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Bamboo in the Green Economy: Enhancing Employment Opportunities in India

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Abstract:

India harbours a rich diversity of bamboo resources, with 136 species (125 indigenous and 11 exotic) distributed across 23 genera. The country possesses approximately 15 million hectares of bamboo-bearing area, of which nearly two-thirds of the production is concentrated in the eight northeastern states. The North Eastern Region alone accounts for about 35.79% of the total bamboo area, covering nearly 14.94 million hectares. The annual bamboo production in India is estimated at 14.6 million tonnes, with productivity ranging between 1 and 3 tonnes per hectare. The bamboo and rattan sector in India is valued at approximately USD 4.35 billion. Despite its vast resource base, India remains a net importer, with imports worth USD 24.19 million compared to significantly higher exports from countries such as China. The sector has substantial employment potential, generating an estimated 516.33 million man-days annually. Additionally, bamboo is emerging as a promising raw material for bioethanol production, contributing to the expanding biofuel industry. Given its ecological and economic significance, the promotion of bamboo cultivation among farmers can enhance green cover, support sustainable livelihoods, and strengthen the green economy. The present study is aligned with this perspective and aims to contribute to the understanding and development of the bamboo sector in India.

Keywords: Bamboo, Employment, Green cover and India

Introduction

Bamboo is known by different local names in Asia and is called "friend of people, wood of the poor and "the brother" in China, India, and Vietnam, respectively (Waite, 2009 and Farrelly, 1984). Bamboo is a highly prevalent plant in tropical and subtropical latitudes between 46°N and 47°S. The woody-stemmed grass (Ruiz-Sanchez *et al.*, 2019) has the highest growth rates in the world and contributes to achieving several United Nations 2030 Sustainable

Development Goals -mainly, SDG1, SDG7, SDG 11, SDG 12, SDG 13, SDG 15 and SDG 17. It is the most valuable economic resource for local people in bamboo-growing areas (Wu *et al*., 2009). It is regarded as a superior herb (Yu *et al*., 2011) and classified as a non-timber forest product (NTFP) plant (Van *et al*., 2009) because of its rapid growth, high biomass, yield in a short amount of time, and high efficiency in a few years (Yu *et al*., 2011). It covered more than 31 million hectares of forestland worldwide, with more than 60% of that area being in China, Brazil and India (FAO United Nations, GFRA, 2010). In India, the North Eastern regions account for 35.79 per cent of the total bamboo-bearing area of 14.94 million hectares (ISFR, 2021).

Bamboo utilize in over 1500 commercial products (Li *et al*., 2004) and these products have wide range of applications, such as low-rise dwellings (Chung *et al*., 2002), paper pulp, fencing, basketry (Pearson *et al*., 1994), water pipes, utensils (Liu *et al*., 2008), bicycles (Johnson, 2008), bridges (Xiao, 2010) and musical instruments (Cho *et al*., 2011). And, it significantly contributes in social, economic and ecological development of any region as well as the subsistence needs of more than 2.5 billion people universally (ISFR, 2021).

Bamboo's remarkable growth rate, high biomass production, and low input requirements make it a promising candidate for biofuel production. As a lignocellulosic material, bamboo contains cellulose, hemicellulose and lignin, which can be converted into fermentable sugars for ethanol production. The high cellulose content in bamboo (around 40-50% of its dry weight) allows for a significant yield of fermentable sugars, making it an ideal feedstock for bioethanol production.

From bamboo to ethanol, India's biofuel business is expected to grow into a $15 billion market, with Indian oil corporations investing in biofuel refineries to increase ethanol production from non-molasses sources such as agricultural leftovers. A joint venture between Numaligarh Refinery Ltd. and Finnish technology firm Chempolis Oy would crush bamboo, the longest grass family, to create 60 million liters of ethanol annually in Assam. That amount is sufficient to meet the northeastern region's statutory blending requirements with gasoline. The purpose of this paper is to identify the most widely used bamboo for researchers by discussing the green economy associated with this unique plant.

Bamboo's Potential in a Diversifying Green Economy

Concept of the Green Economy

A green economy is defined as one that "improves human well-being and social equity while significantly reducing environmental risks and ecological scarcity" (UNEP, 2010). It is based on promoting economic growth and investment while improving environmental quality and social inclusion (UNEP, 2011). The goal of the green economy model's conception is to offer potential solutions for the current environmental and economic issues facing the world. It is regarded as a key mechanism for the practical realisation of sustainable development, encompassing

improved green technologies, resource efficiency, biological resource conservation, renewable energy, material reduction, recycling and reuse, and green infrastructure (Aina *et al*., 2021).

