Inclusive and Sustainable Bamboo Cultivation, Harvesting, Treatment, and Processing for Construction in Fiji

Final Report

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This project is a consultancy for the Fiji Bamboo to Adapt and Mitigate Climate Change initiative.

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Abstract

This report presents comprehensive, field-based guidelines for the sustainable cultivation, harvesting, treatment, and processing of bamboo for construction in Fiji. It consolidates stakeholder consultations, national assessments, and pilot trials led by Pacific Ark, under the GGGI–Ministry of Forestry *Fiji Bamboo to Adapt to and Mitigate Climate Change* Project, to propose a strategy for establishing bamboo as a viable, climate-resilient construction material and renewable resource.

Bamboo offers Fiji a unique opportunity to simultaneously advance sustainable construction, rural livelihoods, and ecosystem restoration. Its strength, rapid growth, and renewability make it an effective substitute for imported timber and carbon-intensive materials such as concrete and steel. However, the sector's development remains constrained by fragmented propagation systems, absence of treatment infrastructure, and inconsistent management of wild bamboo clumps. This report integrates scientific research with local field evidence to outline a Fiji-specific framework for species selection, propagation, agroforestry integration, clump management, harvesting, treatment, and processing.

Key Findings

Species Selection and Adaptation: Fiji's bamboo landscape is dominated by *Bambusa vulgaris*, a hardy species suitable for small-scale and temporary structures. Trials conducted by Pacific Ark in the Savusavu and Valelawa regions confirm that *Bambusa balcooa* and *Dendrocalamus asper*, high-performance species with superior structural and treatment characteristics, can be successfully cultivated in Fiji's climatic and soil conditions.

Propagation and Agroforestry Systems: Bamboo integrates well into agroforestry and mixed-farming systems, contributing to soil stabilisation, water regulation, carbon sequestration, and diversified farm income. Vegetative propagation (culm, branch, and rhizome cuttings) remains the most practical and reliable method given the unpredictability of flowering and seed supply. The study recommends expanding regional nurseries and establishing a national bamboo gene bank to secure quality planting material and genetic diversity.

Clump Management and Harvesting: Proper clump management is essential for maintaining productivity and quality. The B.S.B.O.D. (Bent, Short, Broken, Old, Diseased) system is recommended as a simple clump health monitoring tool. Harvesting should target culms aged three to six years, determined through branch counting, colour, and resonance testing. Selective cutting maintains rhizome vitality and continuous regeneration. Field coding systems using colour marks are encouraged to track planting and harvesting cycles at community level.

Treatment and Preservation: Fiji's humid climate accelerates decay in untreated bamboo. Recommended methods for Fiji include Cold Immersion, Hot Immersion, Vertical Soak Diffusion (VSD), and Modified Boucherie, using eco-friendly chemicals such as boric acid and borax in compliance with ISO 22156:2021, which could extend its lifespan to over 20 years. Establishing shared regional treatment hubs in regions like Savusavu, Deuba, and Naitasiri is recommended to lower costs, standardise quality, and enable community-level participation.

Processing and Value Addition: Processing steps such as straightening, splitting, planing, and lamination adds commercial value and consistency. Small-scale processing cooperatives can enhance employment opportunities while supporting Fiji's emerging bamboo and green construction market.

Pacific Ark Field Validation: Pilot projects across Savusavu and Vanua Levu demonstrates the full bamboo construction value chain, from propagation and harvesting to treatment and structural application, on a small scale. Pacific Ark's field trials demonstrated that boron-based VSD and Hot Immersion methods significantly enhance bamboo's durability and is economically viable, with treatment costs averaging FJD $40–60 per 3.5 m pole. Development of integrated bamboo agroforestry systems combining bamboo with crops such as cocoa, mahogany, small fruit trees, and bananas, and the construction of Fiji's first bamboo market store at Da Roko Settlement and a bamboo playground at Urata Primary School, demonstrate feasibility with Fiji's first locally verified performance data and practical cost benchmarks for bamboo as a construction material.

Despite promising progress, challenges persist such as limited propagation material and nurseries, lack of standardised treatment and certification frameworks, fragmented market linkages, low public awareness, and land tenure complexities under the *Mataqali* system (communal land ownership). However, Fiji's abundant bamboo resources, supportive policy frameworks, and growing collaboration between ministries, research institutions, private innovators, and communities, present strong foundations for sectoral growth.

Key recommendations

- Prioritise national propagation and treatment programs focused on *Bambusa balcooa* and *Dendrocalamus asper*
- Establish bamboo gene banks and regional nurseries for species conservation and quality planting stock
- Develop modular treatment and processing hubs in high-production regions to standardise quality
- Adopt formalised harvesting and clump management protocols and codes through training and certification
- Integrate bamboo into national building codes and climate adaptation policies as a certified sustainable material

With strategic investment, training, and policy alignment, bamboo can become one of Fiji's most valuable renewable resources, supporting low-carbon housing, land restoration, and inclusive green growth. The findings presented here provide a technical foundation and actionable roadmap for scaling bamboo-based production and construction, enabling Fiji's transition toward a circular, climate-resilient, and community-driven economy.

Acknowledgements

This report was developed under the Global Green Growth Institute (GGGI) engagement with the Ministry of Forestry and the Ministry of Public Works and Housing, Fiji. The work contributes to advancing a sustainable and inclusive bamboo sector that supports Fiji's national goals for climate-resilient housing, reforestation, and green growth.

Sincere appreciation is extended to the Ministry of Forestry for its close collaboration and technical input throughout the project, and to the Ministry of Public Works and Housing for its engagement in exploring bamboo's potential for sustainable construction in Fiji.

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Vinaka vakalevu to everyone who has contributed — directly or indirectly — to advancing the vision of a sustainable and regenerative bamboo industry for Fiji and the wider Pacific.

Table of Contents

List of Figures

List of Tables

Acronyms and Abbreviations

CATD – Centre of Appropriate Technology and Development

CIC – Construction Industry Council

FBA – Fiji Bamboo Association

FNU – Fiji National University

INBAR – International Bamboo and Rattan Organisation

MoF – Ministry of Forestry

NbS – Nature-based Solutions

NDCs – Nationally Determined Contributions

PICs – Pacific Island Countries

SPC – The Pacific Community

USP – University of South Pacific

1 Introduction

There are over 1600 species of bamboo, belonging to about 121 genera, of which over 14% (232 species) are found outside their natural range of distribution. Globally over 14mha of the earth's surface is covered by bamboo, 80% of which occurs in Asia[1]. Bamboo grows widely from lowlands to about 4,000 meters above sea level in tropical, subtropical, and temperate regions of all continents in the world except Antarctica and Europe. Most bamboo species are found in the Asia-Pacific (> 937 species) followed by South America (>258 species) while Africa has the world's lowest number of bamboo species (5 species)[2].

Bamboo falls in the grass family Poaceae with a single sub-family Bambusoideae. Bambusoideae includes the Bambuseae tribe which is characterised by woody bamboo and the Olyreae tribe which is characterised by herbaceous bamboo. The flowering period of woody bamboos can range from 7 to 120 years, and they frequently do so in gregarious events resulting in mass seed production followed by the death of the parent plants. Since flowering is typically a rare phenomenon in woody bamboos most plants are encountered in their vegetative state making it challenging for a non-specialist to identify the species[3].

Bamboo is the world's fastest growing perennial plant that matures in as little as three years, and an average of five to seven years. Bamboo is well recognised for its versatility serving a multitude of functions across various sectors. Its light weight, strength and flexibility make it a viable substitute for traditional timber in the furniture and construction industries. Bamboo is valued in the pulp and paper industry owing to its fibre length which is greater than all non-wood fibres except cotton. It is also used as fuel, food and medicine, and plays an important role in soil conservation and carbon sequestration. In addition, near-source pre-processing where farmers split the culms into separate parts that are channelled into separate value chains at the harvesting site enhances farmer income ensuring greater efficiency in meeting poverty alleviation and pro-poor development goals[4].

