to increase income generation would be help them to adapt to plantation programmes.
- International and national institutions relating to bamboo should support further research and the upscaling of programmes.

Thailand

Compiled by Jack Durrell[10]

Introduction

Coastal erosion is a major threat to ecosystems and livelihoods in Thailand. Government estimates suggest that more than 50 per cent of the Gulf of Thailand and Andaman Sea coastlines – some 1400 km is severely eroded (Phransi 2011). Studies have suggested that in some locations erosion could actually exceed 25 m every year (Kanparit 2007; Rattanamanee 2008). As a result, communities have been forced to relocate inland, and many have lost a major source of their income – as sea animals have disappeared and migrated elsewhere.

Coastal erosion can be attributed to both natural processes and manmade activities, including (a) wave-induced currents – particularly during the monsoon period; (b) decreasing sediment supplies from rivers – mainly the result of dams constructed upstream; (c) land subsidence or sea-level rises – which increase water depth, deepen the base of waves and enhance wave energy; and (d) the mining of sand and shells along the coastline.

Figure 29. Bamboo dam and mangrove farm (source: somkku9kanokwan).

Although mangroves previously provided some protection, the rapid growth of shrimp farms has removed this form of defence in some areas (DMCR 2014), and rather than providing a solution to the erosion crisis, some coastal defences such as sea walls may have actually contributed to the problem by increasing erosion in adjacent areas (Phransi 2011).

10 INBAR is grateful to Thailand's Department of Marine and Coastal Resources for the use of figures and images included in this case study.

Coastal communities in Thailand have adopted a practical and cost-effective material to support their fight against erosion – bamboo – which is abundant along many stretches of the country's coastline. Initially adopted by a single farmer, the approach was subsequently enhanced by a government-sponsored initiative that combined indigenous knowledge and scientific expertise and promoted bamboo barriers across six locations in five provinces.

The idea is straightforward: the barriers act as wave breaks which reduce the height and therefore the energy and strength of waves as they approach the coastline, and this enhances the build-up of sediment behind the barriers which can eventually support the growth and re-establishment of mangrove forests, and ultimately, help stabilise coastal areas (see Figure 30).

Project implementation

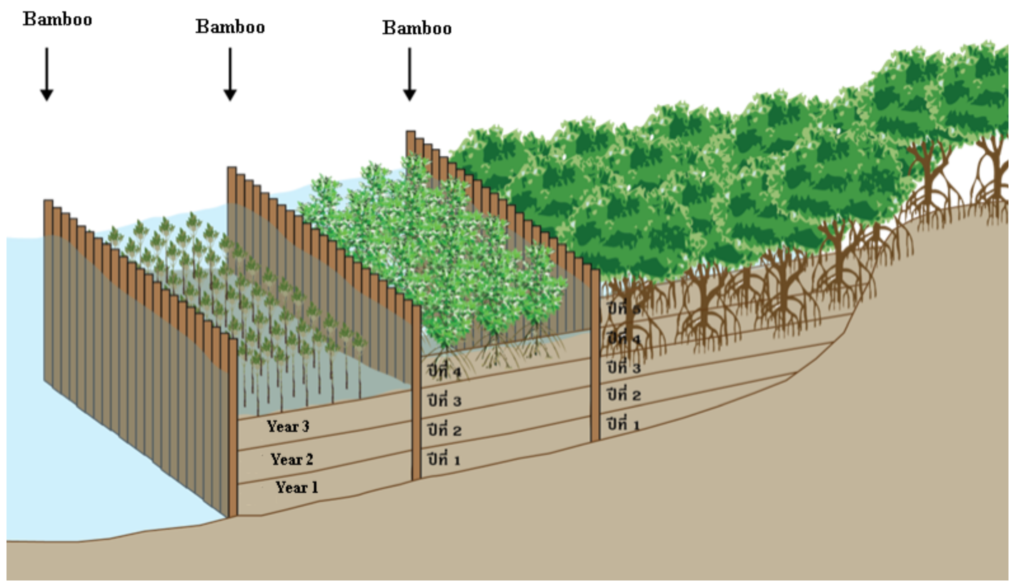


Figure 30. Arranging bamboo poles in rows helps to reduce the height and strength of waves, facilitate the accumulation of sediment and re-establish mangrove forests for more resilient coastal defences (source: Bamboo Revetment Project) (DCMR 2014).

