1

INBAR
INTERNATIONAL NETWORK FOR BAMBOO & RATTAN

Policy Synthesis Report

Bamboo: A strategic resource for countries to reduce the effects of climate change

Climate-smart approaches that add value to forestry and agriculture strategies

- Mitigation
- Adaptation
- Landscape restoration
- Rural income & livelihoods

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

Global Landscapes Forum

About 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 Network for Bamboo and Rattan, is an Intergovernmental organization bringing together some 40 countries for the promotion of the ecosystem benefits and values of bamboo and rattan.

Acknowledgments

This synthesis is based on the results of a range of projects and initiatives funded by donors and development agencies including the Government of China, IDRC, The World Bank, European Union and the Common Fund for Commodities. Written by Peter Fredenburg.

Key Words

climate change, bamboo, resilience, mitigation, landscape restoration, INBAR, climate smart agriculture, forestry, agro-forestry, green economy, sustainable development

International Network for Bamboo and Rattan (INBAR)
PO Box 100102-86, Beijing 100102, P. R. China
Tel: +86-10-6470 6161; Fax: +86-10-6470 2166; Email: info@inbar.int

ISBN 978-92-95098-54-1

Contents

Key messages

- Bamboo is a vast untapped development resource that countries in the world's tropical and sub-tropical regions can use in many ways to provide climate smart mitigation and adaptation solutions to their populations. It also brings ecosystem services and income generating opportunities. Benefits include cheap and renewable local energy sources, renewable components for affordable housing, rapid regeneration of soils and rangelands, the basis for new types of small and large industries, new sources of animal fodder, and more.

- Bamboo forests mitigate climate change and have great potential to do more, especially as carbon markets start to recognize and reward bamboo afforestation and reforestation to sequester carbon at rates comparable or even better rates than trees.

- Communities that include bamboo in their strategies for adapting to climate change benefit from the resilience that derives from bamboo's fast growth and ability to recover quickly from extreme weather events, as well as its use in constructing climate-smart housing, and provision of climate-friendly alternative fuels.

- Bamboo provides livelihoods to communities at risk from climate change, especially to their most marginalized and vulnerable members, whose development options multiply as research improves crop management and expands the range of products made from bamboo.

- The various species of bamboo are excellent choices for restoring degraded landscapes, as they are well adapted to tropical and semitropical conditions. By using bamboo as a timber substitute, pressure on forests can be reduced.

Executive Summary

To combat climate change, bamboo is a core resource for landscape-focused approaches

Bamboo provides countries and development partners with a wealth of practical solutions to climate change. If it is recognized as a strategic resource in national strategies and international initiatives, bamboo will reduce the negative effects that changing climate patterns have on millions of rural communities.

Change is coming. As scientists and policy makers increasingly recognize the need to adopt landscape approaches to climate change mitigation and adaptation — and to fighting rural poverty and restoring the natural resource base that is the foundation for economic sustainability — bamboo is finding a place at the table. As a core element of national strategies and international climate change frameworks, bamboo addresses the challenges of climate change through mitigation, adaptation, landscape restoration and sustainable livelihoods.

Mitigation. Landscape approaches to mitigating climate change succeed to the extent that they sequester carbon, the main greenhouse gas. Bamboo plays multiple roles in sequestering carbon. It helps avoid fossil fuel use by offering an alternative, highly renewable source of biomass energy, both as a substitute for wood fuel and charcoal and fossil fuels in power generation. Its fast-growing and renewable stands sequester carbon in their biomass. The many durable products made from bamboo can also be potentially carbon negative because they act as locked-in carbon sinks in themselves and encourage the expansion and improved management of bamboo forests.

Adaptation. Bamboo helps rural communities become less vulnerable to climate change when they include it in sustainable forestry and agroforestry systems. The plant's rapid establishment and growth allow frequent harvesting, which limits exposure to disaster, and let farmers flexibly adapt their management and harvesting practises to new growing conditions as they emerge under climate change. Among the bamboo products that facilitate communities' adaptation are those used to construct climate-smart housing and generate alternative forms of bioenergy.

Restoration. Bamboo is integral to many natural and agricultural ecosystems in and near the tropics. It is useful for restoring degraded lands for several reasons. It thrives on problem soils and steep slopes that are unsuitable for other crops. It is an effective windbreak, and its sturdy rhizomes and roots regulate water flows and prevent erosion.

Livelihoods. Bamboo is a versatile and rapidly renewable resource with a wide range of livelihood applications in traditional economies. Its economic role is likely to expand at an accelerating pace — both locally and in international trade — as other forest resources become increasingly strained under climate change, as the imperative to mitigate climate change enforces less dependence on fossil fuels and endangered forest resources, and as research discovers new applications. Bamboo integrates well into many mixed production system, providing forest products that farmers and foresters would otherwise have to source, often unsustainably, from fragile natural forests.

Guideline: integrating bamboo in national sustainable development strategies.

	Approaches & Activities	Country Actions	Participating ministries/agencies
Mitigation	Include bamboo in afforestation and reforestation programmes	Incorporate bamboo into national siviculture programmes	Forestry, Environment, Agriculture, Climate Change, Energy.
	Promote bamboo utilization as a substitute for timber in UN REDD+ Programmes	Provide training, finance and marketing extension services to local communities to enable them to utilise and benefit economically from bamboo resources	
	Include bamboo biomass in renewable energy programmes	Create policy frameworks for renewable/bioenergy that explicitly include bamboo	
	Incorporate durable bamboo products in national Inventories for harvested wood products	Develop methodologies for accounting for carbon stored in harvested wood products made from bamboo and implement them	
Adaptation	Incorporating bamboo into sustainable forest management plans	Explicitly include bamboo in sustainable forest management programmes as a complement to timber	Forestry, Environment, Housing, construction
	Developing climate-smart bamboo housing and infrastructure	Include bamboo in national building codes and social housing programmes	
		Build capacity of communities and building professionals to construct with bamboo	
Restoration	Include bamboo in global, regional, and national landscape restoration programmes, such as Terrafrica	Develop regulations/ guidelines for planting bamboo in degraded areas	Forestry, Environment, Lands, Natural Resources
		Develop bamboo components in sustainable land management programmes	
Livelihoods support	Standardisation of bamboo production	Develop national and industry standards to ensure quality control and sustainability	Industry, Trade, Commerce, Forestry, Agriculture, Finance, Infrastructure.
	Capture and disseminate trade data on bamboo	Utilise international HS custom code system to record export and import trade	
	Create enabling environment for bamboo SME development and growth	Develop national bamboo industry development sector policies	

1 Bamboo: a strategic resource for countries to reduce the effects of climate change

Including bamboo in climate change policies and rural development investments makes countries' sustainable development goals more effective.

Bamboo is a vast untapped strategic resource that countries in the world's tropical and sub-tropical regions can use to better manage climate change, provide beneficial 'ecosystem services' and new income sources for their rural populations. Two obstacles to bamboo's more rapid development are the current lack of appreciation of its significant benefits by national policy makers; and the classification of this grass species under forestry regulations, curtailing wider beneficial use for frequent harvesting and trade.

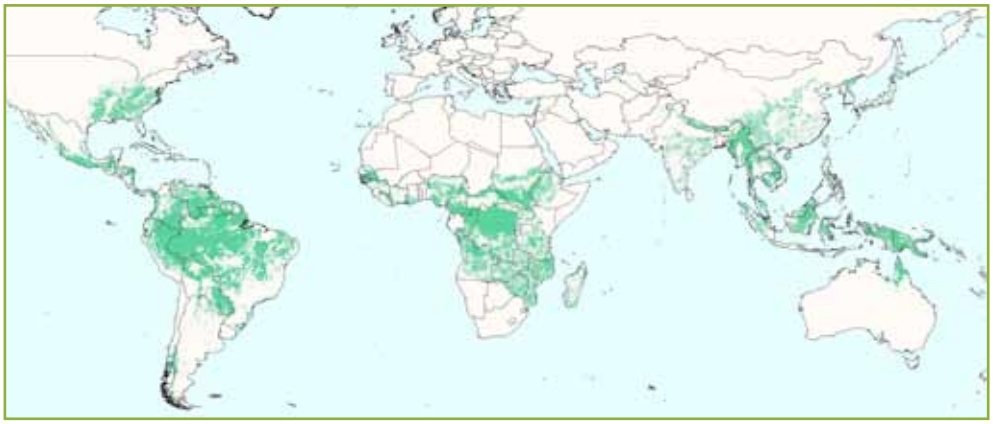
On the path to sustainable development now being agreed by governments for the post-2015 Sustainable Development Goals, countries putting in place practical and measureable ways to increase the quality of life for their populations, while delivering a maximum of environmental security. And addressing and managing the effects of climate change are at the center of the sustainable development agenda.