Despite significant potential in generating viable livelihoods for communities, efforts to mainstream bamboo into Fiji's forestry sector have met with limited success. This is due to a combination of factors such as limited knowledge and awareness, lack of value chains, and inadequate policy and institutional framework. Unlike countries in Asia and Latin America where bamboo has historically served as a primary construction material, Fiji lacks a bamboo construction culture. Consequently, there is limited expertise in bamboo architecture, joinery, and preservation techniques. This cultural gap has hindered widespread adoption of bamboo in the construction sector, despite its potential for low-cost sustainable housing.

Realising the untapped potential of bamboo calls for not only enhancing local production, developing sustainable harvesting guidelines and value chains, but also raising awareness, capacity building, and integration with traditional knowledge systems. Resilient local production systems supported by well-defined sustainable harvesting practices would ensure a consistent supply of high-quality bamboo for meeting raw material requirements, while meeting conservation goals. Strengthening value chains would stimulate local economies by creating employment opportunities while targeted awareness campaigns would shift public perception of bamboo from a 'poor man's timber' to a sustainable, resilient, eco-friendly and climate-resilient construction material. Capacity building would equip local builders and engineers with the necessary skills and techniques to design and construct safe, durable and high-quality bamboo structures. Integrating traditional Fijian building knowledge with modern codes and standards would enhance cultural relevance, community ownership, and climate adaptability. Such a multi-faceted approach would holistically address existing limitations while positioning bamboo as the cornerstone of sustainable construction in Fiji.

While the primary focus of this consultancy is on bamboo cultivation, harvesting, treatment, and processing for construction, the study also acknowledges the presence of two rattan (Calamus) species in Fiji — *Calamus vitiensis* (native) and *Calamus erinaceus* (introduced from northern Australia). Although rattan currently has no established construction use, its presence contributes to understanding the evolution of plant-based material resources within Fiji's forestry and INBAR membership context.

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[1] Yeasmin et al., 2015

[2] Das et al., 2008

[3] Kelchner and Bamboo Phylogeny Group, 2013

[4] Emamverdian et al., 2020

2 Aims and Objectives

The aim of this consultancy is to develop a comprehensive research report and set of guidelines outlining the most inclusive and sustainable methods for cultivating, harvesting, treating, and processing bamboo for construction purposes in Fiji.

The primary objectives of the consultancy are to:

1. Identify current practices in Fiji for cultivating, harvesting, treating, and processing bamboo (for use in construction)
2. Identify costs (including time spent) related to cultivating, harvesting, treating, and processing bamboo (for use in construction)
3. Assess the sustainability of current practices used in Fiji
4. Identify the best global practices in cultivating, harvesting, treating, and processing bamboo (for use in construction)
5. Assess the applicability of these best practices to the local Fiji context
6. Identify who currently cultivates, harvests, treats and processes bamboo in Fiji; develop guidelines for inclusive and sustainable Fiji bamboo production (from cultivating to processing)
7. Develop guidelines for inclusive and sustainable Fiji bamboo production (from cultivating to processing).
8. Identify opportunities for community engagement and economic empowerment around bamboo production in Fiji

This final report presents consolidated findings from literature review, field assessments, and stakeholder consultations. It provides an evidence-based framework to guide sustainable bamboo production in Fiji, linking ecological, technical and social dimensions of the value chain.

3 Bamboo as a Sustainable and Climate Resilient Material

In Fiji, about 90% of the population lives in coastal areas and is highly dependent on natural resources, making them especially susceptible to the negative impacts of climate change such as sea level rise, biodiversity loss, warming oceans, and increased frequency of natural disasters like cyclones and flooding[5]. This is further exacerbated due to land degradation, a major issue in Pacific Island Countries (PICs) like Fiji due to deforestation, unsustainable farming practices, excessive grazing, population growth, extractive activities like mining, and land ownership challenges[6]. These human-induced stressors pose serious risks to environmental sustainability and food security in growing populations of the PICs due to impacts on soil health, depleting organic carbon and plant nutrients, leading to declining crop yields[7]. Furthermore, 70% of the population in the PICs is dependent on fish as a source of animal protein[8]. However, this traditional source of protein is under major threat due to climate change, causing rising sea levels, saltwater intrusion into agricultural land, and increasingly frequent cyclones, and other anthropogenic stressors like overfishing and pollution, leading to chronic hunger and malnutrition[9].

Addressing these complex socio-economic and environmental challenges calls for a viable, sustainable low-cost strategy. Bamboo as a nature-based solution holds considerable potential to enhance the resilience of local communities. Found extensively across tropical and subtropical regions of the Global South, bamboo is a rapidly regenerating and highly sustainable natural resource[10]. Research highlights bamboo's significant role in carbon

[5] Charan et al., 2018; Regional Pacific NDC Hub, 2022
[6] Wairiu, 2017
[7] Wairiu, 2017
[8] WFP & SPC, 2018
[9] WFP & SPC, 2018
[10] UNOSSC & INBAR, 2017

sequestration, biodiversity conservation, and soil and water health, demonstrating its potential as a cost-effective scalable solution for climate action and sustainable livelihoods[11].

As coastal communities face intensified storms, flooding, and erosion, bamboo's deep root systems can stabilise soil and prevent erosion on riverbanks, slopes, and degraded coastlines. Bamboo can also serve as an effective windbreak, bending without breaking during cyclones, and protecting crops and homes from strong coastal winds[12]. Bamboo's lightweight, high natural strength, and flexibility also make it an ideal construction material for disaster-resilient infrastructure, offering a low-cost, sustainable alternative for vulnerable communities[13]. Bamboo's low energy footprint compared to conventional building materials also positions it as a sustainable alternative for green infrastructure and climate-smart development[14].

Bamboo supports sustainable livelihoods by offering fast-growing, harvestable culms within a few years, creating steady income streams and financial resilience for smallholder farmers. It thrives on marginal lands and can be processed locally, making it widely accessible. Bamboo further contributes to ecosystem resilience by rapidly regenerating after extreme weather events. Bamboo's resilience to intense cyclones further highlights its value for coastal communities, as it recovers quickly from damage, unlike trees that may be uprooted or snapped during severe storms[15]. Bamboo can rehabilitate degraded lands by improving soil quality and boosting the productivity of food and commercial crops[16]. Additionally, bamboo contributes to food security by providing protein-rich edible shoots for human consumption and leaves for livestock and fish feed[17]. By offering an annual supply of woody biomass, bamboo can reduce pressure on other forest resources like native trees (e.g. Vesi (*Intsia bijuga*)) and could reduce reliance on imported or environmentally harmful materials, helping to curb deforestation and contributing to climate adaptation and mitigation and biodiversity conservation[18].

Overall, the use of bamboo for construction in Fiji directly supports Fiji's updated Nationally Determined Contributions (NDCs), such as the commitments to strengthen climate resilience through cost-effective, nature-based infrastructure, conserving biodiversity to enable long-term provision of ecosystem services, reducing carbon emissions, and adopting climate smart agriculture practices[19]. It could also support Fiji's National Disaster Risk Reduction Policy 2018-2030 which includes using "Build Back Better" principles for reconstruction after disasters to ensure that infrastructure is restored with improvements to be resilient to future disasters[20].

4 Methodology

The research methodology for this consultancy adopted a mixed-methods, participatory, and context-specific approach to ensure a comprehensive mapping of Fiji's bamboo construction value chain and assessment of local knowledge and skills gaps. The study was conducted in three interlinked phases;

1. Literature review and desktop research;
2. Field assessment and stakeholder engagement;
3. Results synthesis and guideline & recommendations development

Together, these methods provided a holistic understanding of the ecological, social and economic dimensions of Fiji's bamboo sector with a focus on community engagement and capacity building.