The experience of a government-community partnership at Samut Sakhon suggests the most effective form of defence is to place the barriers within at least 50 m of the coastline, with successive parallel rows at least 50 m apart, with zig-zag patterned rows in-between. The poles should be pinned together and positioned upright in the seabed – approximately 2 m below the seabed and 3 m above (although exact measurements can vary depending on the type of sediment) – and every metre should have no fewer than 35 poles. Although studies are still needed to determine the optimal bamboo species and size, the initiative at Samut Sakhon used aged bambusa bamboos, with a diameter of at least three inches, to provide the required strength (DMCR 2014).
To ensure effective long-term maintenance, special attention must be paid to the presence of shipworm between October and December which can attack the poles and cause them to rot. Openings should also be provided for boats – no wider than 10 m – and as sediment accumulates behind the rows of bamboo, trees can be planted to re-establish or initiate mangrove forests.

Community involvement

At every stage – planning, construction and maintenance – implementation should be managed in close cooperation with local communities to encourage ownership and ensure they benefit from income-generating opportunities. Planning meetings should be held in communities so that local people can help to identify priorities, and a small group of community representatives should be appointed to check the suitability of targeted areas, verify the types of bamboo used, evaluate work, and inspect damage and oversee maintenance.

Long-term success is also dependent on securing agreements from legal land owners and ensuring that local communities commit to maintenance efforts and afforestation, once sediment has accumulated behind the rows of bamboo.

Targeting suitable areas

Areas most likely to support this intervention are tidal and mud flats where sediment accumulates annually. Approximately 3148.32 km of Thailand's coastline are sand beaches, tidal flats and mud flats, and tidal flats and mangrove forests are scattered across 24 coastal provinces (DMCR 2014) – meaning that there is considerable potential to expand the application of bamboo coastal defences to other areas threated with erosion.

Identifying suitable areas can be enhanced through the use of high-resolution satellite images which will also aid effective monitoring efforts once the bamboo barriers have been established.

Results

Assessments carried out since the introduction of these defences have demonstrated positive benefits for ecosystems and local livelihoods. At one location – Pak Klong Bang Bo in Samut Songkhram Province – the bamboo walls successfully limited the amplitude and the energy of waves. By measuring wave heights in front of and behind the bamboo as they approached the coastline, researchers calculated that wave heights were reduced in size by 15.2 to 86.6 per cent (Phransi 2011).

Some rules for establishing bamboo barriers:

- Use aged bamboo poles with a diameter that is no less than 3 inches
- Rows of bamboo should be within at least 50 m of the coastline
- Poles should be pinned together and positioned upright in the seabed – 2 m below the seabed and 3 m above
- Every metre of each bamboo wall should include at least 35 poles
- Construct zig-zag bamboo rows in the spaces between parallel bamboo walls

Figure 31. Assessments demonstrated that wave heights declined significantly behind the bamboo walls constructed at Pak Klong Bang Bo. (source: Bamboo Revetment Project) (DCMR, 2014).

Subsequent measurements across the six locations targeted by Thailand's Department of Marine and Coastal Resources also revealed barrier impacts on wave strength, which declined by 50-60 per cent at Pak Klong Meunharn, 5-70 per cent at Pak Klong Pramong and 30-60 per cent at Majchanu Shrine (DMCR 2014). Sediment accumulation was also impressive. Between November 2010 and March 2013, approximately 23.50 to 56.20 cm of sediment accumulated in participating areas; in some locations more than predicted seal-level rises (DMCR 2014).

Selected impacts:

- Wave strength was reduced – from 5 to 70 per cent at different coastal communities.
- At one location, wave heights were reduced by 15.2 to 86.6 per cent.
- Sediment accumulation increased in participating areas by 23.50 to 56.20 cm.
- The coastline stabilised and aquatic animal species recovered – including clams,
- oysters and crabs.