National climate change strategies include forestry and agro-forestry activities, plans to expand agriculture in more environmentally sensitive ways, development and management of 'ecosystem services' to benefit the natural environment and provide rural populations with 'climate smart' approaches to address changing weather patterns – that affect their livelihoods and ability to produce food and provide nutrition. Repairing and restoring damaged and degraded landscapes are at the core of solutions to the problems brought by changing climate patterns.

How bamboo benefits Sustainable Development goals

Bamboo adds value to climate change mitigation and adaptation.

- **SDG7:** Ensure access to affordable, sustainable, and reliable modern energy services for all, especially 7.2 which aims to double the share of renewable energy by 2030.
- **SDG13:** Promote actions at all levels to address climate change.
- **SDG15:** Protect and restore terrestrial ecosystems and halt all biodiversity loss, especially 15.2 which calls for restoration of 15% of all degraded ecosystems by 2030, 15.5 which aims to increase forest cover and 15.11 which calls for integration of natural resources into planning and development processes.



Potential distribution of bamboo within existing forest cover. (Source: Bamboo & Rattan in the World.)

"….bamboo should be considered the most important, fast-growing, strategic intervention for afforestation and reforestation in the mountainous and degraded areas in the country."
Ato Sileshi Getahun
Ethiopian State Minister for Agriculture

In developing strategies, action plans and investment options today, countries and development agencies are building on decades of past experience in forestry, agriculture and natural resource management. A range of tested approaches is emerging. But few of these include bamboo. This highly productive plant grows faster than trees, is extremely effective in sequestering carbon, restores degraded landscapes in months as opposed to years, and brings new income and livelihood options to villages that have been hit by degraded soils and loss of vegetation.

Bamboo alone will not solve the world's climate change problems. But it is a perfect complement to land restoration and forestry strategies in the planet's subtropical belt. Including bamboo in climate change mitigation, adaptation, land restoration and restoration strategies makes national plans more effective and brings a range of 'climate smart' options to national and regional climate change strategies.

For this to happen, decision makers, environmental planners and development programs need to better understand the properties and benefits of this versatile plant, and how it adds value to current national and regional strategies. A global body of evidence is emerging on how bamboo sequesters carbon at a very rapid rate and how it rapidly rejuvenates degraded lands, returning soil fertility – as a first stage in longer-term agro-forestry and agricultural re-development.

Should all relevant countries to have a 'bamboo strategy' for sustainable development and climate change? This is one approach. But it is clear that that the value of bamboo needs to be better recognized and valued by decision makers and planners. It should be explicitly included as a strategic resource that brings documented benefits to national climate change, environment and sustainable development strategies and for plans for developing agro-forestry and rural development. For all countries located in the world's topical and sub-tropical agro-ecosystems bamboo, can bring direct environmental and financial benefits to populations.

The two obstacles to bamboo's more rapid development are the current lack of appreciation by national policy makers managing forestry, environmental services and agriculture, of its potential. And the fact that – while it is biologically a grass species - it often falls under forestry regulations, curtailing beneficial use for frequent harvesting and trade.

Bamboo and land restoration

There is general agreement that the conservation, restoration and sustainable management of ecosystems are a proven and cost-effective means to sequester carbon dioxide and prevent the loss of other greenhouse gases. Achi Target 15 calls for restoration of at least 15 percent of degraded ecosystems by 2020.

If we are to achieve this, landscapes need to be viewed as 'mosaics' that consider all aspects of forestry, agro-forestry and agricultural land. And this perspective opens the door for the use of bamboo. This very special plant is neither a timber species, nor a crop, and is therefore often forgotten. Yet, bamboo has 1250 different known species that grow naturally worldwide in the tropical and sub-tropical belt, and today covers vast covers areas of the globe.

To reap the full benefits of bamboo to effectively manage climate change, countries and development agencies need policies and investment plans that explicitly call for this plant to be used.

This report documents the benefits that bamboo can bring to national and international climate change strategies. It summarizes some of the existing body of evidence and practice in bamboo for use for development, to inform policy approaches for countries and for international development frameworks, particularly the United Nations Framework Convention on Climate Change, but also the other Rio Conventions on Biodiversity (CBD) and Desertification (UNCCD).

2 Bamboo for climate change mitigation

Based on available evidence, the United Nations Framework Convention on Climate Change can explicitly recognize bamboo's existing and potential contributions to mitigating climate change and encourage the inclusion of bamboo-based carbon accounting methods in agreements on carbon market mechanisms. Bamboo is a versatile plant that offers carbon sinks to countries and international climate initiatives, that will significantly reduce the negative effects of greenhouse gases on the planet.

Bamboo biomass as an energy source, can avoid deforestation, and reduce the use of fossil fuels for millions of households. Its fast-growing and renewable characteristics enable the rapid creation of dense vegetation on a large scale. Its potential can be expanded with more research and sharing of findings with stakeholders, many of whom are poor and extremely vulnerable to climate change.

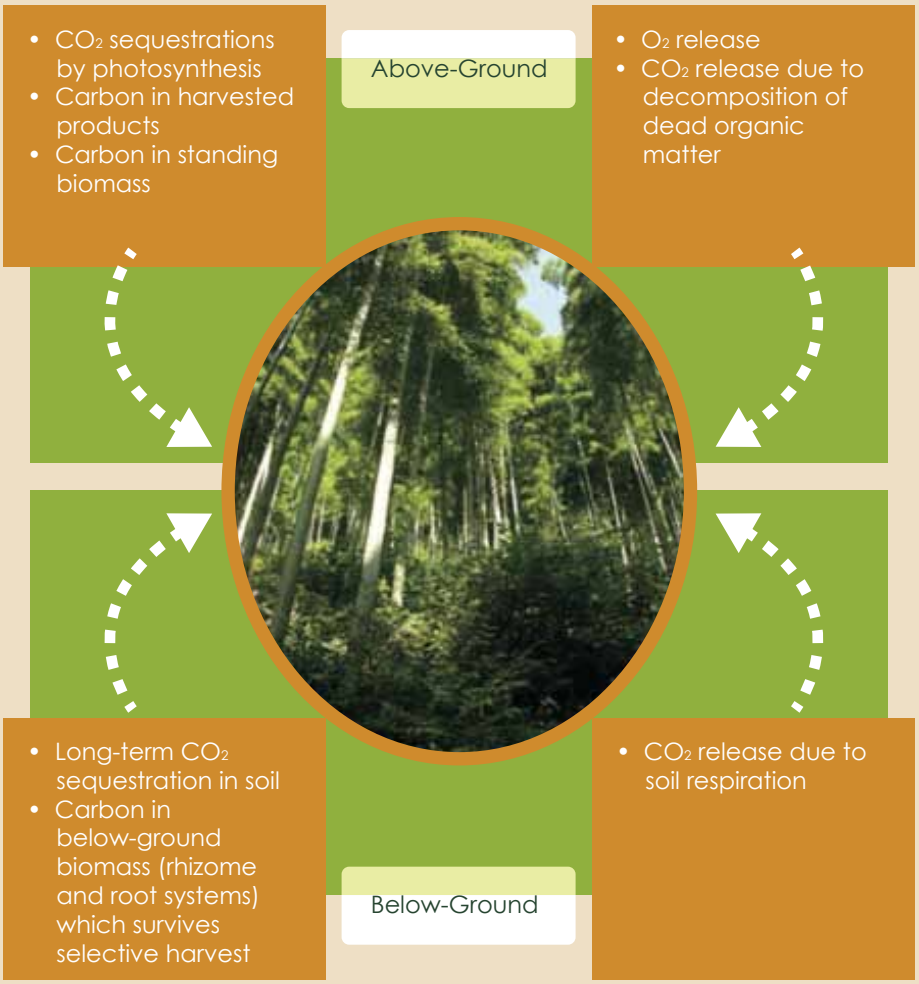
Global climate change is caused by increased and unrelenting human activity on the planet that releases into the atmosphere carbon dioxide and other vapours collectively called greenhouse gasses. They are so named because, like the glass that encloses a conservatory, they block the outward radiation of heat. Just as open windows moderate the accumulation of heat in a conservatory, curtailed emissions of greenhouse gasses promise to mitigate climate change by allowing more heat to escape into space. Carbon emissions can be curtained by trapping them in solid or liquid 'sinks' on or below the surface of the earth.