[11] Dutta et al., 2025
[12] Lou et al., 2010; UNOSSC & INBAR, 2017
[13] Lou et al., 2010
[14] Lou et al., 2010
[15] Thomson et al., 2021
[16] Lou et al., 2010
[17] Lou et al., 2010
[18] Lou et al., 2010; Elkharboutly & Wilkinson, 2022
[19] UNFCCC, 2020
[20] UNDRR, 2025

4.1 Literature review and desktop research

In the first phase, a comprehensive desk review and literature analysis were undertaken to assess academic research, policy frameworks, and technical reports related to bamboo production, utilisation, and construction applications in Fiji and other comparable tropical regions. The review examined sustainable cultivation methods, harvesting cycles, eco-friendly treatment technologies, and small-scale processing models, drawing lessons from Asia, Africa, and Latin America.

Global and regional best practices were identified in countries such as Indonesia, India, Thailand, China, and Colombia, focusing on how bamboo production systems were developed into viable, community-based industries. Insights were used to outline a preliminary process map of Fiji's bamboo production system, from propagation to construction, identifying key actors, enabling institutions, and existing technical or policy gaps.

At the national level, relevant policy and planning frameworks were reviewed, including the Forestry Bill (2016), Forest Harvesting Code of Practice (2013), Low Emission Development Strategy (LEDS), National Adaptation Plan (NAP), and the Climate Change Act (2021). These documents were analysed to determine how bamboo can be positioned as a climate-resilient, nature-based solution within Fiji's forestry and construction sectors.

Existing initiatives by the Ministry of Forestry, (TVET) and Higher Education (HE) institutions, the Fiji Bamboo Association, NGOs, and donor partners were also reviewed to map ongoing projects, training efforts, and value-chain linkages. Findings from this phase provided the conceptual foundation for the field assessment and guided the identification of priority areas for data collection.

4.2 Field assessment and stakeholder engagement

The second phase consisted of field assessments and extensive stakeholder engagement to document current practices and validate findings from the desk review. Purposive sampling was used to select participants representing the full bamboo production spectrum, including farmers, community groups, artisans, builders, processors, educators, NGOs, and government officials.

Field visits, semi-structured interviews, participatory workshops, and both quantitative and qualitative surveys were conducted to understand the technical methods, skill levels, institutional support, and socio-economic drivers shaping bamboo production in Fiji. These engagements also examined the inclusivity of bamboo-based livelihoods, such as gender participation, youth involvement, and community ownership.

Stakeholder consultations were held across Viti Levu and Vanua Levu, capturing perspectives from bamboo-growing regions and processing hubs. Key informants included farmers and landowners, bamboo harvesters, construction practitioners, TVET/HE trainers, and representatives from relevant ministries and local organisations.

The list of interviewees, key objectives, and learnings from each consultation is presented in Table 1, while Figures 4-1 to 4-6 show selected interviewees and field locations.

Organisation / Stakeholder name	Individual(s) Interviewed	Meeting day	Objective and Learnings
Centre of Appropriate Technology and Development (CATD)	Opeti Ritova, Training Manager	18 Jun 2025	• Institutional capacity and interest in integrating bamboo into vocational education and training
Fiji Bamboo Association (FBA)	Mark Borg - Trustee	19 Jun 2025	• FBA's structure, challenges, and role in Fiji's bamboo sector
Farmer, bamboo enthusiast, local coordinator (Buiduna Village, Verata Wailevu, Tailevu)	Lala Bukarau - Bamboo Enthusiast	20 June 2025	• Practices around bamboo production by local farmers • Community-level entry points for bamboo propagation and conservation • Need for basic training and accessible treatment techniques • Barriers to engagement for landowners without commercial intent but strong ecological or cultural motivations • Visionary roadmap for how bamboo could support sustainable livelihoods, decentralised processing, and native species preservation
Farmer, bamboo enthusiast, local coordinator (Bach, Western Division)	Wilmo "Bill" Nimbalka Bamboo Enthusiast	Jun 2025	
Construction Industry Council (CIC)	Jon Orton - Chair	30 Jun 2025	• Standards and certification pathways and current regulatory, institutional, and technical environment • Identify the workforce capacity, training needs, and professional acceptance for bamboo.
Ministry of Forestry (MoF)	Alivereti N Naikatini Deputy Conservator Forests-Research & Development & Tevita Kunadei R&D Director	15 Jul 2025	• MoF's role in Fiji's bamboo sector; Past and present bamboo projects by MoF; Existing bamboo standards & codes, skills & capacity, infrastructure & processing • MoF's strategic direction
Fiji Pine Ltd.	Akuila Driso - Plant Manager, Noa Vakacegu - Lands Manager, & Rakuita Vakalalabure - Executive Chair	18 Jul 2025	• Pine industry in Fiji and its alignment with GGGI bamboo research objectives • Value chain & construction relevance; Community Engagement, Inclusion & Livelihoods; Potential Collaboration & Cross-Learning; Treatment & Regulatory Frameworks
Fiji National University (FNU), Department of Forestry	Dr Shipra Shah Associate Professor	01 Aug 2025	• Role of bamboo in Fiji's forestry and construction industry • Gaps in policies and skills & training for use of bamboo as a valuable forestry product

Pacific Ark	Arno Roos - Director	03 Aug 2025	• Role of private organisation with bamboo expertise in bamboo value chain • Best practices for bamboo production, treatment and processing • Community engagement and bamboo construction projects
Sunnyville Bamboo	Sukulu Soko - Director	05 Aug 2025	• Practices around bamboo production and value chain by local bamboo small-business owner • Collaboration with MoF for community engagement and training programs
Deadline Construction	Joseva Naqota - Director	06 Aug 2025	• Interest of local small construction business in bamboo-based construction and gap in skills & training
University of the Sunshine Coast, Pacific agroforestry and botany (Author of Bamboo Compendium for the South Pacific / Bamboo Species List Fiji (2021))	Dr Lex Thomson Associate Professor	20 Aug 2025	• Discuss opportunities to strengthen Fiji's bamboo industry through improved species knowledge, propagation, agroforestry integration, and policy alignment in support of the GGGI research reports
Kontiki Bamboo, Uganda	Dr Koojo Charles - Director	27 Aug 2025	• Understand journey of Kontiki Bamboo in setting up value chain and capacity building of local communities in Uganda • Learning lessons and recommendations for strategic roadmap for Fiji's value chain and capacity building

Table 1: Interviewees and key learning objectives

Figure 4-1: Wilmo "Bill" Nimbalka

Figure 4-2: Fiji Pine Ltd

Figure 4-3: Lala Bukarau "The Bamboo lady"

Figure 4-4: CATD

Figure 4-5: Navala Village

Figure 4-6: Nakanatagi Village

4.3 Community study: Navala Village

The village of Navala was identified to carry out a community study. Navala was chosen as this village still builds mostly traditional houses (*bures*) in Fiji which incorporate bamboo in some aspects of traditional construction practices. Participatory methods were used to understand the methods of construction of the *bures* in Navala and uses of bamboo for this construction. The community constructs and repairs the *bures* annually. The field researcher spent two days living in the village and participated in this together with the community, learning about construction techniques of their *bures* and uses of bamboo in their construction through observations, hands-on trials and semi-structured interviews and *talanoa*[21] as seen in Figures 4-7 to 4-10.

[21] Talanoa is a traditional Fijian way to facilitate dialogue that is inclusive, participatory, and transparent

Figure 4-7: Traditional bures in Navala village

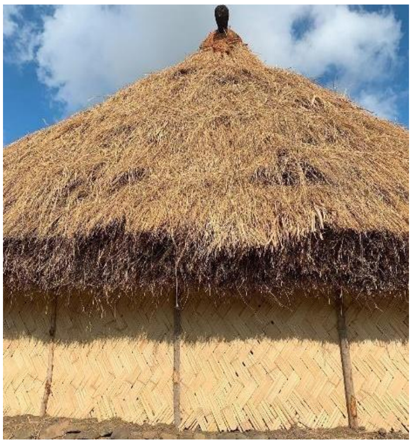

Figure 4-8: Use of bamboo for weaving walls in bure

Figure 4-9: Use of bamboo for roof support trusses and thatching support bracing in bure

Figure 4-10: 15-Year-old Bure – sign of powder post Beatles and fungi

5 Bamboo Sector in Fiji: History and Current Status

5.1 Historical uses and Introductions

Historically, bamboo in Fiji served limited yet practical roles in daily life, for rafts, fishing traps, and parts of construction[22]. The first recorded introduction of an exotic species occurred in the early 1860s, when a German botanist Jacob Storck brought *Bambusa vulgaris* (*bitu ni vavalagi*) to the Nausori highlands. It was distributed to villages along the river to assist with transporting produce downstream for sale at coastal markets. This species quickly became naturalised and remains the most common bamboo across Fiji today.