(a) (b)

Figure 32. (a) Before and (b) after. These images demonstrate how the construction of bamboo barriers helps increase mangrove forests and reduce erosion. (source: Bamboo Revetment Project) (DCMR 2014).

The sediment layer supported the growth of young mangroves, which stabilised coastlines and provided a habitat for aquatic animals – surveys found that populations of important species recovered and increased, including mullets, clams, oysters, hairy rock crabs, blue swimming crabs and king crabs.

Latin America
Colombia

Compiled by Juan Carlos Camargo, Angela Maria Arango,
Juan Martin Maya, Liliana Bueno Lopez

Introduction

In recent decades, land use changes have impacted Colombia's coffee plantations. Many plantations were converted to more competitive commercial crops, especially pasture for cattle farming (Guhl 2004), as well as to make way for the expansion of peri-urban areas (Giraldo et al. 2015; Etter et al. 2006). The transformation in agricultural land use change was driven, in part, by a decrease in Colombian coffee's wholesale market value due to phytosanitary problems, first by rust (roya) and then the berry borer (broca) (Guhl 2004; Aguilar Zambrano 2003). As a result, cattle farming is now Colombia's dominant land use (e.g. Muñoz 2017; Camargo and Cardona 2005).

In Colombia's remaining coffee region, the bamboo species *Guadua angustifolia* (guadua) dominates the forest area. Their distribution corresponds with ecological conditions between 900 and 2000 m above sea level (m.a.s.l) and usually with precipitation over 2000 mm per year. Although Klein and Morales (2006) estimated a total of 28,000 ha of guadua forest, Camargo and Cardona (2005) observed high levels of fragmentation, with more than 67 per cent of patches less than 5 ha in area. Muñoz (2017) identified a loss of 2317 ha between 1989 and 2016 at a rate of 85.8 ha/year. In this case, bamboo forest fragments in 2016 became 1.8 ha on average, down from 4.5 ha in 1989, whereas pastures and urban areas were about 2.5 and 2.7 times, respectively, more extensive in area during the same period.

Guadua bamboo forests fulfil critical ecological functions that benefit the coffee region's population (see Figure 33). Ramirez (2017) found over 172 plant species associated with managed guadua stands. Sanchez and Camargo (2012) recorded 115 bird species. In addition, researchers have documented soil conservation (Camargo et al. 2010a) and water resources benefits (Chara et al. 2010). Economic benefits from guadua bamboo forests are significant if sustainable forest management is practised (Arango et al. 2017) guaranteeing valuable ecosystem services provision (Muñoz 2017a).

(a) (b) (c)

Figure 33. (a) Landscape in the coffee dominated by Guadua anustifolia (source: author); (b) Galeandra beyrichii registered by Ramirez 2017, within a natural bamboo forest (source: Fernando R. Diaz); and (c) Momutos aequatorialis registered within a natural bamboo forest (source: author).

Project implementation

In 2002, the Faculty of Environmental Sciences at Universidad Tecnologica de Pereira, in Colombia, initiated two experiments to evaluate the contribution of guadua plantations to improve the connectivity between fragmented bamboo forests in the country's coffee region. The experiments were designed to generate information about growth, productivity and changes to soil properties after guadua plantations were established in the region. In addition, the experiments were designed to generate data on these guadua plantations potential commercial value as a source of raw material.

Two sites, with different land uses, located close to natural guadua bamboo forests, were selected after consultation with local farmers. Both sites elevations were 1,200 m.a.s.l with precipitation of 2000 mm per year on average and a mean temperature of 24°C. The soils were andisols, slightly acidic with a depth, located on the slopes, between 7 and 12 per cent (Ramirez 2017). The farms, Napoles and El Bambusal, are located in the municipality of Montenegro, northwest of the Quindío Department in Colombia (see Figure 34). The first site, Napoles farm, was under pastures for more than 30 years. The second site, El Bambusal farm, had been a coffee plantation for 20 years. Farmers from both sites were involved in the decisions on land use change based on their interests in increasing bamboo's commercial productivity.