Green Economy and Bamboo

Bamboo, often known as the "wonder plant," "poor man's timber," and "green gold," contributes greatly to ecological sustainability because of its unique potential to provide environmental, economic, and social advantages to humanity (Scheba *et al*., 2017; Manandhar *et al*., 2019). It is widely regarded as a green alternative to traditional construction materials because of its green growth, sustainable harvesting, and wood-like qualities. Though not classified as a wood, bamboo is a fast-growing woody grass species that can be used as a raw material to reduce the demand for wood and wood products, thereby alleviating the high rate of forest depletion (Atanda, 2015). It has been described as one of the quickest growing plants on the planet, with a short gestation period of 3 to 5 years before maturity and harvest (Atanda, 2015). Its rapid growth rate makes it appropriate for afforestation, as it may be cut and replanted in seven years, compared to 10 to 50 years for certain indigenous tree species (Mohamed, 2003; Basumatary *et al*., 2015).

Bamboo's Environmental Benefits in a Sustainable Green Economy

(a) Carbon sequestration potential of Bamboo

A product's greenness is determined by whether it is generated from a sustainable and fast renewable source, which is unique to bamboo. Bamboo is an underutilized natural resource that offers significant answers to worldwide land degradation, desertification, climate change mitigation, and adaptation (Holt, 2019; INBAR, 2014). It is a rapidly growing plant that absorbs more carbon than both native and imported wood species. It generates 30% more oxygen than hardwood species. When used as a construction material, it traps carbon and prevents it from re-entering the environment for an extended period. Bamboo is thought to store 30 to 121 mg of carbon per hectare and sequester 6 to 13 mg of carbon per ha per year (Nath *et al*., 2015).

The yearly rate of CO_2 sequestration in bamboo forests was reported to be 22.41 Mg ha^{-1}, which was nearly two times higher than the rate in montane temperate and pine plantations and six times higher than the rate in tropical deciduous forests. Bamboo can absorb 12 metric tonnes of damaging CO_2 per hectare from the atmosphere, which is two times more than a similar-sized forest (Tariyal *et al*., 2013; Scurlock *et al*., 2000; Choudhary, 2008). The annual carbon fixation of the tree layer in Moso bamboo forest was 5.10 t ha^{-1}, which was 1.33 times that of a tropical mountain rain forest and 0.94 times that of Chinese fir (*Cunninghamia lanceolata*) at 5 years old in Huitong County (Zhou and Jiang, 2004; Zhao *et al*., 2009). One hectare of bamboo may sequester up to 62 tonnes of CO_2 per year, while a young forest can sequester 15 tonnes of CO_2 per year (Yadava and Thokchom, 2014; Das and Chaturvedi, 2006; Nath and Das, 2011).

Gopal and Bakshi (2021) also evaluated five selected accessions of *Dendrocalamus strictus* Roxb. and found that the Uttarakhand accession was the most photosynthetically efficient, had low transpiration, and had the highest instantaneous water-use efficiency. It has the potential to be used for improvement and breeding programs, and can be multiplied en masse for future plantations in various agro-climatic zones of India.

(b) Bamboo's potential for sustainable energy sources

Construction materials such as concrete, steel, and wood contribute significantly to environmental degradation and global climate change issues because these materials have higher production energy efficiency than bamboo, making it more efficient (Laroque, 2007). Cement, a major component of concrete, is produced by heating limestone and other ingredients to 1,400 °C using fossil fuels. This means that every ton of cement produced generates at least one ton of carbon dioxide (CO_2). As a result, cement production and transportation contribute significantly to world carbon dioxide emissions (Bhalla *et al*., 2012). Similarly, the steel sector emits more than 2 tons of CO_2 into the atmosphere for every ton of steel produced (Ghavami, 2007). However, from a greener environmental perspective, the production of every ton of bamboo sequesters approximately 2 tons of CO_2, releasing new oxygen into the atmosphere (Bhalla *et al*., 2012).

(c) Bamboo's ability to reduce environmental pollution

Bamboo is a sustainable natural resource that is good for the environment and helps to protect biodiversity (Gichohi, 2014). Bamboo's strong root system contributes to soil stability and erosion management. It reduces deforestation, makes better use of wasteland, resulting in greater soil conservation and flood disaster prevention. A lot of nitrogen is absorbed and transformed into nutrients for physiological growth (Nwoke and Ugwuishiwu, 2011).