One kind of carbon sink is fossil fuel, the coal and petroleum formed underground from the remains of ancient organisms. We can preserve these sinks by switching to alternative fuels and leaving fossil fuels in the ground. Another kind of sink is living plant matter in green expanses around the world. We can preserve these sinks by maintaining healthy forests, grasslands, wetlands and water bodies, and we can expand them by restoring forests and other green ecosystems where unsustainable exploitation has destroyed or degraded them. Still another kind of carbon sink is the built infrastructure and artefacts that constitute our cities, towns and villages: our homes, offices, factories, stores, farms, schools, hospitals and civic buildings, as well as the furnishings that make them comfortable. We can take full advantage of these built sinks by choosing materials for their ability to trap carbon and processing them to maximize their durability and useful life.

Bamboo plays a role in all three kinds of carbon sink. This versatile plant offers charcoal and gas alternatives to fossil fuels, fast-growing and remarkably renewable stands of dense vegetation, and harvested materials with an array of uses that date from the dawn of humanity and are now multiplying and improving in step with the accelerating advance of science.

The carbon stored in Chinese bamboo forests is projected to increase from 727 million tonnes in 2010 to 1,018 million tonnes in 2050, or by nearly 40% in 40 years.

The Bamboo Carbon Cycle

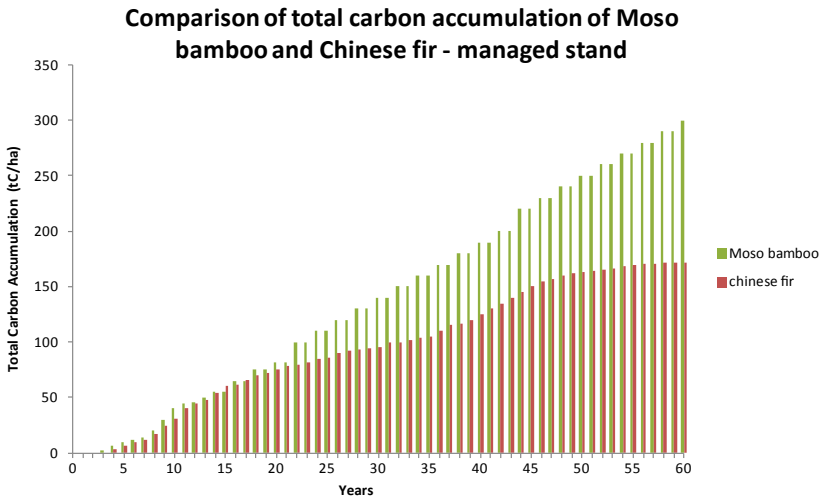


We can expand and strengthen these roles by supporting more research on bamboo and more energetically extending research findings to stakeholders, many of whom are poor and extremely vulnerable to climate change. Further, the United Nations Framework Convention on Climate Change should explicitly recognize bamboo's existing and potential contributions to mitigating climate change by ensuring the inclusion of current bamboo-based carbon accounting methodologies for afforestation and reforestation projects in the convention agreements on carbon market mechanisms, as well as supporting the development of new methodologies to incorporate bamboo into REDD+ programmes and national greenhouse inventory accounting for Harvested Wood Products.

Unique among 'trees', bamboo is taxonomically a grass. While bamboo is included under most international definitions of forests (though not all of them), bamboo silviculture is unique and so poorly served by or integrated into existing international agreements on forests. Further, bamboo is often a feature of agroforestry systems that fall outside of the scope of government departments of agriculture or forestry, with neither counting bamboo as part of its core business. New approaches that emphasize landscape approaches to sustainable rural development promise to change these perceptions — the sooner the better.

2.1 Bamboo as a carbon sink

Because it is botanically a grass — actually more than 1,000 species of grass — bamboo is not classified as a tree in forestry evaluations and often omitted from discussions of forests and climate change. However, studies increasingly find that bamboo has important roles to play in sequestering carbon in forest ecosystems. Attempts to determine how much carbon bamboo forests contain have shown great variation, demonstrating the need to harmonize measurements of carbon density across different sites, species, climates and other conditions. Reliable estimates of global bamboo carbon stock must await further research in Asia, Africa and the Americas, but recent research in China — often called the Kingdom of Bamboo — has compared bamboo with the fast-growing Chinese fir tree. The results indicate that bamboo is comparable and in some cases superior in its ability to sequester carbon.



Accumulation of carbon comparison between Moso Bamboo and Chinese Fir. In a managed bamboo forest where harvested bamboo is converted into durable bamboo products a significantly higher amount of carbon is sequestered for the long term. (Source: INBAR Technical Report 32)

Substantial amounts of carbon are stored in the bamboo forests of China, the world's largest, and the total will increase as planned afforestation programmes expand. The carbon stored in Chinese bamboo forests is projected to increase from 727 million tonnes in 2010 to 1,018 million tonnes in 2050, or by nearly 40% in 40 years.

Bamboo has an important role to play in reducing pressure on forests, not least in China. Since nationwide logging bans of certain forests came into effect in 1998, bamboo has increasingly been a possible substitute for wood timber and has entered many markets traditionally dominated by wood. Forests left standing because bamboo has been harvested in their stead offer a bounty of environmental services, ranging from carbon sequestration and climate stabilization to erosion control and biodiversity conservation, and on to recreational use and aesthetic enrichment.

Bamboo is now recognized in fledgling carbon offset programmes in China, including a nationally approved carbon afforestation and reforestation methodology developed with the help of the International Network for Bamboo and Rattan (INBAR) and its partners, and in South Africa. One high-profile purchase made the news when Alibaba, the Chinese internet retailing giant, bought offsets for 46.7 hectares of bamboo planted in Lin'an County of Zhejiang Province in 2009. The Geneva-based Gold Standard Foundation has included bamboo in its afforestation and reforestation methodology and has supported work by INBAR and its partners toward harmonizing principles informed by robust science with approaches to implementation that are simple, practical and user-friendly. In addition to this, the 'Panda Standard' has issued the equivalent of 46,000 tonnes of carbon credits for bamboo reforestation in China's Yunan Province. Other carbon sequestration methodologies are also being developed internationally, such as South Africa's Verified Carbon Scheme. The successful use of bamboo in an expanding array of product lines demonstrates the high potential for bamboo as a sustainable alternative material for making many products.

2.2 Durable bamboo products

The studies discussed above that compare carbon sequestration by Chinese fir with that by bamboo assumed that all harvested woody material was converted into durable products. This is important because carbon remains sequestered in these products for as long as they last. Recent innovations in processing and product development have increased the portion of bamboo converted into such durable products as construction materials, floorboards, panel products and furniture. This strengthens the contribution of bamboo products to carbon sequestration over the long term.

Bamboo compares favourably with many timber species in terms of its tensile strength, flexibility and hardness, but bamboo products are often viewed as being less durable than those made of wood. Modern materials development has shown that the difference in durability between bamboo and wood has more to do with how the materials have been used it the past than with how they can be used now and in the future.