To establish the plantations, sites were manually cleared and guadua seedlings were planted at 5 m x 5 m spacings. In total, 400 culms per ha were planted. At both sites, the total planted area was approximately 1.5 ha. Using macro-proliferation techniques, the rhizome seedlings came from established natural bamboo stands. Plantation establishment and management during the first year cost on average an estimated 1100 US dollars. To monitor growth and productivity during the first eight years, measurements were carried out on plots with eight culms. When delimitation of culms was no longer feasible, 10 m x 10 m plots were used.

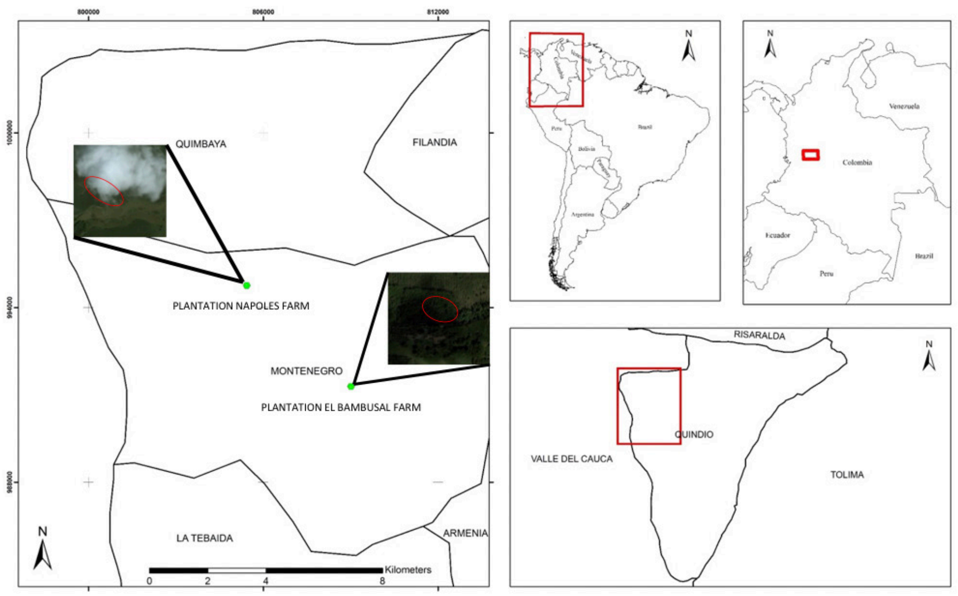


Figure 34. Location of guadua plantations farms Nápoles and El Bambusal in Montenegro, Quindio, Colombia.

Guadua Plantations: Ecological Impacts

The two projects demonstrated how, in a short period, landscape restoration could be achieved through the strategic promotion of guadua plantations. Fifteen years after the plantations were established, improvements in the landscape ecosystem were evident.

Increased connectivity: At both Napoles and El Bambusal, farms connectivity between the plantations and the surrounding natural bamboo forests increased (see Figures 35 and 36). The reduced fragmentation created valuable ecological areas for both plants and animals (Forman and Baudry 1984).

(a) (b) (c)

Figure 35. The plantation area is highlighted by the red circle in Napoles farm: (a) 2002. Source: Google Earth. (b) 2016. Source: Bing Maps. (c) 2017. Orthomosaic from drone images.

(a) (b) (c)

Figure 36. The plantation area is highlighted by the red circle in El Bambusal farm: (a) 2002. Source: Google Earth. (b) 2016. Source: Bing Maps. (c) 2017. Orthomosaic from drone images.

A panoramic view shows where plantations have grown and the increased connectivity within the landscape (see Figure 37).

(a) (b)

Figure 37. (a) Guadua plantation in Nápoles farm (2017). The plantation area is highlighted with by the red circle (source: author) and (b) Guadua plantation in El Bambusal farm (2017). The plantation area is highlighted by the red circle (source: author).