(d) The Benefits of Bamboo for Green Building Materials

Bamboo is known for being a high-quality, ecologically friendly material. Bamboo's potential as a sustainable, environmentally friendly building material has been examined by a number of studies and findings (Aina *et al*., 2021).

(e) Bamboo's potential for industrial use in a sustainable green economy

Bamboo has been used as a raw material since human history (Atanda, 2015). Bamboo is now recognized as the new super material for about 4000 commercial items or products ranging from textiles to construction (Singh, 2008; Wooldridge, 2012; Musau, 2016; INBAR, 2015).

Issues in the Bamboo Sector

(a) Demand and Supply Gap

In the country, 10 million people rely entirely on bamboo for survival. According to Salam (2013), the current demand for bamboo for various purposes is projected at 26.69 million tonnes, whereas the country's supply is 13.47

million tonnes. The share of global bamboo trade and commerce is rarely 4%, but accounting for 45% of global bamboo growth. According to policy pronouncements, the Indian government aims to focus the country's bamboo sector in the northeast, to account for 27% of the global market by 2015, when the international bamboo trade is estimated to reach $950 billion (Kumar *et al*., 2005).

(b) Lack of quality planting material

There is no high-quality planting material for bamboo due to the gregarious nature of the species. The majority of plantations in India are cultivated from seed obtained from unknown sources, with no processes in place to guarantee the source's production credentials (FRI, 2014). Vegetatively propagated plants are supplied in limited quantities.

(c) Mechanisation, Specifications and value addition

Bamboo handicrafts are mostly traditional, leading to low production levels. Bamboo handicrafts require a large amount of splits, sticks, and semi-processed raw materials. Currently, artisans manually process whole bamboos, resulting in waste and lower-quality products. To improve production without sacrificing quality, it is crucial to provide ready-to-use raw materials such as housing, improved tools, and skill development (Tewari *et al*., 2019).

Conclusions

India has the second-highest bamboo diversity and the largest bamboo-bearing area in the world, yet its productivity is very low. In order to boost productivity, superior clones of bamboo should be planted at cultivated wasteland, which will store more carbon in a durable form after harvesting. Bamboo planted on wasteland can be readily felled and transported, meeting demand and creating new jobs in the bamboo sector while also boosting the green economy in Northeastern India.

References

Aina, K.S., Adeniyi, I., Olayiwola, Y.B., Falemara, B.C. and Ademola, A.A., 2021. Bamboo as an engineering material in a green economy. Proceedings of the 7th Biennial Conference of Forests and Forest Products Society, Held At University of Uyo, Uyo, Nigeria. 26th - 30th April, 2021

Atanda, J., 2015. Environmental impacts of bamboo as a substitute constructional material in Nigeria. Case Studies in Construction Materials. 3, 33-39.

Basumatary, A., Middha, S.K., Usha, T. Brahma, B.K., Goyal, A.K., 2015. Bamboo, as Potential Sources of Food Security, Economic Prosperity and Ecological Security in North-East India: An Overview. Research in Plant Biology. 5 (2), 17-23.

Bhalla, S., Gupta, S., Sudhakar, P. and Suresh, R., 2012. Bamboo as green alternative to concrete and steel for modern structures. Journal of Environmental Research and Development. 3(2), 362-370.

Bitariho, R. and McNeilage, A. 2008. Population structure of montane bamboo and causes of its decline in echuya central forest reserve, south west Uganda. African Journal of Ecology. 46 (3), 325-332.

Cho, E., Um, Y., Kwan, Y.S. 2011. An expressed sequence tag analysis for the fast-growing shoots of *Bambusa edulis* murno. Journal of Plant Biology. 54 (6), 402.

Choudhary, M.L., 2008. One year of national bamboo mission in the states of NE Region, West Bengal, Orissa, Jharkhand and Bihar 2007– 2008. Cane and Bamboo Technology Centre Guwahati, Assam, India.

Chung, K.F., Yu, W.K. 2002. Mechanical properties of structural bamboo for bamboo scaffoldings. Engineering Structures. 24 (4), 429-442.

Das, D.K. and Chaturvedi, O.P. 2006. J. Bamboo Rattan, 5: 47-59.

Farrelly, D. 1984. The Book of Bamboo: A Comprehensive Guide to his Remarkable Plant, its Uses, and its History, Ames and Hudson, London, UK.