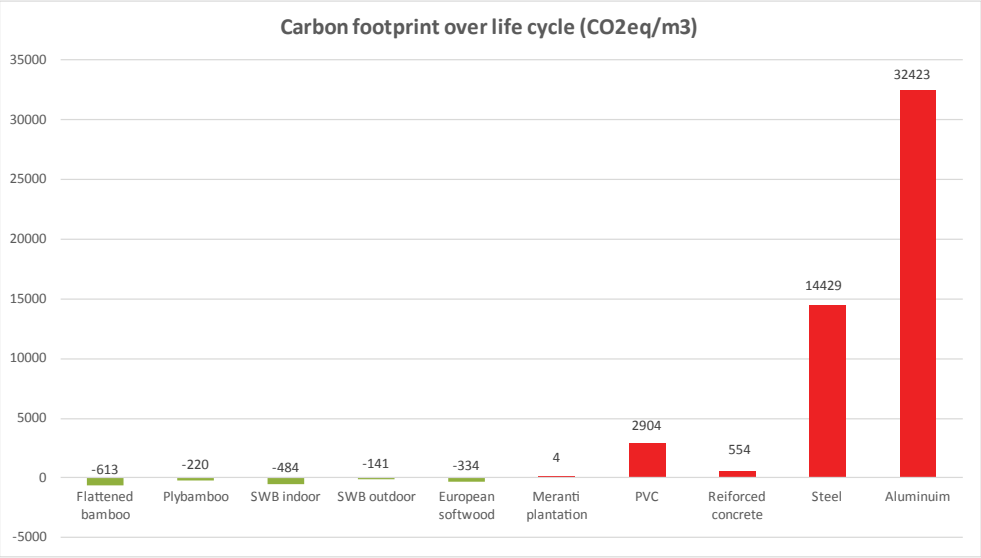
A recent life-cycle assessment of durable bamboo products made in China and sold in Europe found that they can be carbon negative. In other words, the carbon credits the products earn through carbon sequestration of bamboo forests and, avoided fossil fuel emissions when they are burned at the end of their useful life to generate electricity, outweigh the emissions caused by their production and transport.

The assessment is premised on the observation that demand for boreal and temperate softwood from Europe and North America encourages better forest management and expanded forest area, and so more sequestered carbon. By contrast, demand for tropical hardwood causes deforestation in the tropics and so reduces the amount of carbon sequestered there beyond what the carbon sequestered in hardwood products can counterbalance. Expanding demand for bamboo from China encourages, as does demand for temperate softwood, better forest management and expanded area. In both cases, rising demand for products sequesters ever more carbon in buildings, in the form of final products, and in forests that are sustainably managed to supply materials for those products.

On a global scale, bamboo keeps its negative carbon footprint only so long as the market for bamboo products continues to grow, placing more bamboo in buildings and stimulating more bamboo plantation. The processing of bamboo products consumes the most energy and therefore has the largest positive carbon footprint, but sea transport from China to Europe comes second — a cost that could be slashed if Europe sourced more of its bamboo from Sub-Saharan Africa, where renewable energy often also tends to play a much more prominent role in the electricity generation mix than in China.

A surprise finding of the assessment is that the resin used to process modern industrial bamboo products contributes little to the carbon footprint or eco-cost. (The eco-cost includes, in addition to the carbon footprint, harmful effects from water acidification and eutrophication, smog and dust, land use, and the generation of toxicity and waste.) There is nevertheless room for improvement by using resins that contain less formaldehyde.

The assessment found various industrial bamboo materials competitive, especially in terms of carbon footprint, with sustainably source European softwood. They are more environmentally friendly than tropical hardwood harvested from plantations managed for sustainability — and much more so than tropical hardwood taken from natural forests.



Lifecycle carbon footprint of durable bamboo products compared to other commonly used industrial materials. Bamboo compares favourably to European soft wood and performs better that tropical hard wood. (Source: INBAR Technical Report 35)

Several other advantages derive from bamboo being harvested as a perennial crop, rather than by clear-cutting or, as is often the case in natural forests, illegal logging. Selecting culms that are 4-5 years old for harvest encourages careful management, which actually makes the bamboo stand more productive. This provides a steady income to farm and forester communities, which enhances their stability. Bamboo's large rhizomes and extensive root systems means the crop can be planted where other crops would not thrive, such as on degraded land and eroded slopes, where it improves the soil quality and helps restore the water table. As bamboo grows very quickly — some species by up to a metre per day — a bamboo plantation starts producing a harvest much more quickly than a plantation of even the fastest-growing trees.

Similarly, taking up regular harvests in previously unmanaged bamboo forests merits inclusion under REDD+, which aims to reduce emissions from deforestation and forest degradation in developing countries.

2.3 Bamboo for biofuel and bioenergy

Bamboo can be used to produce both wood fuel and charcoal for cooking and heating, as well as to generate electricity using biomass gasification technology. Bamboo charcoal has a calorific value similar to that of wood charcoal but is much less polluting. INBAR has demonstrated that using bamboo to make charcoal can take pressure off other forest resources, avoiding deforestation and thus the release of previously sequestered carbon into the atmosphere. It is also an alternative to fossil fuels, both for burning and for use as a fertilizer to restore and sustain soil health.

Converting biomass into biochar helps keep carbon in the soil. As such, biochar has potential to enhance agricultural productivity on nutrient-poor soils. It has proven long-term benefits in terms of inhibiting nutrient leaching and so retaining nutrients in the soil, while simultaneously making them more bioavailable to crops. It may also help retain water in the soil and benefit the microorganisms that are essential to soil health. Biochar made from bamboo has interesting prospects but requires a lot more research.

Case Study

China's managed Moso bamboo forests – a massive carbon sink

One study compared Chinese fir with moso bamboo (Phyllostachus edulis, or mao zhu in Chinese), a temperate giant timber species that occupies around 70% of that country's 6 million hectare bamboo area, 3% of its total forest area. It found that moso bamboo plantation sequestered more carbon than did Chinese fir over a period of 60 years. This was true, however, only if the bamboo was properly managed and regularly harvested.

Research found that unmanaged stands of bamboo added new biomass above ground at an accelerating annual rate during the first decade of growth, at the end of which growth hit a plateau. At the 10-year mark, bamboo culms started to die off naturally at rate that accelerated until the 19th year, when the rate of deterioration hit the same plateau as that of new growth. The net result of these trends was that carbon accumulation in unmanaged moso bamboo levelled off midway through its second decade. Chinese fir, on the other hand, continued to accumulate carbon, albeit at a slowing rate, throughout its typical 30-year growth period to harvest. In that period, unmanaged moso bamboo plantation sequestered only about 30% as much as Chinese fir.

Relative sequestration was dramatically different, however, where the bamboo was managed with regular harvesting cycles, in which about a sixth of the biomass above ground was taken annually to be replaced by new growth in the following year. Stands of bamboo grew larger in response to selective harvesting. At the end of the first 30-year rotation of Chinese fir, when all Chinese fir biomass above ground was harvested by clear-cutting (and assumed, for the purposes of the study, to be converted into durable products), the carbon that had accumulated in a given area of Chinese fir and managed moso bamboo was about the same. Chinese fir was replanted, but soil depletion meant less carbon accumulated during its second 30-year rotation. By the end of 60 years (after which land under Chinese fir is typically put to another use), the calculated total carbon accumulation in moso bamboo plantation was 217 tonnes of carbon per hectare, or 22% more than the 178 tonnes that accumulated in Chinese fir. Because bamboo was not clear-cut like trees grown in plantations, annual net carbon sequestration was more constant.

The comparison could favour bamboo even more strongly. The study assumed an initial planting density of 315 culms per hectare, expanding to reach canopy closure and maximum density of 3,300 culms in the tenth year. However, moso bamboo forests have been intensively managed in China to reach a density of 4,500 culms per hectare. While this would suggest higher carbon stock and annual sequestration in biomass above ground, further study is needed to determine if such intensive management simultaneously reduces the sequestration capacity of the soil layer or causes higher emissions from such management practices as adding fertilizer.

Because they have similar rapid growth rates and climatic requirements, the same study also compared eucalyptus plantations with sympodial ma bamboo (Dendrocalamus latiflorus) and found that they sequestered comparable amounts of carbon. These results argue for encouraging the regular harvesting of bamboo to maximize its carbon sequestration as well as to harvest marketable products. They further suggest that projects to sequester carbon bamboo plantations merit inclusion in afforestation and reforestation initiatives under the Clean Development Mechanism. Similarly, taking up regular harvests in previously unmanaged bamboo forests merits inclusion under REDD+, which aims to reduce emissions from deforestation and forest degradation in developing countries.