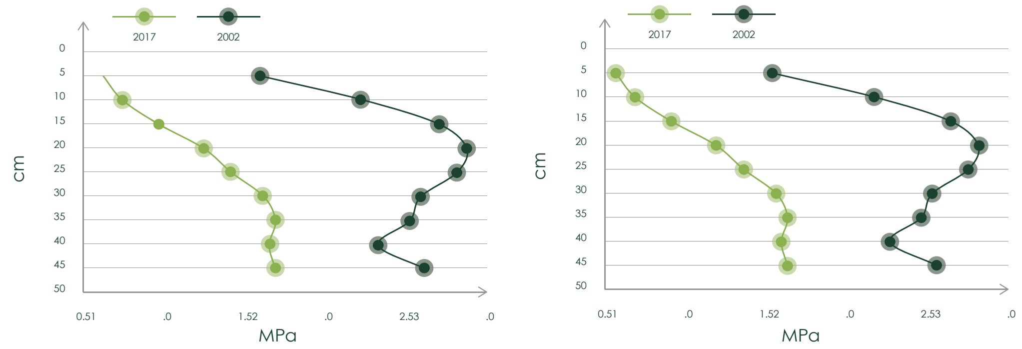
Forest carbon sequestration: Both plantations have contributed to climate change mitigation through CO_2 sequestration. Using the dendrometric value variables obtained during the inventory, the estimated total carbon stock accumulated in biomass was estimated at a rate of 5.9 and 11.5 Mg/ha/year CO_2, sequestered respectively for the plantations at Napoles and El Bambusal farms. Owing to the dimensions of culms, the plantation in El Bambusal farm has captured 138.3 (sd: ±19) Mg / ha CO_2; this is almost double Napoles farm plantation which sequestered 70.4 (sd3: ±12) Mg / ha CO_2. Additionally, from the soil properties (soil organic matter and bulk density), it was estimated that 131.1 (sd3: ±1.6) Mg/ha CO_2 was sequestered at Napoles farm and 137.5 (sd3: ±7.6) Mg/ha CO_2 at El Bambusal farm. These values corresponded to a soil depth of 25 cm.

Soil restoration: Soils play an important part in maintaining valuable ecosystems services (Dominati et al. 2010; Lal 2014). In Columbia's coffee region, soils were degraded; compaction and erosion were ordinary occurrences. On Napoles farm, for example, soils were under pastures and, due to cattle farming, were densely compacted. To identify changes in the soils' physical conditions, the porosity and fluxes of water, air and nutrients were assessed throughout the project. The monitoring focused on those variables that respond quickly to land use changes rather than those inherent properties slower to change (Palm et al. 2007). The data gathered from the project detailing the improvements to soils is valuable for those involved in making future decisions about land use in the region and elsewhere.

After the guadua plantations were established, the soils' properties demonstrated positive changes on both project sites. Soil resistance to penetration decreased by more than half at both plantations; for example, at 5 cm depth, from 1.6 MPa to 0.6 MPa at Napoles farm and from 1.2 MPa to 0.7 MPa at El Bambusal farm (see Figure 38).

The calculations for soil resistance to penetration due to compaction were evaluated in 2002 and 2017. The resistance rose from 5 cm to a depth of 45 cm. The bulk density and total porosity were also evaluated. These changed from 0 cm to 5 cm, 5 cm to 10 cm and from 10 cm to 15 cm depth over the same period.

