

Bamboo-based carbon farming: A pathway towards sustainable development goals

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Carbon farming, a nature-based solution, integrates climate change mitigation methods with livelihood enhancement and ecosystem restoration. Among various plant-based carbon sequestration options, bamboo stands out as a fast-growing, renewable and multifunctional resource with exceptional carbon capture potential. Bamboo-based carbon farming offers a unique opportunity to sequester atmospheric carbon dioxide while supporting rural livelihoods, restoring degraded lands and contributing directly and indirectly to several Sustainable Development Goals. Thus, bamboo can play a transformative role in climate-resilient and low-emission development pathways. This article discusses the concept of carbon farming, mechanisms of carbon sequestration and bamboo-based farming systems, along with their ecological, socio-economic and policy dimensions.

Keywords: Agroforestry, Carbon sequestration, Ecosystem restoration, Rural livelihood

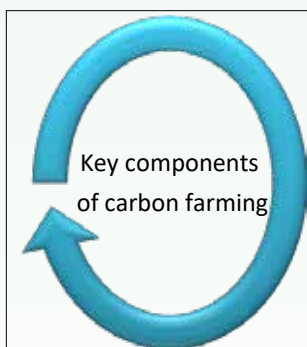
GLOBAL climate change, driven largely by increasing concentrations of greenhouse gases (GHGs), poses serious threats to ecosystems, food security and human well-being. The agricultural and forestry sectors are both contributors and victims of climate change. Consequently, there is an urgent need to adopt land-use practices that reduce emissions while enhancing carbon sinks. Climate change mitigation and sustainable development are among the most pressing global challenges of the 21st century. Carbon farming, which involves land management practices that increase carbon storage in vegetation and soils, has gained recognition as an effective climate-smart strategy.

Bamboo, often referred to as the 'green gold' or 'poor man's timber', has recently gained global attention for its role in carbon sequestration and sustainable development. Belonging to the family Poaceae, bamboo is a perennial, woody grass with extraordinary growth rates, capable of attaining maturity within 3–5 years; much faster than conventional timber species. Beyond climate mitigation, bamboo provides

multiple ecosystem services, including soil conservation, biodiversity support and livelihood generation. Its versatility across construction, handicrafts, bioenergy, paper and textile industries further strengthens its role in sustainable development. Further, it also contributes to emission reductions with renewable bamboo products, which store carbon for extended periods in construction and engineered applications.

Concept of carbon farming

Carbon farming refers to agricultural and forestry practices designed to enhance the sequestration of atmospheric carbon dioxide in biomass and soils while reducing greenhouse gas emissions. It integrates climate mitigation with sustainable land management and income generation.



- **Biological carbon sequestration** through trees, grasses and perennial crops
- **Soil carbon enhancement** via organic matter addition and reduced disturbance
- **Emission reduction** by minimising fossil fuel use and land degradation
- **Carbon credits and incentives** through voluntary or regulated carbon markets

Carbon farming practices include agroforestry, afforestation/reforestation, conservation agriculture, pasture management and biochar application. Bamboo-based systems fit seamlessly into this framework due to its high productivity and low environmental footprint.

Bamboo: A climate-resilient species

Growth and biomass characteristics: Bamboo is widely recognised as one of the fastest-growing plant groups on Earth, exhibiting extraordinary growth rates that distinguish it from most woody perennials. Certain species of bamboo have been reported to grow up to 90 cm per day under favourable climatic and soil conditions, enabling rapid canopy establishment and early biomass accumulation. It typically attains harvestable size within 3–5 years. This accelerated growth cycle allows bamboo to capture atmospheric carbon dioxide at a much faster rate, making it particularly suitable for carbon farming and climate change mitigation initiatives. A defining feature of bamboo is its unique regenerative growth habit through an extensive rhizome system. Following harvesting, bamboo does not require replanting, as new culms regenerate naturally from underground rhizomes. This perennial and self-renewing nature ensures continuous biomass production without soil disturbance, which is critical for maintaining soil organic carbon stocks. The absence of repeated land preparation operations further minimises carbon losses from soil respiration and erosion. Consequently, bamboo-based systems provide long-term stability of carbon pools while sustaining productivity over multiple harvest cycles.