3 Adaptation to climate change with bamboo

Bamboo is an important new tool that rural communities can use to be less vulnerable to climate change when they include it in sustainable forestry and agroforestry systems. As it is highly resilient and its rapid establishment and growth rates allow frequent harvesting that limits exposure to risks such as fire and extreme weather. Rapid growth — allowing harvesting to begin in 3-6 years, depending on the species and growing conditions — gives farmers the flexibility to adapt their management and harvesting practices to new growing conditions that emerge under climate change.

Bamboo has great potential to help rehabilitate degraded lands, a task made all the more challenging by climate change. This is topic is covered in Section 4 of this report, but it bears mentioning here that bamboo performs a number of vital ecosystem services. Its large permanent rhizome and root systems bind the soil and protect it from water erosion, as well as help restore depleted water tables. Its tall evergreen culms form windbreaks that protect the soil from wind erosion and crops from wind damage, especially in coastal areas that are frequently buffeted by strong winds, which are projected to become more frequent and damaging under climate change. Falling leaves further inhibit erosion, including from splashing rain, and return nutrients to degraded soils.

Among the many products derived from bamboo that strengthen adaptation are those used to construct climate-smart housing. Also prominent is bamboo's conversion into bioenergy and substitution for other forest products. As substitution allows foresters to avoid the deforestation that would otherwise degrade forests of slower-growing trees, it contributes to climate change adaptation and mitigation.

3.1 Resilience under climate shocks

A major cold snap in southern China in 2008 wreaked havoc on large areas of bamboo and timber production forests. While plantations of Chinese fir will take decades to recover, bamboo was producing profitable harvests only three years later. Research on the damage caused by the storm revealed ways to manage bamboo for even faster recovery.

As individual culms were susceptible to being snapped or uprooted in proportion to their size, researchers recommend that mature culms be harvested in a timely way. Optimizing the culm harvest has the further benefit of stimulating regrowth to make stands denser and more productive. A technique worth borrowing from farmers in some bamboo-producing areas of China is to partly decapitate new culms. This greatly reduces the size of the crown and therefore the load of snow and ice that can accumulate there.

Halfway around the world in Ecuador and Peru, INBAR has been working since 2009 to help communities use bamboo to become less vulnerable to heavy rain and flooding. A new study looked at climate change vulnerability in forests of guadua bamboo, the most important American bamboo species, in coastal areas of Peru and Ecuador. It highlighted the crucial role these forests play in stabilizing riverbanks, regulating watersheds, preventing landslides, protecting against soil erosion, and recycling water nutrients. The study has shown that, while guadua forests are not invulnerable to climate change, they are likely to maintain their functionality under precipitation changes and temperature rises of up to 2° Celsius, as currently projected. This outcome depends, however, on these forests being granted appropriate policy protection and on local farmers and foresters receiving further training on sustainable management. Aside from their environmental services, guadua forest are highly valued for their building materials, from which half a million homes in Ecuador and Peru are constructed.

In coastal areas of Peru and Ecuador bamboo forests play a crucial role stabilizing riverbanks, regulating watersheds, preventing landslides, protecting against soil erosion, and recycling water nutrients.

3.2 Climate-smart housing in Latin America

A primary focus of the research conducted by INBAR and its partners in Ecuador and Peru is housing. A result is innovative elevated climate-smart houses that minimise vulnerable coastal communities exposure to climate-related flooding and landslide risks, as well as earthquakes. These structures also have low building and maintenance costs, while offering more comfort than traditional designs are able to offer and even protection against mosquitos and the diseases they carry. Four models use Guadua angustifolia Kunth bamboo, commonly known as guadua, to construct schools and other public buildings, in addition to private houses. Impressed by buildings constructed under INBAR-led projects — which were recognized in a 2009 development fair completion run by the World Bank — partners in civil society and the private sector have adopted the designs in their own projects. Coastal communities in Ecuador and northern Peru have further benefited as more than 2,000 people received on-the-job training in bamboo silviculture and construction.

Bamboo structures for affordable, sustainable and disaster-resilient housing offer tremendous potential for socioeconomic and public welfare benefits. A traditional bamboo shelter typically costs $1,500 to build and needs to be replaced every 5 years.
New-technology homes promoted by INBAR and its partners cost $4,000 in Ecuador and $5,000 in Peru and last 30 years, saving 30% of construction costs over the long term.

In both countries, losses from floods and landslides, which in Ecuador alone between 1997-2006 accounted for 0.01% of GDP and affected over 400,000, are projected to increase with the effects of climate change. Unless climate-smart solutions are enacted this will only compound the shortage of housing in both countries that totals 2.5 million units today.

The provision of affordable, sustainable and disaster-resilient housing offers tremendous potential for socioeconomic and public welfare benefits. Whereas a traditional but substandard bamboo shelter typically costs $1,500 to build and needs to be replaced every 5 years, the homes promoted by INBAR and its partners cost $4,000 in Ecuador and $5,000 in Peru but last 30 years, saving at least a third of construction costs over the long term. These figures discount the losses to disasters that the resilient designs avoid. The new bamboo designs are also cost-effective alternatives to the earthquake-vulnerable concrete homes and schools built by the government.

Aside from standing up to earthquakes and the worsening threat of floods and landslips under climate change, the bamboo designs for elevated houses are well suited to the climate, their high ceilings and wide eaves keeping out even windblown rain while allowing better ventilation and natural light penetration than is typically achieved in buildings that use concrete or steel. This reduces energy costs while maintaining a healthy indoor environment. Because the walls are prefabricated bamboo panels, construction can be completed in 2 weeks.

INBAR is scaling up these innovative building technologies to contribute to climate change adaptation and disaster preparedness throughout the Andes. Toward addressing the challenges of rapid urbanization, it showcased the work at the 7th World Urban Forum in Medellín, Colombia, in April 2014.

Ecuador - Census of population and housing (2010)

REGIONS	*Number of bamboo houses*	*Percentage per region*
Costal	306,883	93.16%
Rangelands	18,311	5.56%
Eastern Amazon	4,200	1.27%
Galápagos	22	0.01%
Total	**329,416**	**100.00%**

Census of population and housing data shows a growing coastal population potentially affected by climate induced flooding, and a significant number of vulnerable communities living in bamboo housing. Better quality bamboo housing, now available, will improve government investment in low-cost housing and protect populations from increasing threat of flooding.

3.3 Biomass energy in Africa

Bamboo can be used to produce both charcoal and biogas for generating electricity. With a calorific value similar to that of wood and almost half that of petroleum by weight, bamboo charcoal produces fewer pollutants than either. It has the potential to help many of the 1.7 billion people around the world who still rely on biomass as their primary energy source and the 1.3 billion people worldwide who live without electricity. In Africa, up to 90% of the populace depends to some extent on energy from biomass, usually wood or charcoal derived from wood. Because charcoal can be produced with little capital investment, it is a common sideline for rural families. The catch is that the wood is usually harvested unsustainably, making Africa's vast charcoal industry one of the principal drivers of deforestation on the continent.

Bamboo charcoal has the potential to help many of the 1.7 billion people around the world who rely on biomass as their primary energy source and the 1.3 billion people worldwide who live without electricity. In Africa, up to 90% of the population depends on energy from biomass, usually wood or charcoal derived from wood.

Bamboo as Sustainable Biomass Energy, a project led by INBAR and financed by the European Union, set out in 2009 in Ethiopia and Ghana to develop bamboo firewood and charcoal as alternatives to traditional fuelwood from trees. Training and workshops in local communities, some using demonstration kilns, raised awareness of bamboo as an energy alternative. At the national level in both countries, INBAR is introducing appropriate bamboo species, guiding the establishment of small enterprises, and supporting government and civil society efforts to develop bamboo charcoal value chains.