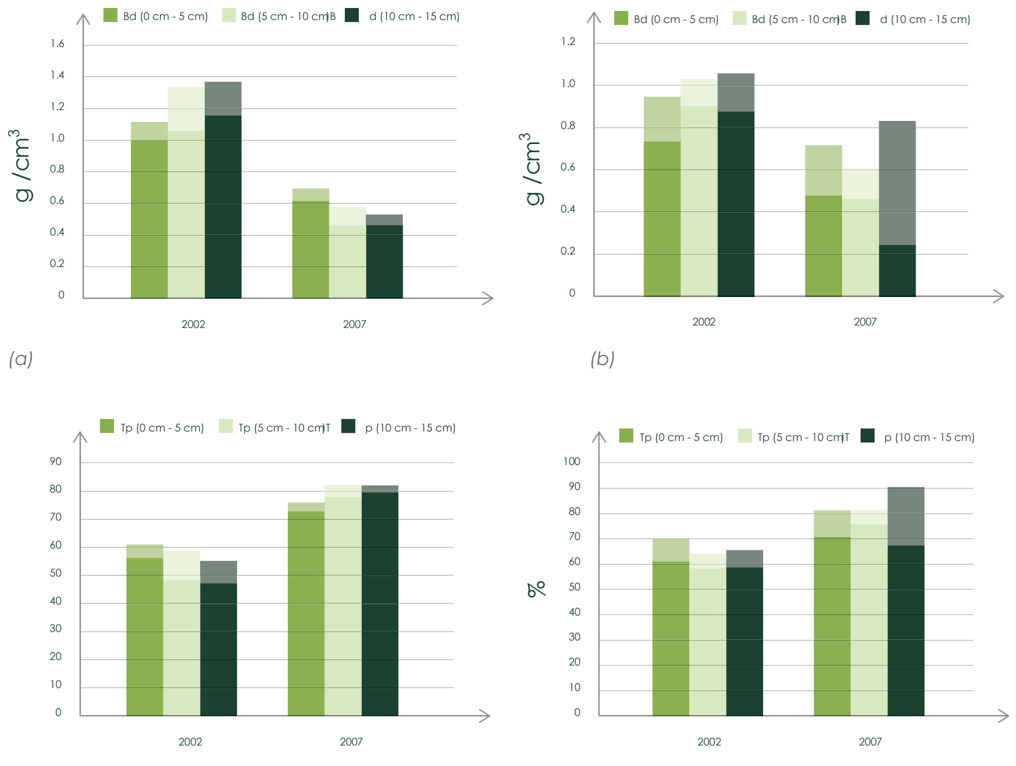
The soils' bulk density also showed a similar trend, improving after the plantations were established. At Napoles farm at 5 cm depth, bulk density was 1.05 g/cm^3 in 2002 and 0.65 g/cm^3 in 2017. At El Bambusal farm in 2002, it was 0.84 g/cm^3 and 0.58 g/cm^3 in 2017 (Figure 39a and 39b). Meanwhile, total porosity increased in the same period at both sites (Figure 39b and 39c). The low values of soil resistance to penetration and bulk density, and the high total porosity, contribute to restoring ecological functions, such as water regulation and nutrient recycling.



a) b)

Figure 38. Soil resistance to penetration (MPa) in 2002 when guadua plantations were established and 15 years later (2017). (a) Plantation at Napoles farm and (b) plantation at El Bambusal farm Montenegro, Quindío, Colombia.

Napoles farm **El Bambusal farm**



(a) (b) (c) (d)

Figure 39. Bulk density (Bd) (g / cm³) (a and b) and total porosity (Tp) (%) (c and d), before (2002) and after (2017) the establishment of guadua plantations in the Napoles farm and El Bambusal farm, Montenegro, Quindío, Colombia. Lines on the bars are standard deviation.

Finally, the chemical properties pH, soil organic matter (SOC) and total bases (Ca, Mg and K) between 0 cm and 25 cm depth were evaluated in 2002, 2003, 2007 and 2017. These properties are associated with soil fertility and SOC, and with physical properties such as bulk density. The evaluations were complemented in 2017 with respirometry data to determine the biological activity in soils (e.g. Mohantya and Panda 2011). This variable was compared with soils from nearby land uses to those of guadua plantations. The chemical properties showed fewer contrasts after the establishment of plantations. Although in the beginning there was a slight increase to SOC, these changes were not significant. Likewise, pH and total bases demonstrated similar behaviour during the period evaluated. A slight tendency for SOC values to increase over time confirmed that this chemical property is sensitive to changes. This sensitivity was more evident at Napoles farm where the variable significantly increased over the first five years from 3.4per cent to 4.4 per cent and then became stable. For the pH and total bases, values did not vary, although at El Bambusal farm, the values decreased. It is possible that this decrease was due to the coffee plantation periodically being fertilised.[11]

Andisols were present at both sites where the plantations were established. These soils are dominant in Colombia's coffee region. Andisols soils' inherent properties make it difficult to determine contrasting changes in soil properties associated with land use changes (Dossman 2009). There appear to be no visible changes in most chemical properties assessed (except with SOC) or the respiratory values between guadua plantations and the nearby land (see Figure 40). However, it is important to note that both the agroforestry system and the pasture evaluated, as well as nearby land uses, may occasionally receive organic matter (fertiliser) and cattle dung, which would promote microorganism activity and thereby increase soil respiration.