Bamboo research and development in Fiji started during the late 1970s, when a project was initiated with the support of the Government of China and the United Nations Development Program (UNDP) in the villages of Vunidawa and Somosomo. The project aimed at promoting bamboo as a source of rural livelihoods by training youth in bamboo weaving and furniture making. Though limited success was achieved in technology transfer, the initiative failed owing to inadequate project design and the vulnerability of local bamboo species to pest infestations[23].

Another notable example is Bitukau Enterprises which was started in Vusuya village, Kuku, Nausori by a local entrepreneur. The enterprise mostly utilised *B. vulgaris* which was widely available on community owned land. Though landowners did not receive any remuneration for the resource, it was hoped that once the enterprise

[22] Kasanawaqa et al., 2024

[23] FAO, 2008

started generating profits, payments would start pouring in. The enterprise received limited support from the Governments of Fiji and Indonesia, and The Pacific Community (SPC). In 2006 expert trainers were brought in from Indonesia to train local youths in using bamboo for weaving and furniture making. The products were introduced in the domestic market where they generated some interest from potential buyers but failed to meet quality standards[24].

5.2 Programmes, Institutions, and Lessons Learnt

Over the past 25 years, the Ministry of Forestry (MoF) and the Fiji Bamboo Association (FBA) made further efforts to trial and introduce new species for construction and craft use. Various clumps of *Dendrocalamus asper*, *Gigantochloa apus*, *Dendrocalamus giganteus*, and *Bambusa tuldoides* were imported through government and development programs, and research plots were established in locations such as Naduruloulou, (1950's) Colo-i-Suva and Deuba (2001).

Two major national attempts to institutionalise bamboo can be identified[25]:

1. **Forestry Research Plot (P25):** A trial plot was established by the Ministry of Forestry (MoF) on leased land to cultivate multiple species and supply cuttings for propagation. However, Forestry was unable to maintain lease payments, and the land reverted to the landowners. The collection was subsequently destroyed by developers, though a few species were salvaged by individuals such as S. Soko before its loss[26].

2. **Bamboo Seed Bank & Nursery Initiative:** A nursery and seed bank was initiated but collapsed due to poor management, land access issues, and limited institutional follow-through. The lack of long-term commitment and resources meant the initiative never matured into a functioning national resource[27].

These setbacks highlight a recurring pattern of enthusiasm without sustained commitment. Forestry's limited resources leading to limited prioritisation of bamboo development is a central constraint. Despite repeated introductions and pilot projects, bamboo did not transition into a mainstream program within government forestry work.

The Bamboo Association (FBA) was established in the early 1990's but it became inactive and eventually dissolved. In 2019, the Fiji Bamboo Association was re-established with a trustee board and a five-year strategy (*Fiji Bamboo Association Strategy 2020–2025*). The strategy set out goals for propagation, awareness, and policy support. However, in the absence of a dedicated secretariat, funding, a global epidemic Covid and membership mobilisation, the strategy has remained largely unimplemented. The Association's outreach (newsletters, online presence, and public engagement) has also been minimal, limiting its influence to a small circle of trustees. A new strategy is currently in the making for the period 2025-2030

In 2020, Fiji formally joined the International Bamboo and Rattan Organisation (INBAR), paying annual membership fees through the Ministry of Forestry. This provided Fiji with access to international expertise and standards but has so far yielded little direct support on the ground due to limited government coordination.

Despite these challenges, bamboo has recently re-emerged as a material of interest due to its climate resilience, fast growth, and versatility for sustainable construction. Renewed efforts through the MoF, GGGI, and private

[24] FAO, 2008

[25] MoF, personal communication, Jul 2025

[26] S.Soko, personal communication, June 2025

[27] M. Borg, personal communication, 19 June 2025

sector champions now present an opportunity to build upon past lessons and avoid the failures of earlier attempts.

The following is an overall timeline of bamboo in Fiji:

- **Pre-colonial era** – Indigenous *Schizostachyum glaucifolium* (*bitu dina/bitu kau*) used for rafts (*bilibili*), fishing traps, house walling, and ceremonial cooking.
- **Early 1860s** – *Bambusa vulgaris* (*bitu ni vavalagi*) introduced by a German botanist in the Nausori highlands to support river transport of produce.
- **1970s–1990s** – Small training and research projects trial exotic species; additional introductions from Australia and Asia.
- **1990s–2000s** – Forestry establishes research plots (e.g., Colo-i-Suva, Deuba, P25 plot) with imported species. P25 later abandoned due to lease non-payment, with plantings destroyed.
- **2000s** – Attempts at a bamboo seed bank and nursery fail due to land disputes and lack of institutional support. Collaboration between local bamboo champions and the MoF in conducting community awareness, shows and expos.
- **2019** – Fiji Bamboo Association re-established with a five-year strategy (2020–2025) but limited activity due to lack of funding and secretariat.
- **2020** – Fiji joins the International Bamboo and Rattan Organisation (INBAR) via Ministry of Forestry.
- **2024 - (present)** – Renewed interest through GGGI, private champions, and Ministry of Forestry initiatives focusing on bamboo as a sustainable, climate-resilient construction material.

5.3 Present Distribution, Uses and Potential

Fiji currently hosts approximately 22 bamboo species, one native species, *Schizostachyum glaucifolium* (locally known as Bitu dina), one naturalised species, *Bambusa vulgaris* (locally known as Bitu vavalagi), and a wide range of introduced species. Species records differ across MoF, FBA, and academic sources, highlighting the need for a verified national inventory. The complete species list and technical specifications are provided in Appendix A.

In addition to bamboo, Fiji also supports two known rattan species — *Calamus vitiensis* and *Calamus erinaceus*. The former is native but limited to upland forests, mainly in Tavueni, where it prefers well-drained soils and shaded conditions, while the latter, introduced from northern Australia, has shown better adaptability to intermediate zones. Neither species is currently cultivated or utilised commercially, yet both are part of Fiji's broader grass and cane family resources relevant to future sustainable material assessments.

Bamboo is most abundant in the high rainfall zones of Viti Levu and Vanua Levu, particularly along river valleys, wetlands, and coastal plains. It thrives in well drained alluvial soils and intermediate forest zones, with smaller plantings scattered across drier islands where communities have introduced it manually.

Current uses remain informal and small scale:

- **Construction**: woven walls, rafters and roof bracing in traditional bure housing[28]. Traditional bure structures (Figure 5-1) now represent ~2 % of housing[29], but retain remarkable cyclone resilience[30].

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[28] Elkharboutly & Wilkinson, 2022; Roös, 2025

[29] Government of Fiji, 2016

[30] Miyaji et al., 2017; Elkharboutly & Wilkinson,2022

Figure 5-1: Navala Village, Central Viti Levu: one of the few remaining examples of traditional bure construction in Fiji

- **Farming:** livestock & garden fencing (Figure 5-2), Yam and longbean trestles, tool handles or poles[31]

Figure 5-2: Students building fencing models at FNU

[31] W. Nimbalka, personal communication, June 2025

- **Culture & Handicraft:** Ceremonial weaving and craft applications (Figure 5-3)[32]

Figure 5-3: Small products and handicrafts made with bamboo by community Qilai village displayed at World Bamboo Day 2024

Despite its abundance and versatility, bamboo remains underutilised. Several factors contribute to this underdevelopment, including limited technical knowledge, the absence of treatment facilities, weak market linkages, and a lack of product standards and financing mechanisms. Inadequate policy support and poor institutional coordination have further discouraged long-term investment. For example, earlier public programmes such as the P25 research plot and the Bamboo Seed Bank and Nursery Initiative collapsed due to weak planning, insufficient technical expertise, and limited follow-up support. Likewise, private ventures such as Bitukau Enterprises struggled to sustain operations in the absence of formal guidelines, incentives, or market frameworks.