Carbon sequestration potential: Bamboo enhances carbon sequestration through above-ground biomass (culms, branches, leaves), below-ground biomass (rhizomes and roots) and soil organic carbon pools. Its rapid growth and dense stand structure enable quick accumulation of carbon, while underground rhizomes and root systems enrich deeper soil layers and improve soil quality. Leaf litter and root turnover further increase soil organic carbon through decomposition and stabilisation. Well-managed bamboo forests can sequester significantly more carbon than many fast-growing tree species due to continuous regeneration and high productivity. Additionally, carbon remains stored in long-lasting bamboo products such as construction materials and furniture, and substituting bamboo for carbon-intensive materials like steel and concrete further reduces emissions. Thus, bamboo-based carbon farming supports both biological carbon sinks and long-term climate mitigation.

Bamboo-based carbon farming systems

Bamboo plantations: Dedicated bamboo plantations established on degraded, marginal and wastelands function as highly effective carbon sinks while simultaneously supporting land restoration efforts. Bamboo is particularly well suited for reclamation of fragile and unproductive landscapes due to its rapid growth, extensive root-rhizome system and adaptability



Bamboo plantation under mid-hill conditions of Himachal Pradesh

to a wide range of soil and climatic conditions. Its dense root network helps stabilise loose substrates, reduce soil erosion and improve soil structure, making bamboo an ideal species for rehabilitating mine spoils, eroded lands, riverbanks and hill slopes. In addition, bamboo plantations on degraded forest lands enhance biomass production and soil organic carbon accumulation without exerting pressure on natural forests. Through continuous regeneration and sustained carbon sequestration, bamboo plantations contribute to long-term climate change mitigation while promoting ecological restoration and sustainable land management.

Bamboo based agroforestry systems: Bamboo based agroforestry systems involve the strategic integration of bamboo with agricultural crops, horticultural species and fruit trees, thereby enhancing overall land productivity. The inclusion of bamboo in farming systems modifies the microclimate by regulating temperature, reducing evapo-transpiration and improving soil moisture retention, which collectively create favourable growing conditions for associated crops. When planted as boundary plantations, alley crops, or block plantations within farms, bamboo acts as an effective windbreak and shelterbelt, protecting crops from strong winds, frost damage, and soil erosion. This protective function is particularly valuable in climatically vulnerable regions where extreme weather events are becoming more frequent.

In addition to its ecological benefits, bamboo based agroforestry systems provide significant economic



Bamboo based agroforestry system under mid-hill conditions of Himachal Pradesh



Bamboo handicraft production by local artisans in Mandi District of Himachal Pradesh

advantages to farmers. Bamboo culms can be harvested periodically without affecting crop production, offering a regular and supplementary source of income. The diversified production system reduces dependency on single crops, enhances farm resilience to climate variability and improves livelihood security. Thus, bamboo-based agroforestry represents a climate-smart land-use strategy that simultaneously supports carbon storage, ecological stability and sustainable rural livelihoods.

Bamboo in community and farm forestry: Bamboo-based community and farm forestry systems significantly support participatory conservation, sustainable resource management and equitable benefit sharing. In community-managed forests, bamboo cultivation strengthens local institutions by engaging them in planning, protection, harvesting and regeneration, while its rapid growth and non-destructive harvesting make it ideal for sustainable production. Particularly in rural and tribal areas, bamboo sustains livelihoods through handicrafts, housing, tools and fuel. When integrated into farm forestry, it enhances household resource security and provides both subsistence and commercial benefits. These systems also contribute to carbon sequestration by maintaining perennial vegetation and improving soil organic carbon, while generating income that enhances socio-economic resilience and reduces pressure on natural forests. Overall, bamboo-based community and farm forestry offer an inclusive and ecologically sustainable approach linking climate mitigation with rural development.