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11 The chemical properties values for both plantations are available on request.

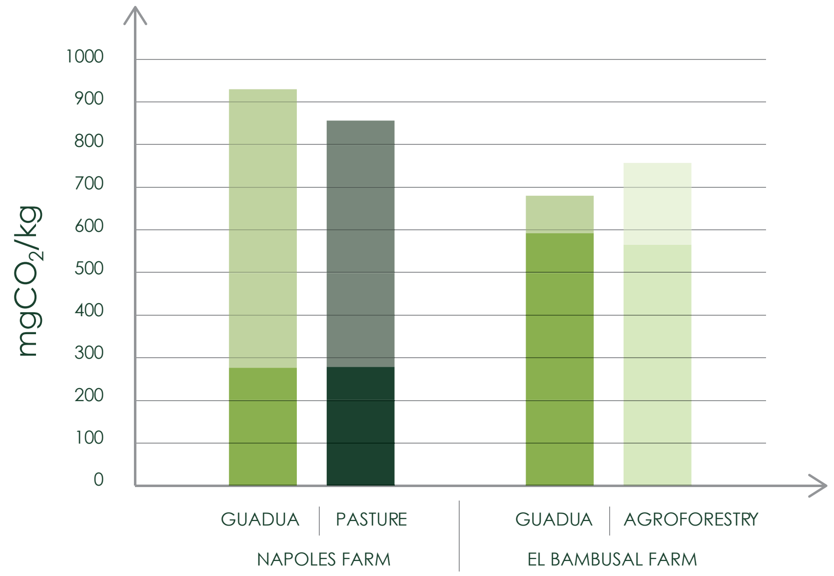

Figure 40. Soil respiration after 72 hours (mg CO_2/ kg) for soil samples from guadua plantations at the Nápoles and El Bambusal farms, as well as nearby land, pasture and agroforestry systems. (Lines on the bars are standard deviations.)

The results of soil properties from the plantations at the farms evaluated are consistent with previous studies carried out with soils under guadua forest (e.g. Salamanca and Sadeghian 2005), where ecological benefits are associated with the increased land coverage (e.g. Muñoz 2017a; Chará et al. 2010; Camargo et al. 2010).

Guadua plantations: socio-economic opportunities

It is important to highlight the potential socio-economic benefits that can be gained from guadua plantations, especially for farmers. The guadua plantations gave farmers who already had experience of managing natural guadua forests an opportunity to increase their incomes by exploiting the new resource. At an estimated 15 per cent harvest intensity of commercial culms, an estimated 800 pieces (6 m each)/ha/year could be obtained from each plantation (Muñoz 2017a). This harvest rate would provide a net income for farmers of USD 880/ha/year when round pieces are sold or USD 5280/ha/year for preserved materials.

Notably, the total number of culms on the two plantations is fewer than those in the natural guadua forests. Consequently, the values of the culm length, diameter and net volume are all smaller (see Table 8). However, in the last five years, both plantations were harvested for commercial culms: 43 per cent at Napoles farm and 62 per cent at El Bambusal farm. These values respectively represent a potential net volume marketable of 37.4 m^3/ha and 98.4 m^3/ha.

Colombia has a significant amount of land suitable for establishing guadua plantations. Approximately 124,515 ha and 1,614,691 ha of land have been identified as potentially being of high and moderate capability, respectively (Camargo et al. 2007). The areas are located close to urban centres with good road infrastructures, which is important given that owing to the current fragmented state of the natural guadua bamboo forest, the possibilities of industrialisation are challenging because of high transportation costs. Reducing costs associated with transportation increases the commercial viability for enterprises based on newly established guadua plantations.