By 2013, over 600 hectares of new bamboo had been planted in Ethiopia and Ghana, and 10,000 hectares of existing stands had been placed under sustainable management. The project had trained 4,000 individuals in bamboo cultivation, carbonization, and briquette production and use, resulting in the production of 550 tonnes of bamboo charcoal and allowing more than 10,000 households to start using bamboo for fuel. Residents of villages near the pilot communities in Ethiopia have adopted the technology, indicating that self-perpetuating value chains for bamboo charcoal are starting to take hold.

Using bamboo to make charcoal takes pressure off other forest resources, avoiding deforestation and the release of previously sequestered carbon into the atmosphere. This mitigates climate change even as it empowers communities to adapt to climate change by replacing diminished energy sources. They do so while pursuing livelihoods that are sustainable under climate change, a topic explored in more detail in the next section.

Type of charcoal	Moisture (%)	Volatile matter (%)	Ash content (%)	Fixed carbon (%)	Calorific value (cal/gm)
Acacia Spp. Charcoal	3.67	22.90	3.64	69.79	7780
Bamboo charcoal	9.31	15.03	14.80	60.86	6959
Prosopis charcoal	3.90	25.90	3.50	66.80	6256
Cotton stalk charcoal briquette	4.10	17.20	20.30	58.40	4588
Chat stalk charcoal briquette	8.04	28.58	16.54	46.84	5100

Composition and calorific values of charcoal produced from bamboo and other commonly used sources of biomass in Ethiopia (Source: Seboka & Duraisamy, 2008)

4 Restoring landscapes with bamboo

When strategically placed, bamboo supports a new 'ecological infrastructure' – a cost-effective way for countries to adapt to risks caused by climate change. It regulates water flows and prevents erosion on slopes and along riverbanks and removes pollutants from wastewater put into streams. Bamboo forests and plantations make good windbreaks, sheltering natural vegetation and crops. In short, bamboo is an asset to any landscape in which it appears.

In China, over the past 15 years, bamboo-based restoration of degraded lands has been done in 2,300 counties in 25 provinces, involving 32 million rural households and 124 million farmers. The total conversion area is 29 million ha, and financial input from Central government during this period totalled an estimated $60 billion.

Bamboo is widely distributed across tropical and semitropical Asia, the Pacific, the Americas and Africa, covering an estimated area of 37 million hectares, or almost 4% of the world's woodlands. It is integral to many natural and agricultural ecosystems, providing a number of ecosystem services. It provisions consumers with food and raw materials for shelter, clothing and other needs.

It regulates water flows and prevents erosion on slopes and along riverbanks, as well as removing pollutants from wastewater dumped into streams. Stands of bamboo make good windbreaks, sheltering natural vegetation and crops. In short, bamboo is an asset to just about any landscape in which it appears.

When strategically placed, bamboo can be the kind 'ecological infrastructure' that is increasingly acknowledged as a cost-effective way to adapt to risks from climate change. Mangrove forests are the best-known example of ecological infrastructure, as they protect shorelines from storm surges at least as effectively as built infrastructure but at a lower cost, while providing other ecosystem services as a bonus. Similarly, bamboo forests are useful and cost-effective when deployed as part of a comprehensive approach to rehabilitating degraded hillsides, catchments and riverbanks.

Many landscapes in or near the tropics suffer degradation that has accelerated in recent decades. The Food and Agriculture Organization published a study in 2011 that found fully a quarter of the land on the planet highly degraded and another 8% moderately degraded. Because bamboo is hardy, and its many species are adapted to a wide range of environments in and near the tropics, the plant can be used to help restore the fertility and productivity of much of this degraded land.

Bamboo in the Bonn Challenge to reclaim 150 million hectares of degraded land

The Bonn Challenge is a global movement launched in September in 2011 at a ministerial conference in Germany, to restore 150 million hectares of degraded and deforested land by 2020 — a first step toward restoring the estimated 2 billion hectares of degraded land worldwide that has potential for restoration.

INBAR'S 40 member countries have collectively agreed to the restoration of 5 million hectares using bamboo, by 2020, with the motivation that this could result in 10 million as national plans and initiatives progress over the coming decade.

There are many advantages to planting bamboo on degraded land to restore its fertility. Bamboo establishes systems of underground rhizomes and roots that can measure up to 100 kilometres per hectare and live for a century. These systems allow bamboo stands to survive and regenerate even if the biomass above ground is largely destroyed in a fire or storm. As harvesters take culms from a managed stand little by little, amounting each year to between a sixth and a third of the biomass above ground, they actually encourage thicker growth in the coming years.

Bamboo grows well on problem soils (including acid soils) and steep slopes that can sustainably support few other food, fodder, cash or groundcover crops (when compared with potato on slopes in western China, bamboo curtailed water runoff by 25% and soil erosion by 79%).

Bamboo grows quickly — up to a metre per day in some circumstances — to produce a dense evergreen canopy from which leaves fall to the ground throughout the year, preventing splash erosion, mulching the soil and enhancing infiltration. Extensive root systems 60 centimetres deep help bind topsoil, slowing water runoff and reducing soil erosion. Because it is so versatile — growing in pure stands or together with other species, at the edges of fields, along streams and at homesteads — bamboo integrates well in almost any production system that mixes agriculture, agroforestry and aquaculture.

Healthy stands of bamboo can conserve nearby forest lands from deforestation and degradation. They do so by providing to rural and peri-urban communities an attractive substitute for less renewable timber. Farmers and foresters who can regularly harvest raw materials and fuel from bamboo stands are under less economic pressure to unsustainably exploit less renewable forests, especially if the bamboo is closer to home. To the extent that fuelwood and charcoal from bamboo supplants those derived from trees in the trade between rural communities and nearby urban centres, bamboo can further deflect pressure from vulnerable woodlands while providing regular income to marginalized people who would otherwise need to exploit them to survive.

4.1 Uplift in Allahabad

As construction boomed in India in the 1960s, it devoured vast expanses of rural land in Allahabad, a district of India's Uttar Pradesh province with a population of some 5 million. This happened because many farmers agreed to sell their topsoil to brickmaking companies, reaping immediate profits that were 20 times higher than they could earn from a year of farming. As topsoil was ruthlessly mined, sometimes to a depth of 3 metres, over 4,000 hectares of formerly productive land became denuded. The resulting updrafts in the heat of summer caused windstorms that wrought further destruction and even an estimated 380 deaths. Farmers who had allowed their arable land to be carted away fell ever deeper into poverty.

In the mid-1990s, a nongovernmental organization called Utthan ('uplift' in Sanskrit) realized that the only way to restore the land and the local economy was to embark on a large greening programme. It decided with local stakeholders to depend heavily on bamboo in addition to a range of income-generating trees. INBAR provided technical assistance and financial support to restore a pilot area of 106 hectares. Farmers planted bamboo primarily on bunds between crop fields, where it could bind the soil and prevent wind and water erosion.

Eighteen years later, the results are impressive. Bamboo is now part of a programme of land rehabilitation in 96 villages in Allahabad with 786,000 residents. Farmers receive an average of 10% of their income from bamboo products. Bamboo has helped raise the water table from 40 metres in 1996 to 33 metres in 2003 and 15-18 metres today. Each year, bamboo leaf adds 15-20 centimetres of humus to the soil, which has restored its carbon content (from zero to as much as 0.9 tonnes per hectare) and such micronutrients as boron and zinc, neutralized excessive alkalinity, and helped make phosphorus more bioavailable to crops. Long absent birds and other wild animals are returning. Bamboo is now a major source of the biogas that fuels 80% of the cooking done in the programme area, reducing carbon emissions. In a similar way, much of the 300 million hectares or more of degraded land in India could be restored to productivity using bamboo.

4.2 Encore in Ethiopia

Ethiopia is on track to achieve further success in land restoration as part of the $95 million second phase of the Sustainable Land Management Project, managed by the Ministry of Agriculture and the Government of the Federal Democratic Republic of Ethiopia, as part of the NEPAD-supported Terra Africa programme. INBAR is working with many partners to institute sustainable watershed management in 135 highland districts, benefiting 2 million people. Bamboo is being used to restore 1,000 hectares of degraded land and enrich a further 1,000 hectares of natural bamboo stands over the 5 years to 2019.