These institutional gaps not only hindered government-led initiatives but also discouraged private-sector engagement. Without clear standards, fiscal incentives, and certification systems, investors and construction companies perceive bamboo as a high-risk material. As a result, few private enterprises, builders, or financiers have entered the value chain, leaving the sector largely informal and under-capitalised.

Overcoming these barriers is essential to activate market confidence and develop Fiji's bamboo industry. This report therefore analyses cultivation, harvesting, treatment, and processing systems to identify and recommend contextually relevant approaches that can increase bamboo's use in construction—ensuring the transition is inclusive, sustainable, and commercially scalable.

[32] S.Soko, W. Nimbalka, personal communication, June 2025

6 Mapping Fiji's Bamboo Production System

This section presents the consolidated findings of the study, outlining key insights on bamboo growth and ecology, species selection for consumption, cultivation and harvesting practices, and treatment and processing methods. It also integrates lessons from international best practices to contextualise opportunities and challenges for developing a sustainable bamboo production system in Fiji

6.1 Bamboo Growth and Ecology

Bamboo stands function as dynamic ecological systems, with their own cycles of growth, regeneration, and nutrient exchange. Unlike timber trees that grow for decades before regeneration, bamboo culms emerge, mature, die, and are replaced annually through a clonal cycle driven by underground rhizomes. These cycles sustain productivity while simultaneously delivering ecological benefits that are particularly relevant to Fiji's island environments. The following section details bamboo growth and ecology.

6.1.1 Growth (Flowering) Patterns

Bamboo can be classified based on their flowering and root systems into various types. Based on the flowering system they are classified into annual, sporadic or irregular, and synchronous or gregarious:

Annual flowering: Annual flowering bamboos including *Indocalamus wightianus*, *Ochlandra scriptoria*, and *O. stridula* are iteroparous, flowering and fruiting multiple times in their life cycle. These bamboo species grow to maturity and then produce seeds every year. However, some bamboos such as *Pseudosasa amabilis* have an extended flowering period of 15 years and are easily mistaken for an annual flowering species[33].

Sporadic or irregular flowering: This category includes species such as *Bambusa emeiensis*, *Chimonobambusa* sp., *Dendrocalamus latiflorus*, and *Dendrocalamus hamiltonii*. Sporadic or irregular flowering implies that only a few culms or a small area in the population produces flowers. Sporadic flowering often occurs in species that are cultivated or intensively managed.

Synchronous or gregarious flowering: While most mast flowering plant species are iteroparous, bamboo is an exception. Most mast flowering bamboo species including *Bambusa bambos*, *Bambusa arnhemica*, *Bambusa tulda*, *Dendrocalamus strictus*, *Dendrocalamus longispathus*, and *Thamnocalamus spathiflora* are smelparous. Semelparous bamboos have an extended clonal growth phase that may even extend over 100 years followed by only one flowering episode before death[34]. Synchronous flowering therefore is a relatively rare phenomenon which occurs when more than 50% of individuals in a population flower and die together.

6.1.2 Bamboo ecology

Based on the root system, there are two major groupings of bamboo, sympodial (clumping) and monopodial (running). One analogy to understand how bamboo grows is to think of it as a family made up of a combination of smaller 'family groups'. Each of these 'family groups' is made up of 4 generations: a baby, a mother, a grandmother and a great-grandmother. Each generation represents a new year of life in the clump. Most bamboo mature in 3 to 5 years, and mature culms no longer produce any shoots. For best practice, the culms to harvest are the fourth-generation culms, or the "great-grandmother" culms, at 4 years of age. We count 4 years as 4 generations based on the amount of annual rainy seasons. In Fiji, there is one rainy season per year, which means that here one year is a generation in the life cycle of a bamboo culm (this could differ from the west to the east

[33] Zheng et al., 2020

[34] Mulatu et al., 2024

of Fiji's islands). Table 2 shows the different root systems while Table 3 lists the bamboo genera under different growth forms.

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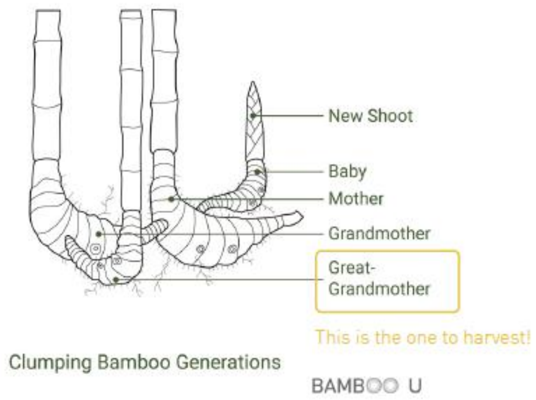
<tr>
<td>

Figure 6-1: Sympodial roots (Source: BambooU)</td>
<td>A. Sympodial (one mother with many offspring)

The underground stem of a sympodial bamboo is called a rhizome and is made of a network of what look like inter-connected umbrella handles (other Rhizomes). Buds (called rhizome buds) sprout off these rhizomes, turn into shoots when they emerge from the soil and then into culms as they extend into the canopy. The distance between mother and offspring is small, and thus sympodial bamboos grow in clumps. Sympodial bamboo is the dominant bamboos in the tropics.</td>
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Figure 6-2: Monopodial roots (Source: BambooU)</td>
<td>B. Monopodial (one mother with one offspring)

Monopodial bamboos are known as running bamboo, because their rhizomes extend far from the origin of the bamboo plant (mother). Buds emerge from nodes on the rhizomes and can either emerge from the soil as a bamboo shoot or turn into another rhizome. Monopodial bamboos are infrequent in the tropics and are not currently known to be found in Fiji.</td>
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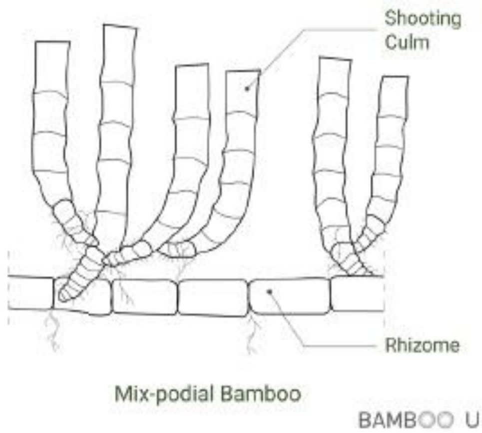
<td>

Figure 6-3: Amphipodial roots (Source: BambooU)</td>
<td>C. Amphipodial

Amphipodial bamboo has a combination of both the growth patterns as in the Sympodial and Monopodial bamboo.</td>
</tr>
</table>

Table 2: Different bamboo root systems

Clumping type (Sympodial)	Running type (Monopodial)
Arundinaria	*Chimonobambusa*
Bambusa	*Indocalamus*
Chusquea	*Phyllostachys*
Dendrocalamus	*Pleioblastus*
Drepanostachyum	*Pseudosasa*
Fargesia	*Sasa*
Himalayacalamus	*Semiarundinaria*
Otatea	*Shibatea*
Thamocalamus	*Sinobambusa*

Table 3: Bamboo genera under different growth forms (Source: Diver, 2001)

6.1.3 Elements of a bamboo clump

A bamboo clump functions as a self-renewing system composed of interconnected culms and rhizomes at different stages of maturity. Each clump may contain hundreds of culms if unmanaged, but a well-maintained clump typically sustains 80–120 culms of various age classes. Understanding the structure of a clump is essential for determining optimal harvesting and regeneration cycles.