Bamboo forest or Plantation	*N*	*h** (m)	*d* (cm)	*V*n* (m3)
Nápoles farm	7,033 (±3,066)	11.8 (±1.3)	5.5 (±0.8)	0.007(±0.004)
El Bambusal farm	6,566 (±950)	15.1 (±0.6)	7.7 (± 0.4)	0.0140.0 (±0.005)
Coffee region of Colombia[1]	6,284 (±3,128)	20.4 (±3.6)	10.9 (±1.9)	0.03 (±0.02)

Table 8. Growth and Stand Variables for Both Plantations and Natural Guadua Forests in the Coffee Region of Colombia

N= average number of culms per ha; h = average culm length (m); d = average culm diameter measured on the middle of the internode at breast height (cm) and Vn = average net volume of culm (m^3). Values between parentheses are the standard deviation.

1= Information for guadua stands in the coffee region of Colombia (Camargo 2006).
** = values of h and Vn were estimated considering models proposed by Camargo and Kleinn (2010).*

When guadua culms are not valued as a raw material despite their numerous properties, the unfair trade and the excess procedures for getting the permission to harvest is a disincentive for farmers, even though they believe that guadua culms are an excellent material, marketable and useful for restoring degraded lands (personal communication with Lucia Mejia). To address the issue, the Colombian government has introduced different initiatives to increase bamboo coverage and encourage farmers to participate. This is important given that farmers, although acknowledging that guadua plantations are essential for restoring degraded lands, need to be convinced of the commercial opportunities from establishing new plantations. These incentives include tax benefits and subsidies for planting as well as a legal framework for payment for environmental services (Colombia decree 870 of 2017). The government has also developed codes and guidelines to encourage the growth of bamboo. For example, 'The Norm' (Norma Unificada para el manejo de guaduales naturales) provides a legal framework and terms of reference, with guidelines, for the sustainable management of guadua stands.

Despite the government's efforts, some farmers believe that codes and legislation do not help to promote new areas for guadua plantations. Farmers have experienced lengthy application processes to get permission to harvest, mainly because natural forests are under 'The Norm' process. Establishing guadua plantations without requiring permission to harvest, except for initial registration, would help to circumvent delays increasing the areas under the Norm guidelines. It appears that farmers avoid establishing new plantations concerned that their management might become more regulated. They want to get the government to exempt guadua plantations from legislation (personal communication with Ximena Londoño). As Guadua plantations are a means to address both ecological and socio-economic problems, getting the incentives right – in a way that satisfies farmers and achieves bamboo industrialisation – is essential for the Colombian government.

Conclusions and recommendations

The case study has demonstrated that the bamboo species guadua grows well in plantations and improves soil quality in areas where crops such as coffee were commercially grown. The restoration of land and ecological functions can take up to 15 years, however. Yet, given that the co-benefits from the plantations includes carbon sequestration, contributing to climate change mitigation, restoring soil and hydrological functions, the plantations have long-term value in addition to their commercial value.

Given that Colombia's coffee regions' natural forests are highly fragmented, plantations are an alternative strategy to connect these bamboo forest fragments. The forest industry can commercially benefit from reduced transport costs when these large fragmented areas are consolidated. The Colombian government has promoted initiatives for forest plantations including guadua. There is, however, resistance to the regulation and policies introduced by the government from farmers, in part due to poor governance.

Guadua plantations, based on the case study results, can also contribute to goals contained in international initiatives that Colombia is a signatory to, such as the FLR for restoring degraded lands (Bonn Challenge 2015) and the international New York Declaration on Forests (2014), as well as UN agreements such as the climate change-specific Paris Agreement (2015) and the Sustainable Development Goals (2015), both of which encourage land use restoration by signatories.

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Land degradation occurs in many countries, and has serious adverse impacts on the environment and human lives and livelihoods. Bamboo could be an important solution to this problem: it grows quickly, can restore severely degraded soils to health, and provides local communities with an important source of income.

Even though bamboos have already been extensively used in many national and sub-national restoration programmes, public information about bamboo-based landscape restoration initiatives, and the reasons for their success or failure, is limited. This synthesis report aims to address these knowledge gaps, by collating evidence from nine case studies across China, Colombia, Ghana, India, Nepal, South Africa, Tanzania and Thailand. This report should provide a comprehensive guide to development practitioners and policy makers who want to use bamboo to restore degraded land.