5 Bamboo-based livelihoods approaches to fight climate change

Bamboo is a highly versatile and rapidly renewable resource that offers a broad range of livelihood applications. Its economic role is likely to expand at an accelerating pace as other forest resources become strained under climate change, as the imperative to mitigate climate change enforces less dependence on fossil fuels and the resources of fragile forests, and as research discovers new applications for this valuable plant.

5.1 Bamboo in traditional economies

Bamboo looks like a tree but is taxonomically a grass. Like other grasses, it quickly rejuvenates and grows after being cut, such that a mature stand can provide a harvestable yield every year or two. This makes it a quick and reliable source of sturdy fibres that lend themselves to many uses. Because it regenerates by itself from underground rhizomes, it does not need to be replanted and requires little tending or other inputs such as fertilizer. It can grow on land unsuitable for other crops, making it a convenient and useful addition to diversified agriculture and agroforestry systems large and small.

A long-term survey of six of 25 provinces, to 2013, reveals that China's bamboo-based land restoration programme has conserved 18 billion cubic meters of water per year, conserved 200 million tonnes of soil and fixed 213million tonnes of carbon per year, for a total annual value of conserved biodiversity of nearly $20 billion

Although popularly associated with Asia, bamboo has economically important species that grow in the tropics and subtropics of Africa and the Americas. Annual production of bamboo was estimated at 15-20 million tonnes in 1994, before modern developments in bamboo management and materials could have much influence on the traditional bamboo economy.

Bamboo is perhaps best known as an alternative for timber to make homes, requiring little processing to become posts, roofs, walls, floors, beams, trusses and fences. An estimated 1 billion people worldwide live in bamboo housing, most of them in traditional houses that use bamboo culms as the primary frame building material. Many others live in houses that use bamboo in shear walling systems with excellent anti-seismic properties, such as the bahareque and erka housing systems of the Andes and Himalayas, for which bamboo is used as render often with clay or cement mortar. Among common household articles made of bamboo are furniture, mats, baskets, tools and tool handles, hats, and traditional toys. More refined and artistic traditional bamboo products include musical instruments and such woven items as trays, bottles, jars, boxes, cases, bowls, fans, screens, curtains, cushions, lampshades and lanterns.

The young shoots of some 200 species of bamboo are edible. Consumed fresh, they are a delicacy prized for their high-fibre content as well as their taste. Shoots retain their crispiness after cooking and can be packaged for shipment worldwide, commonly turning up in Chinese restaurants and grocery stores around the world.

Bamboo is the world's most important non-timber forest product, that plays a vital role in the the livelihoods of millions of people and communities across the tropics and sub-tropics. Most rural communities view bamboo stands as a common resource available to all. Because bamboo culms weigh little, they are relatively easy to harvest and carry home, and because bamboo poles split linearly, semiskilled workers using simple tools can easily processes them into value-added products. Bamboo thus provides livelihoods to many of the world's poorest communities and especially to vulnerable groups within them, including women and the elderly. It is a pathway out of poverty, as work on bamboo can be undertaken when convenient as a part-time or seasonal supplement to other pursuits.

The recent rise of industrial bamboo products has created new value chains that rural communities can supply if they take on the management of existing stands of bamboo and plant new ones. Bamboo thus promises to provide greatly improved livelihoods to marginalized communities vulnerable to climate change — livelihoods that make bamboo more effective at promoting economic development, while at the same time delivering climate change mitigation and adaptation benefits.

5.2 Modern, engineered bamboo products

Newly engineered materials and fabrication techniques have since the 1980s enabled the emergence of prefabricated bamboo houses made with laminated bamboo boards, veneers and panels (see 'Climate-smart housing in Latin America' on page 12). Among the advantages of new types of prefabricated bamboo houses is that they can be packed flat and transported long distances at a reasonable cost before being erected onsite. They improve on traditional designs to maximize the traditional virtues of low cost, ample ventilation as needed in warm climates, and environmental sustainability. The new designs feature augmented resilience in areas prone to earthquakes and violent storms, as well as resistance to rot and damage from insects.

5.2.1 Bamboo panels. China started producing bamboo panels back in the early 19th century, but the possibilities have multiplied with recent advances in materials science and processing techniques. Today, more than 20 types of panels are produced in Asia. Because the fibres in bamboo are longer than those in wood, bamboo panels outperform their wooden counterparts by some technological measures of strength and rigidity. Bamboo panels are widely used in modern building construction as structural elements or as forms for concrete mouldings. They are also materials for floors, roofs, partitions, doors and window frames. Bamboo can be used as veneer or in strips, laminated to make plywood, or pressed into particle and fibre board. Bamboo pieces can be mixed with wood and other lignocellulose materials or with inorganic substances.

5.2.2 Knockdown bamboo furniture. Traditional bamboo furniture uses sections of natural round poles and split bamboo. The modern alternative is to use glue-laminated bamboo panels that are shipped as a pack-flat kit for assembly at the retail point or the premises of the end user. Knockdown furniture designs overcome many of the problems of traditional bamboo furniture, such as high labour and transportation costs, low productivity, instability, varying quality, and susceptibility to damage from insects and fungi. At the same time, they retain the distinct physical, mechanical, chemical, environmental and aesthetic advantages of bamboo. Exports of laminated bamboo furniture are growing rapidly, but no one can say just how rapidly for lack of a special code for bamboo furniture, which is usually lumped with rattan and wooden furniture.

5.2.3 Processed bamboo flooring. Consumers around the world are becoming increasingly aware of these high-quality products. Processed bamboo flooring is often superior to wooden flooring. It is smooth and bright, retaining the elegance of bamboo grain under a soft natural lustre. It is very stable and resistant to warping, decay and damage from insects, yet can be comfortably flexible. Finally, it is an excellent insulator for use in heated or air-conditioned rooms. Upscale markets in Europe, Japan and North America have welcomed bamboo flooring enthusiastically. China's estimated annual production of bamboo flooring in 2013 was about 28.4 million square metres, 60%-70% of which was exported

5.2.4 Bamboo pulp and paper. Several bamboo-producing countries such as China and India use bamboo for pulp and paper. Depending on how much refinement the pulp has undergone, bamboo paper is equal in quality to that made from wood pulp, but with some natural advantages. Its brightness and opacity are more stable over time than is the case with some paper made from wood pulp. Long bamboo fibres yield paper with a high tear index similar to that of hardwood paper. Bamboo paper is somewhat less stiff than paper made from softwood, and its strain strength is between that of hardwood and softwood paper.

5.2.5 Bamboo fabrics. New technologies are extending bamboo's value as a source of composite fibres for a range of textiles. Clothing that uses bamboo may be either 100% bamboo yarn or a blend of bamboo and cotton, hemp or even specialized synthetics such as Spandex. Cellulose from bamboo leaves and the soft pith inside of bamboo culms can be processed to make viscose rayon, a soft fibre with many uses in clothing, upholstery and carpets.

5.2.6 Other industrial materials. Bamboo can be heated to break it down into charcoal, oil and gas. Changing the parameters of such pyrolysis determines the output. Bamboo charcoal is traditionally used as a cost-effective and easily produced substitute for wood charcoal or fossil coal. It is an excellent fuel for cooking and barbequing, and its calorific value is almost half that of oil of the same weight and on a par with wood charcoal. Activated bamboo charcoal is useful as a deodorant, purifier, disinfectant, medicine and agricultural fertilizer. It excels at absorbing pollution and unwanted moisture, as its absorptive capacity is 6 times that of wood charcoal of the same weight. Bamboo can be processed to yield other extracts useful in pharmaceuticals, creams and beverages. Bamboo gas is a good substitute for petroleum.

5.3 Bamboo production and trade

The global bamboo industry has developed rapidly in recent decades. In China, the world's largest producer, all production in the national bamboo industry was valued at $19.5 billion in 2012, an increase of nearly 50% from $13.1 billion in 2010 (Box 2). In India, some 8.6 million people depend for their livelihoods on bamboo and the industries it supplies. Indian bamboo is projected to create value equal to $4.4 billion in 2015, which is 130 times the $34 million recorded in 2003.