Figure 6-4 shows the key components of a bamboo clump:

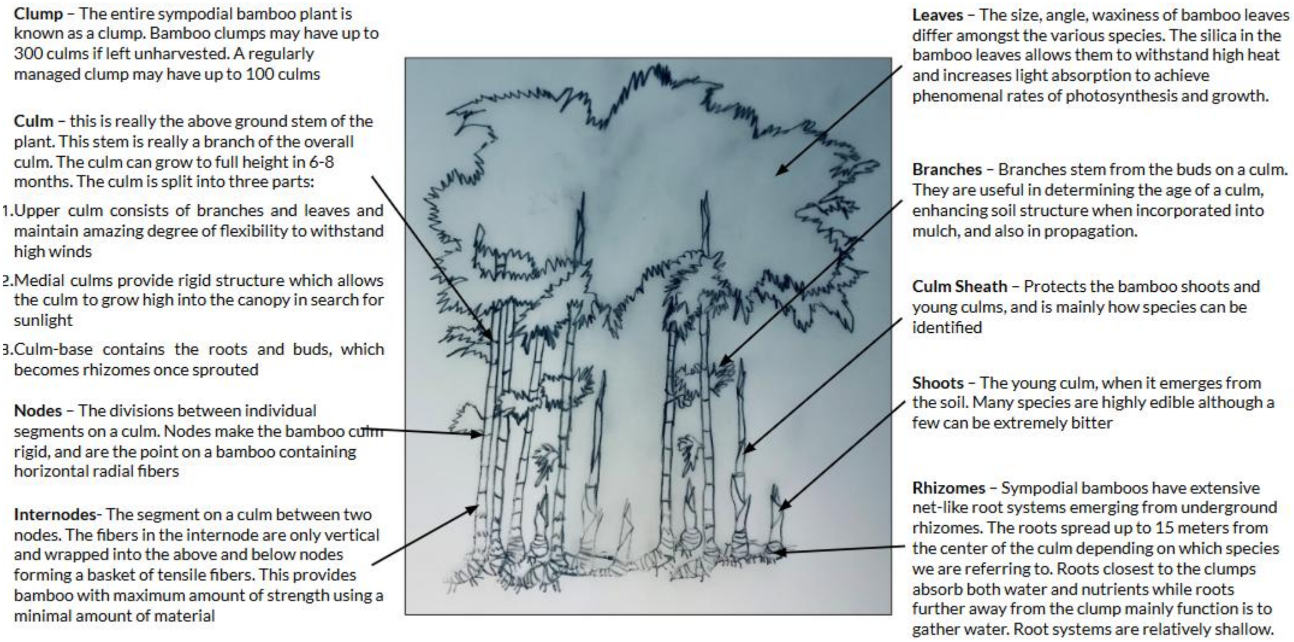


Figure 6-4: Anatomy of a bamboo clump showing key components (Pacific Ark field documentation, 2025)

6.1.4 Growth Phases and Environmental Conditions

Unlike trees, bamboo culms emerge pre-formed from underground rhizomes and grow to their final height in a matter of months. Growth is rapid, highly efficient, and largely predetermined, making bamboo one of the fastest-growing renewable resources. The main phases can be described as follows:

Main growth phases of a bamboo culm can be seen in Figure 6-5.

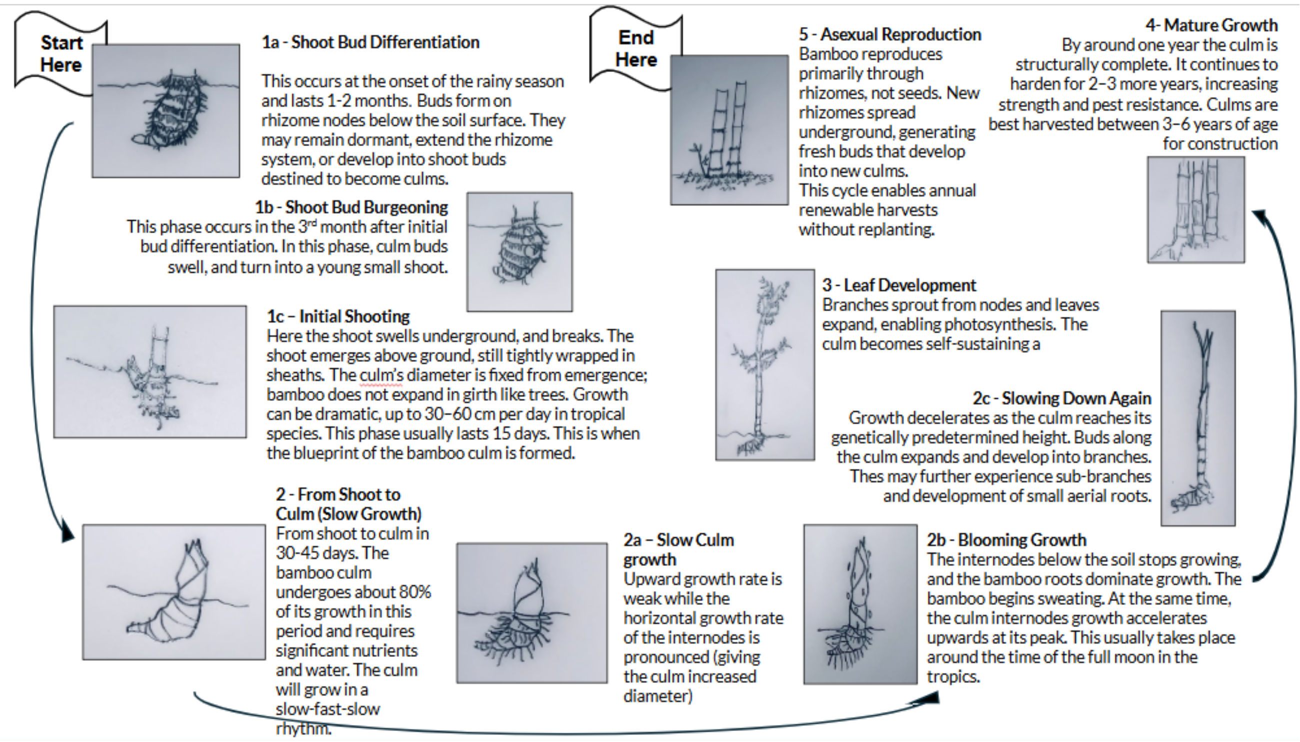


Figure 6-5: Growth cycle of a bamboo culm, from shoot emergence to mature pole (Pacific Ark field documentation, 2025)

6.1.5 Key Environmental Factor Influencing Growth

The growth and productivity of bamboo are highly dependent on environmental conditions. While bamboo is resilient and adaptable, its optimal performance requires specific thresholds of rainfall, soil quality, temperature, and human management. The following factors are the most critical in shaping bamboo establishment and growth in Fiji:

Rainfall

Bamboo thrives where annual rainfall ranges between 1,200 mm and 3,500 mm, ideally well distributed throughout the year. Fiji's wet zones such as the windward coasts of Viti Levu and Vanua Levu (Naitasiri, Ra, Cakaudrove) regularly receive 2,500–4,000 mm of rainfall, supporting continuous shoot emergence and rhizome expansion. By contrast, leeward districts including Nadi, Lautoka, Labasa, Dreketi, and even parts of Savusavu may record less than 1,800 mm per year, with prolonged dry seasons from May to October. Extended droughts in these regions can stunt new culms and reduce clump vigour unless compensated through mulching, contour bunding, or water harvesting systems. Overall, Fiji's rainfall regime strongly favours bamboo in its wet interiors while requiring adaptive irrigation strategies in semi-arid coastal zones[35].