Contribution to Sustainable Development Goals

Bamboo-based carbon farming contributes simultaneously to environmental sustainability, economic development, and social well-being, making it a powerful nature-based solution for achieving multiple Sustainable Development Goals (SDGs). Due to its fast growth, regenerative capacity, and wide range of end uses, bamboo integrates climate action with livelihood generation, ecosystem restoration and responsible resource use. The contribution of bamboo-based carbon farming to selected SDGs includes:

SDG 1: No Poverty: Bamboo-based carbon farming plays a significant role in poverty alleviation by generating sustainable and year-round income opportunities for rural households, particularly smallholders, landless labourers, and tribal communities. Employment is created across the bamboo value chain, including nursery raising, plantation establishment, management, harvesting, primary processing, and value addition. In India, bamboo-based livelihoods support millions of people, especially in states such as Assam, Tripura, Madhya Pradesh, Chhattisgarh, Himachal Pradesh and the north-eastern region. Studies indicate that well-managed bamboo plantations can provide regular income within 3–4 years of establishment, unlike conventional timber species that require decades to mature. Community-managed bamboo resources also reduce dependency on seasonal agricultural income, thereby enhancing financial stability and resilience among vulnerable populations.

SDG 2: Zero Hunger: Bamboo-based agroforestry systems contribute to food and nutritional security by enhancing farm resilience and diversifying income sources. Integration of bamboo with crops and fruit trees protects agricultural fields from wind damage, soil erosion and moisture loss, thereby stabilising crop yields under changing climatic conditions. In addition, several bamboo species produce edible shoots, which are rich in fibre, minerals and vitamins and form an important component of traditional diets in many Asian countries, including India, China and Southeast Asia. Bamboo shoots contribute both to household nutrition and market income. By improving soil health, reducing land degradation and providing supplementary food and income, bamboo-based systems indirectly strengthen food security and support sustainable agricultural production.

SDG 8: Decent Work and Economic Growth: It strongly supports SDG 8 by fostering green employment and promoting inclusive, sustainable economic growth. The bamboo sector supports a wide range of industries, including construction, furniture, handicrafts, paper and pulp, textiles, bioenergy and engineered bamboo products. According to estimates, bamboo-based



Edible bamboo shoot harvested and pickled

enterprises can generate employment for 200–300 days/ha/year, particularly benefiting rural youth and women. Small-scale bamboo industries and micro-enterprises promote decentralised rural industrialisation and entrepreneurship. Furthermore, bamboo role as a low-carbon raw material aligns economic growth with environmental sustainability, ensuring that income generation does not come at the cost of ecosystem degradation.

SDG 12: Responsible Consumption and Production: Bamboo is a renewable, biodegradable and low-carbon alternative to conventional materials such as timber, plastics, steel and concrete. Its rapid regeneration allows sustainable harvesting without permanent ecosystem damage, making it an ideal resource for responsible production systems. Bamboo-based carbon farming supports circular economy principles by enabling the production of durable goods, biodegradable packaging and eco-friendly construction materials. Substitution of bamboo for energy-intensive materials significantly reduces greenhouse gas emissions and pressure on natural forests. The promotion of bamboo products encourages consumers to adopt sustainable consumption patterns while supporting environmentally responsible supply chains.

SDG 13: Climate Action: Bamboo-based carbon farming contributes directly to climate action by acting as an efficient biological carbon sink. Bamboo plantations can sequester substantial amounts of carbon both above and below ground, with studies reporting carbon sequestration rates comparable to or higher than many fast-growing tree species. Estimates suggest that bamboo systems can sequester between 5–12 t CO₂/ha/yr, depending on species, management, and site conditions. In addition to sequestration, bamboo enhances climate adaptation by stabilising soils, regulating microclimates, and improving water-use efficiency. The use of bamboo products also contributes to emission reduction through material substitution, making bamboo a comprehensive climate mitigation and adaptation strategy.