The main bamboo commodities traded on international market are industrial products, woven products, edible shoots and raw materials (mostly poles). Despite being the largest bamboo trade category today, industrial bamboo products have been recognized by the international market only since 2007, when the category received five Harmonized System codes: for charcoal, flooring, plywood, pulp, and paper products.

In the Kingdom of Bamboo: Inside China's bamboo development policy

Bamboo's centre of origin is in southwest China, and the Middle Kingdom was the first to record the plant's harvest and use. China's reopening to the world in the late 1970s began the revitalization of its domestic bamboo industry, which has since enjoyed targeted financing and policy support. The value of domestic bamboo output soared from RMB400 million in 1981 to RMB117 billion in 2012, the last year for which figures are available. Equal to $19.5 billion in 2012, this output is almost a fourfold increase from $5.5 billion in 2004. In 2012, China was the source of two-thirds of the bamboo and rattan products traded on the international market, the country's exports valued at $1.2 billion. The bamboo industry in China now employs 7.75 million people.

Since 1981, China has increased the area under bamboo by 3 million hectares, most of the expansion on degraded landscapes and marginal farmland. As its bamboo industry continues to grow, China plans to continue to expand the growing area. As a result, the carbon stored in Chinese bamboo forests is projected to increase from 727 million tonnes in 2010 to 1,018 million tonnes in 2050.

Because many bamboo trade figures continue to be combined with those of rattan and sometimes other woody products, simple statements of industry and trade value are hard to make. That said, the domestic market for bamboo and rattan products in the major producing countries in 2012 is estimated at $34.2 billion.

World exports of bamboo and rattan products peaked at $2.6 billion in 2008, before the global financial crisis slashed this figure by a quarter the following year. In 2012, the figure stood at $1.9 billion, of which $539 million (29%) was industrial bamboo products, dominated by rising volumes of bamboo flooring, valued that year at $366 million (68% of industrial bamboo exports). Flooring was followed by declining volumes of bamboo plywood, valued at $115 million (21% of industrial bamboo exports). The export value of bamboo charcoal, paper products and pulp totalled $57 million.

The next largest category of bamboo exports in 2012 was woven products, valued at $476 million, or 25% of the bamboo and rattan total. Exports of bamboo shoots had grown to $276 million (15% of the total) from $220 million in 2010. China supplied 87% of all exports of bamboo shoots in 2012, and Japan bought 59% of all imports, with the European Union buying 20% and the United States 15%.

6 Resources and further reading

- **The Potential of Bamboo is Constrained by Outmoded Policy Frames.** AMBIO DOI 10.1007/s13280-011-0138-4. Buckingham K, P Jepson, LR Wu, IVR Rao, SN Jiang, W Liese, YP Lou, MY Fu. 2011.
- **Changes of carbon stocks in bamboo stands in China during 100 years.** Forest Ecology and Management 258:1489-1496. Chen X, X Zhang, Y Zhang, T Booth, X He. 2009.
- **National bamboo industry development plan 2013-2020.** China State Forestry Administration. 2013.
- **Effect of *Dendrocalamus farinosus* bamboo plantation on soil and water conservation in National Conversion Programme in Western China.** Journal of Zhejiang Forestry Science & Technology 27(3). Da ZX, YP Lou, WY Dong, YP Gao. 2007.
- **Bamboo products and trade.** Food and Agriculture Organization. undated. ftp://ftp.fao.org/docrep/fao/010/a1243e/a1243e04.pdf
- **Gold Standard. 2014. Bamboo: tremendous growth requires robust management.** http://www.goldstandard.org/bamboo-tremendous-growth-requires-robust-management
- **Analysis on recovery from snow disaster of *Phyllostachys heterocycla* var. *pubescens* stands for shoot production.** Journal of Zhejiang Forestry Science & Technology 29(6): 61-63 (in Chinese). He D, H Huang, X Qian, Q Qiu, S Qian. 2009.
- **Bamboo: restoring landscapes, rebuilding lives. brochure.** 2014. Expanding beyond the pilot sites. International Network for Bamboo and Rattan. 2014. http://www.inbar.int/2013/02/expanding-beyond-the-pilot-sites/#more-1956
- **Standing up to natural disasters.** ___. 2014. http://www.inbar.int/2014/02/standing-up-to-natural-disasters/
- **Aspects of bamboo agronomy.** In Sparks DL (ed.). Advances in Agronomy 74:99-153. Kleinhenz V, DJ Midmore. 2001.
- **Carbon off-setting with bamboo.** INBAR Working Paper No. 71. Kuehl Y, YP Lou. 2012. International Network for Bamboo and Rattan. http://www.inbar.int/publications/?did=251
- **Non-wood forest products and income generation.** International Network for Bamboo and Rattan and Food and Agriculture Organization. Kumar A, CB Sastry. 1999.
- **Greening red earth: bamboo's role in the environmental and socio-economic rehabilitation of villages devastated by brick mining.** International Network for Bamboo and Rattan. Kutty V, N Chitra. 2003.
- **The Environmental Impact of Industrial Bamboo Products:** Life-cycle Assessment and Carbon Sequestration. J.G. Vogtländer; P. van der Lugt; Design for Sustainability Program Delft University of Technology

- **Bamboo and climate change mitigation.** INBAR Technical Report No. 32. International Network for Bamboo and Rattan. Lou YP, YX Li, K Buckingham, G Henley, GM Zhou. 2010. http://www.inbar.int/publications/?did=1
- **Transforming rural livelihoods and landscapes: sustainable improvements to incomes, food security and the environment.** Nicholls T, I Elouafi, C Borgemeister, JJ Campos-Arce, M Hermann , J Hoogendoorn, JDH Keatinge, S Kelemu, DJ Molden, A Roy. 2013. http://www.inbar.int/publications/?did=286 • The environmental impact of industrial bamboo products: life-cycle assessment and carbon sequestration. INBAR Technical Report No. 35. International Network for Bamboo and Rattan. Vogtländer JG, P. van der Lugt. 2014.
- **The Fifth Assessment Report (AR5)** of the United Nations Intergovernmental Panel on Climate Change (IPCC) http://www.ipcc.ch/report/ar5/index.shtml
- **Ecuador innovates with bamboo houses for the low-income population.** World Bank. 2013. http://www.worldbank.org/en/news/feature/2013/01/23/ecuador-innovates-with-bamboo-houses-for-the-poor___
- **Sustainable Land Management Project-II 2014.** http://www.worldbank.org/projects/P133133?lang=en
- **International Trade of Bamboo and Rattan 2012.** International Network for Bamboo and Rattan. Wu J. 2014http://www.inbar.int/publications/?did=292
- **Impact of the 2008 ice storm on moso bamboo plantations in southeast China.** Journal of Geophysical Research 116. G00H06, doi:10.1029/2009JG001234. Zhou BZ, ZC Li, XM Wang, YH Cao, YF An, ZF Deng, G Letu, G Wang, LH Gu. 2011.
- **Methodology for carbon accounting and monitoring of bamboo afforestation projects in China.** INBAR Working Paper No. 73. International Network for Bamboo and Rattan. Zhou GM, YJ Shi, YP Lou, JL Li, Y Kuehl, JH Chen, GQ Ma, YY He, XM Wang, TF Yu. 2013.
- **Biochar for environmental management Science and Technology** Edited by Johannes Lehmann and Stephen Joseph ISBN 978-1-84407-658-1, Earthscan
- **Charcoal Supply Chain in Ethiopia** From Proceedings of the "conference on Charcoal and Communities in Africa, June 16-18, Maputo, Mozambique, Seboka Y., Duraisamy, J., 2008, edited by Ralk Kwaschik, INBAR Proceedings 15.
- **Panda Standard** http://www.pandastandard.org/Conference/issued_Projects_2014.html
- **Verified Carbon Standard** www.vcsprojectdatabase.org/
- **Bamboo and Rattan in the World**, Chief Editor Jiang Zehui, 2007, China Forestry Publishing House, ISB 978-7-5038-5109-4
- **The Environmental Impact of Industrial Bamboo Products**: Life-cycle Assessment and Carbon Sequestration. J.G. Vogtländer; P. van der Lugt; Design for Sustainability Program Delft University of Technology