Soil Moisture

[35] Fiji Meteorological Service (FMS), 2023a; Fiji Bureau of Statistics (FBoS), 2024; Government of Fiji, 2018

Sustained soil moisture is critical for bamboo rhizome activity and shoot expansion. Fiji's high-rainfall areas provide naturally moist conditions year-round, but leeward soils often dry rapidly due to higher evaporation and coarser textures. Rhizomes, which occupy shallow depths of 10–40 cm, are highly sensitive to desiccation. Mulching with organic residues and intercropping with shade plants such as taro or ginger can help retain soil moisture and moderate temperature fluctuations. In areas like Ba and Bua where water / moisture loss exceeds rainfall during dry months, supplemental watering or the use of biochar enriched soils can maintain active root growth. Moisture management thus determines both survival rates of new plantings and the yield of mature culms[36].

Drainage

Although bamboo prefers moist soils, excessive waterlogging leads to rhizome rot and culm mortality. Well-drained alluvial and loamy soils found along the Rewa, Dreketi, and Navua River basins provide optimal aeration and nutrient flow. Heavy clays common in the Western Division tend to retain water, ensuring raised mounds or contour drains to avoid stagnation. On steep terrain, surface runoff can erode soil around the clump; simple earth bunds or vetiver hedges can help stabilise the site. Appropriate drainage management therefore complements Fiji's high rainfall by preventing anaerobic conditions that limit root respiration[37].

Temperature

Most tropical clumping bamboos grow best between 20°C and 35°C, conditions closely matching Fiji's annual mean temperature of 26°C. Cooler upland regions such as Namosi or Monasavu occasionally drop below 18°C, slowing growth but not causing damage. Unlike temperate species, tropical bamboos are intolerant of frost, which is absent in Fiji, making the islands well suited for year-round propagation. Temperature fluctuations influence lignification rates: higher daytime heat accelerates tissue hardening, producing denser culms valuable for construction. Consequently, Fiji's consistent warmth gives it a competitive advantage for continuous production cycles[38].

Sunlight

Bamboo is a light demanding high solar radiation for efficient photosynthesis. In Fiji, average daily sunshine ranges from 4.5 to 8 hours depending on season and region. Clumps grown in open fields or along riverbanks show faster shoot development and thicker culms compared to those shaded under secondary forest canopy, consistent with findings from tropical Asia where *Bambusa* and *Dendrocalamus* species perform best under high light conditions[39]. However, partial shading during the seedling phase (e.g. 20–30 % shade cloth) helps reduce moisture stress.

Soil

Fiji's soils are highly diverse, reflecting volcanic origin and variable rainfall. Alluvial soils in river plains are deep, friable, and rich in organic matter—ideal for bamboo establishment—whereas upland clay loams and lateritic soils often require organic amendments. Key nutrients influencing culm strength include nitrogen, potassium, and silica. In regions like Naitasiri and Cakaudrove, natural volcanic ash contributes ample silica, enhancing wall hardness. In depleted soils of Western Viti Levu, periodic composting with crop residues or poultry manure improves nutrient balance and microbial activity. Proper soil management not only boosts growth rates but also enhances structural quality for construction applications[40].

Topography

Bamboo adapts well from lowland floodplains to upland slopes. On steep terrain, its fibrous root network binds soil particles, preventing landslides and runoff, and functions particularly valuable in erosion prone areas such as the Sigatoka and Taveuni highlands. In floodplains, bamboo acts as a riparian buffer, filtering sediments and protecting waterways from siltation. Contour planting along slopes increases water infiltration and supports

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[36] Ministry of Forestry (MoF), 2024

[37] Fiji Soil Bureau, 2023

[38] Fiji Meteorological Service (FMS), 2023b

[39] Nath et al., 2009; Sharma & Banik, 2015

[40] Ministry of Agriculture (MoA), 2024

agroforestry integration with crops like kava, cocoa or cassava. These attributes make bamboo an effective nature-based tool for Fiji's watershed restoration and slope-stabilisation programmes[41].

Human influence

Human management remains one of the strongest determinants of bamboo quality and yield. Practices such as selective thinning, timely harvesting, mulching, and fertilisation directly influence culm size and clump regeneration.

In Fiji, active clump management is still limited to small-scale trial sites rather than commercial farms. Most wild bamboo groves remain unmanaged, resulting in dense overcrowding and reduced culm quality. However, pilot clumps maintained under Pacific Ark's community trials in Vanua Levu, where selective thinning and periodic cleaning were introduced, have already shown improved shoot regeneration and more uniform culm growth.

These early results highlight the potential productivity gains achievable through even basic management interventions when extended to wider community contexts.

Soil type and land tenure also shape management: fertile alluvial lands under private lease allow regular cultivation, whereas communal hill lands under *Mataqali* (Indigenous communal*)* ownership are often less maintained. Experience from Indonesia and India shows that training communities in periodic thinning and organic soil care can increase shoot yield by up to 30%, underscoring the potential benefits of improved local practices[42].

In Fiji, the development of community-based bamboo management models could therefore significantly raise productivity while embedding stewardship within traditional governance systems.

6.2 Bamboo Species for Construction

6.2.1 Global Context: Bamboo as a Structural Material

Bamboo is increasingly recognised as a viable substitute for timber and steel in modern construction due to its exceptional strength to weight ratio, rapid renewability, and low embodied energy. More than 1,600 species exist globally in 121 genres, with about 50 commonly used for building and engineered products[43]. Countries such as China, India, Indonesia, and Colombia have standardised bamboo for structural use through design codes (e.g. ISO 22156 and 22157) and national building standards, creating strong precedents for Fiji's future adoption.

Mechanically, well treated bamboo rivals mild steel in tensile strength and surpasses many hardwoods in compressive strength, while remaining far lighter and faster to renew. It also sequesters significant carbon, making it a nature-based material aligned with global net-zero targets.

The following Table 4 lists the most common bamboo species used worldwide[44]:

[41] Thomson, L., Markham, R., & Roös, A. (2025). Bamboo for Watershed Protection and Land Restoration in the Pacific.

[42] INBAR (International Bamboo and Rattan Organisation), 2020

[43] INBAR,2019, Liese & Köhl, 2015; Adier et al., 2023

[44] Adier et al., 2023; INBAR database

Scientific Name	Geographic Location	Diameter (mm)	Primary Construction Applications
Phyllostachys edulis	East Asia (China, Japan)	120–180	Flooring, engineered bamboo, laminated panels
Guadua angustifolia	South and Central America	120–160	Structural framing, bridges
Dendrocalamus asper	South & Southeast Asia, now global	80–200	beams, columns, trusses, bridges
Bambusa Balcooa	India, Bangladesh, Sri Lanks, East Africa	80-150	Structural Poles, scaffolding, heavy framing
Bambusa vulgaris	Pantropical (Asia, Africa, Americas, Pacifics)	80–150	Framing, scaffolding, furniture
Bambusa blumeana	Southeast Asia, Asia–Pacific	60–150	Heavy duty poles, scaffolding, housing
Gigantochloa apus	Southeast Asia	40–100	Weaving, furniture, lightweight structures
Dendrocalamus strictus	South Asia, India, Nepal	25–80	Roof trusses, flooring, laminated boards

Table 4: Most common bamboo species used for construction around the world (Adier et al., 2023)

6.2.2 Species Relevant to Fiji

Fiji currently hosts one native, one naturalised, and multiple introduced bamboo species with varying suitability for construction. The four species showing greatest promise for structural applications are *Dendrocalamus asper*, *Dendrocalamus giganteus*, *Bambusa Balcooa*, and *Bambusa Vulgaris* as seen in Figures 6-6 to 6-9.

Figure 6-6: *Dendrocalamus asper* - locally known as *Bitu Levu*

Figure 6-7: *Dendrocalamus giganteus* - Giant Bamboo

Figure 6-8: *Bambusa balcooa* - Strong bamboo

Figure 6-9: *Bambusa Vulgaris* - Common Bamboo / *Bitu ni Vavalagi*

***Dendrocalamus asper** - locally known as Bitu Levu*

Large, thick walled, sympodial bamboo reaching 15-30m in height and 8-20cm diameter. Highly versatile and globally recognised for engineered construction. Its strength, straightness, and wall density make it the top candidate for Fiji's cyclone resilient structural use. Propagates through offsets and culm cuttings, it matures within 3-6 years and regenerates rapidly when properly managed.