SDG 15: Life on Land: Bamboo plantations and agroforestry systems play an important role in restoring

degraded ecosystems and promoting sustainable land management. Bamboo's extensive root-rhizome network stabilises soils, reduces erosion and improves soil organic matter, making it particularly suitable for rehabilitating degraded forest lands, mine spoils and riverbanks. Bamboo-based systems also support biodiversity by providing habitat for various flora and fauna, especially in mixed plantations and community-managed forests. By reducing pressure on natural forests and enhancing ecosystem services, bamboo-based carbon farming contributes to the conservation, restoration and sustainable use of terrestrial ecosystems.

Ongoing bamboo projects in India

Bamboo plantation-based grouped project: In India, a grouped bamboo plantation project has been proposed under Verra to plant native bamboo species mainly on degraded and fallow lands across a target area of about 500,000 hectares. The initiative aims to reduce greenhouse gas emissions through biomass accumulation and soil carbon enhancement while boosting farmers and communities incomes.

Bamboo plantations by farmers and communities: Another Indian voluntary carbon project involves bamboo plantations established by individual farmers and communities on approximately 4,500 hectares of degraded lands in central (Madhya Pradesh) and western (Maharashtra) regions. This project focuses on enhancing soil carbon, landscape greening and livelihood generation, with registration and carbon verification currently underway.

Meghalaya bamboo carbon credit initiative: In 2025, the state of Meghalaya launched India's first dedicated Bamboo Carbon Credit programme, focusing on monetising carbon sequestration from bamboo forests and biochar production. The initiative aims to generate carbon revenue for local communities while increasing agricultural productivity and climate resilience.

Bamboo projects in other countries

- Bamboo Biochar Project in Thailand by Wong Pai community and Planboo company
- EcoPlanet Bamboo Company Forestry Projects (Philippines and Africa)
- Bamboo carbon projects in Uganda
- RIZOME Kawayan Project (Philippines)

Policy support and institutional framework

India has actively mainstreamed bamboo into national climate and land-use strategies through the National Agroforestry Policy and alignment with its Paris Agreement commitments, particularly the Nationally Determined Contributions (NDCs) for enhancing carbon sinks. The National Bamboo Mission provides institutional, technical, and financial support across the value chain ranging from nurseries and plantations to processing and market linkages, thereby strengthening livelihoods and promoting bamboo-based carbon farming. Regulatory reforms reclassifying bamboo as a grass outside forest areas have reduced

felling and transit restrictions, encouraging farmer adoption and private investment. Several states have further supported bamboo development through targeted initiatives, including the Maharashtra Bamboo Industry Policy 2025 and programmes in Himachal Pradesh, Mizoram, and Odisha.

Challenges

Despite policy support, bamboo-based carbon farming faces challenges such as the absence of standardised MRV protocols, limited access to quality planting material, weak nursery and market infrastructure, underdeveloped value chains, price volatility, and low farmer awareness of carbon finance mechanisms. These constraints limit large-scale adoption and participation in carbon credit markets.

Future prospects

The way forward involves developing species-specific carbon accounting models, integrating bamboo into national carbon credit frameworks, strengthening value chains and green industry linkages, and promoting community-based, landscape-level approaches.

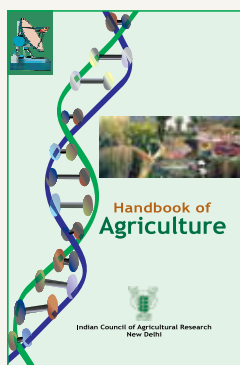
Continued research, institutional support, and enabling policies will be essential to fully harness bamboo's potential as a climate-smart resource for sustainable development.

SUMMARY

Bamboo-based carbon farming represents a viable, scalable, and multifunctional pathway toward achieving the SDGs. Its exceptional carbon sequestration capacity, combined with ecological restoration and livelihood generation, positions bamboo as a cornerstone of sustainable land-use systems. By integrating bamboo into carbon farming frameworks, countries can simultaneously address climate change, rural development and environmental sustainability. Strategic investments, scientific research and supportive policies are essential to mainstream bamboo-based carbon farming as a global solution for sustainable development.

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