Food and Agriculture Organization of the United Nations, Global Forest Resource Assessment 2010, Food and Agriculture Organization of the United Nations, Rome, Italy, 2010.

Ghavami, K. 2007. Bamboo: Low cost and energy saving construction materials,Proc. International Conference on Modern Bamboo Structures, 28-30 October, Changsha, China, 5-21, (2007).

Gichohi, R.N. 2014. Factors Influencing the Use of Bamboo as AFlooring Construction Material: ACase of Garden City Project – Nairobi. Nairobi: University of Nairobi.

Holt, E. 2019. Bamboo, A Sustainability Powerhouse. Accessed on the 9 of February from http://www.inbar.int/bamboo-africa-strategic-resource-drive-continent%E2%80%99s greenhttp://www.ipsnews.net/2018/06/bamboo-sustainability-powerhouse/

https://bambooramagro.com/ethanol-from-bamboo-a-sustainable-path-to-biofuel-production/

https://www.businessstandard.com/article/companies/bamboo-to-ethanol-india-s-biofuel-industry-to-explode-into-a-15-bn-market-118040300588_1.html

https://www.inbar.int/global-programmes/ (Accessed November 18 2021).

INBAR, 2014. Bamboo: A strategic resource for countries to reduce the effects of climate change (Policy Synthesis Report). Beijing: International Network for Bamboo and Rattan.

INBAR, 2015. Bamboo for Africa: Astrategic resource to drive the continent's Green Economy. (Policy Synthesis Report). China, Beijing: International Network for Bamboo and Rattan. Retrieved from http://www.inbar.int/bamboo-africa-strategic-resource-drive-continent%E2%80%99s-green-economy

ISFR, 2021. https://fsi.nic.in/isfr-2021/chapter-8.pdf (Accessed May 18, 2024).

Johnson, S. 2008. Reinventing the Wheel, The Daily Princeton, Princeton, NJ, USA. http://www.dailyprincetonian.com/2008/04/24/20982/.

Kaur, P.J., Kardam, V. and Pant K.K. 2016. Characterization of commercially important Asian bamboo species. European Journal of wood and Wood Products, 74(1), 137–139.

Laroque, P. 2007. Design of a Low Cost Bamboo Footbridge. Massachusetts Institute of Technology economy http://hdl.handle.net/1721.1/39270

Li, Z.H. and Kobayashi, M. 2004. Plantation future of bamboo in China. Journal of Forestry Research. 15 (3), 233-242.

Liu, N.T., Wu, F.H., Tsay, H.S., Chang, W.C. and Lin, C.S. 2008. Establishment of a cDNA library from *Bambusa edulis* Murno in vitro-grown shoots," Plant Cell, Tissue and Organ Culture, 95 (1), 21.

Manandhar, R., Kim, J. and Kim, J. 2019. Environmental, social and economic sustainability of bamboo and bamboo-based construction materials in buildings. Journal of Asian Architecture and Building Engineering. 18 (2), 49-59.

Mohamed, A.H.J. 2003. Macro-Proliferation of *Gigantochloa liglata* seedlings for mass production of planting stock in its field performance. Journal of Bamboo and Rattan 2 (1), 13-21.

Musau, Z. 2016. Bamboo: Africa's untapped potential. Africa Renewal, 22.

Nath, A. J., Das, A. K. 2011. Curr. Sci. 100 (2), 229-233.

Nath, A.J., Lal, R. and Das, A.K. 2015. Managing Woody Bamboos for Carbon Farming and Carbon Trading Global Ecology and Conservation. 3, 654-663.

Nwoke, O.A. and Ugwuishiwu. B.O. 2011. Local Bamboo and Earth Construction Potentials for Provision of Affordable Structures in Nigeria. International Journal of Sustainable Construction Engineering and Technology. 2 (2), 17-31.

Onilude, M. A. 2004. Potentials of Bamboo as a raw material for the wood Industry in Nigeria. Paper presented at the seminar organized by Raw Materials Research and Development Council in collaboration with the Manufacturers Association of Nigeria at MAN House, Ikeja. 14 June, 2006.

Pearson, A.K., Pearson, O.P. and Gomez, I.A. 1994. Biology of the bamboo C*husquea culeou* (poaceae: Bambusoideae) in southern Argentina. Vegetatio. 111 (2), 93-126.

Ruiz-Sanchez, E., Sosa, V., Ortiz-Rodriguez, A.E. and Davidse, G. 2019. Historical biogeography of the herbaceous bamboo tribe olyreae (Bambusoideae: poaceae). Folia Geobotanica. 54 (3-4), 177-189.

Scheba, A., Blanchard, R. and Mayeki, S. 2017. Bamboo for green development? The opportunities and challenges of commercialising bamboo in South Africa. Accessed on the 9 of February from http://www.hsrc.ac.za/en/review/hsrc-review-jan-march-2018/bamboo-for-green-dev-sa

Scurlock, J.M.O., Dayton, D.C., Hames, B. 2000. Bamboo: An overlooked biomass resource, Biomass and Bioenergy. 19, 229-244.

Singh, M., 2008. Improvement of Bamboo productivity and marketing for Sustainable Livelihood. 11 – 17 April, 2008. New Delhi, India. Proceedings Forest Research Institute, Dehradun, India.

Tariyal, K.,Upadhyay, A., Tewari, S. and Melkania, U. 2013. Plant and soil carbon stock and carbon sequestration potential in four major bamboo species of North India, Journal of Advanced Laboratory Research in Biology. 4 (3), 90-98.

UNEP, 2011. Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication. www.unep.org/greeneconomy

UNEP, 2010. Driving a Green Economy through Public Finance and Fiscal Policy Reform. United Nations Environment Programme, Nairobi. Accessed on the 13th of February 2020 from http://www.unep.org/greeneconomy/Portals/30/docs/DrivingGreenEconomy.pdf United Nations, Department of Economic and Social Affairs, Population Division (2019). World Population Prospects 2019: Highlights (ST/ESA/SER.A/423).

Van, D.L., P., V.J., Brezet, H. 2009. Bamboo, a sustainable solution for Western Europe design cases, lcas and land-use, Technical Report, INBAR, Beijing, India.

Waite, M. 2009. Sustainable textiles: the role of bamboo and comparison of bamboo textile properties, Journal of Textile and Apparel, Technology and Management. 6, 1-21.

Wooldridge, M. 2012. Booming Bamboo: The next super-material? BBC News Magazine. 3rd April, 2012.

Wu, F.H., Liu, N.T. and Chou, S.J. 2009. Identification of repressed gene transcript accumulation in three albino mutants of *Bambusa edulis* munro analysis by cDNA microarray analysis. Journal of the Science of Food and Agriculture. 89 (13), 2308-2316.

Xiao, Y., Zhou, Q., Shan, B. 2010. Design and construction of modern bamboo bridges. Journal of Bridge Engineering. 15 (5), 533-541.

Yadava, P.S. and Thokchom, A. 2014. In Carbon Capture, Storage and Utilization (ed. Goel, M.), TERI Publishers, New Delhi.

Yeasmin, L., Ali, M.N., Gantait, S. and Chakraborty, S. 2015. Bamboo: an overview on its genetic diversity and characterization. 3 Biotech. 5 (1), 1-11.

Yu, Y. Jiang, Z., Fei, B., Wang, G. and Wang, H. 2011. An improved microtensile technique for mechanical characterization of short plant fibers: a case study on bamboo fibers. Journal of Materials Science. 46 (3), 739-746.

Zhao, M., Xiang, W., Peng, C. and Tian, D. 2009. Simulating agerelated changes in carbon storage and allocation in a Chinese fir plantation growing in southern China using the 3-PG model, For. Ecol. Manage. 257(6), 1520-1531. doi:10.1016/j.foreco. 2008.12.025.

Zhou, G.M. and Jiang, P.K., 2004. Density, storage andspatial distribution of carbon in *Phyllostachys pubescens* forest, Sci. Sil. Sin.. 40, 20-25.

Tewari, S., Negi, H. and Kaushal, R. 2019. Status of Bamboo in India. International Journal of Economic Plants. 6 (1), 30-39.

FRI, 2014. Proceeding of National Seminar "Bamboo Productivity in Forest and Non – Forest Areas" 30th to 31st January, 2014. Bamboo Technical Support Group. Indian Council of Forestry Research and Education. Forest Research Institute, Dehradun.

Kumar, B.M., Rajesh, G. and Sudheesh, K.G. 2005. Above ground biomass production and nutrient uptake of thorny bamboo [*Bambusa bambos* (L.) Voss] in the homegardens of Thrissur. Kerala Journal of Tropical Agriculture, 43, 51-56.