***Dendrocalamus gigantus** - Giant Bamboo*

The tallest bamboo species (up to 35m, 30cm diameter). Although not yet common in Fiji, it performs well in deep alluvial soils with high rainfall. Its impressive culm size makes it ideal for large trusses and beams, though handling and curing require space and skill. Trail plots are recommended to assess growth performance under Fijian humidity and wind exposure.

***Bambusa balcooa** - Strong bamboo*

Native to India and Bangladesh, this thick walled, straight species has proven performance in structural applications. It combines high compressive strength with lower starch content, reducing pest attack risk. It can thrive in both intermediate zones, making it an excellent candidate for mixing plantations and agroforestry systems in Fiji's interior valleys.

***Bambusa Vulgaris** - Common Bamboo / Bitu ni Vavalagi*

The most widespread naturalised species in Fiji. While easily accessible, it has a comparatively thinner wall and higher starch content than structural grade species such as *Dendrocalamus asper* or *Bambusa Balcooa*, it can still be used for structural purposes if properly selected, seasoned and treated.

6.2.3 Design Implications of Species Selection

Selecting the right bamboo species for construction requires balancing physical properties, local availability, and cultural construction practices. The suitability of each species depends not only on its anatomy and mechanical performance, but also on how it aligns with local design traditions, climatic conditions, and resource accessibility.

Physical properties

Wall thickness, internode length, taper, and fibre density are the main determinants of a species load-bearing capacity. Thick-walled species such as *Dendrocalamus asper* and *Bambusa balcooa* exhibit high compressive and bending strength, making them ideal for beams, columns, and trusses. In contrast, species like *Gigantochloa apus* or *Bambusa textilis* are lighter and more flexible, suited for bracing, rafters, or woven walling. Mechanical studies show that the tensile strength of mature *Dendrocalamus asper* (up to 200 MPa) can equal or exceed mild steel on a strength-to-weight basis, while its elasticity allows superior seismic performance in tropical housing[45].

Local Availability

Construction methods naturally evolve around what species are locally abundant. In Indonesia and the Philippines, *Dendrocalamus asper* and *Gigantochloa apus* dominate rural and resort architecture. In Colombia, *Guadua angustifolia* underpins the national bamboo construction code (NSR-10). In China, *Phyllostachys edulis* forms the foundation of the engineered bamboo industry[46]. Each region has developed treatment and joinery systems adapted to its species' properties, for instance, *Dendrocalamus asper* is used for load-bearing frames in Bali and Java, while *Guadua angustifolia* in Colombia supports multi-storey buildings due to its rigidity and local craftsmanship. Using native or naturalised bamboo species reduces transport costs, supports ecological adaptation, and reinforces cultural continuity, a critical factor for Fiji's rural and island-based communities.

Construction Culture

Regional joinery traditions and architectural styles evolve around the characteristics of local bamboo. In Southeast Asia, pegged and lashed joints complement the high flexibility of clumping species, while in Latin America, bolted connections are preferred for the more rigid *Guadua* species[47]. In Fiji, traditional bure construction shares similar principles, using lightweight, flexible connections to absorb wind loads, making bamboo a natural extension of vernacular design. Integrating this cultural foundation with modern design standards can bridge tradition and innovation, enabling locally appropriate, cyclone-resilient architecture.

Regional Precedence and Relevance for Fiji

Dendrocalamus asper and *Dendrocalamus giganteus* have both been proven as structural species in multiple tropical regions that share climatic and socio-economic similarities with Fiji. In Indonesia and Thailand, *Dendrocalamus asper* forms the basis of engineered bamboo construction through organisations such as the Environmental Bamboo Foundation and BambooU, where it is used for trusses, bridges, and modular housing[48]. In India, *Dendrocalamus giganteus* has been used in large-span roof structures and community pavilions due to its immense height and wall thickness, although it requires intensive curing and handling[49]. Both species thrive in high-rainfall, warm-humid climates comparable to Fiji's wet zones (2,500–3,500 mm/year, 25–30°C), indicating strong environmental compatibility.

However, unlike these countries, Fiji currently lacks extensive bamboo processing facilities and structural design codes, which constrains scalability. Developing national treatment standards (aligned with ISO 22156 and ISO

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[45] Liese, W. & Köhl, M, 2015

[46] INBAR (International Bamboo and Rattan Organisation), 2019

[47] Hidalgo López, O, 2018

[48] Environmental Bamboo Foundation (EBF), 2022

[49] Singh, R. & Bhattacharya, P, 2021

22157) and small-scale pilot structures could mirror the pathways taken by Indonesia and Colombia in formalising bamboo as a mainstream construction material. Investing in trials of proven global construction species, particularly *Bambusa balcooa* and *Dendrocalamus asper* will provide Fiji with durable, cyclone-resilient building materials while creating a foundation for future certification and export opportunities.

6.3 Propagation, Cultivation and Agroforestry Systems

6.3.1 Bamboo Propagation

Bamboo propagation forms the foundation of all sustainable bamboo production systems. It determines the genetic quality, growth rate and long-term resilience of bamboo stands used for construction and community livelihood. Since bamboo flowering and seed availability are highly unpredictable, vegetative propagation methods are the most reliable and practical for Fiji's conditions. This section outlines both sexual and vegetative propagation methods, their advantages and limitations, and how they can be applied effectively within Fiji's tropical context.

Seed Propagation

Seed propagation relies on natural flowering cycles, which in most bamboo species occur only once every 30 – 120 years. When flowering happens, it is often that entire populations bloom and then die, producing large amounts of seed for a short period. Because of this rarity, seed propagation in Fiji is largely opportunistic and seldom practiced.

Method: Collected seeds are soaked in warm water (approximately 25 °C) for 24 hours to soften the husk. They are then sown in compost-rich, well-drained soil under light shade, keeping the medium consistently moist but not waterlogged. Germination generally occurs within 10–20 days. When seedlings reach 25–30 cm in height, they are transplanted into individual pots or nursery bags and later field-planted at the onset of the wet season.

Advantages: Genetic diversity among seedlings strengthens adaptability and disease resistance, making this method useful for breeding and research purposes.

Limitations: Natural bamboo seed viability is short (typically 4–6 weeks under tropical conditions) unless seeds are dried and stored under controlled conditions. While viable commercial seeds are available internationally (e.g., China, India, Thailand), maintaining a local seed bank in Fiji would require temperature- and humidity-controlled storage facilities to ensure long-term viability.

Use in Fiji: *Bambusa vulgaris*, the most widely naturalised bamboo species in Fiji since its introduction in the 1860s, rarely flowers and has not been formally recorded to produce viable seeds locally. Propagation therefore relies almost entirely on vegetative methods such as branch or culm cuttings.

Similarly, field observations in 2025 recorded flowering of *Bambusa balcooa*; however, no viable seeds were found, only empty florets (Figure 6-10). This aligns with reports from India and Bangladesh, where *Bambusa balcooa* frequently exhibits sterility despite prolific flowering[50].

Future opportunities exist to establish a national seed-bank and gene-bank for research and conservation of introduced bamboo species in Fiji.

[50] Singh et al., 2013; Seethalakshmi & Kumar, 1998

Figure 6-10: Flowering inflorescences of Bambusa balcooa observed in Fiji (2025) showing empty florets with no viable seeds

Vegetative Propagation (Clonal Methods)

Vegetative propagation ensures uniform culm quality, rapid establishment, and reliable supply. Because it reproduces genetically identical plants, it is particularly valuable when promoting proven structural species such as *Dendrocalamus asper* and *Bambusa balcooa*. The different methods and their advantages, limitations, and use in Fiji are presented below:

Rhizome Cuttings (offsets):

Method: Excise a 30–40 cm rhizome section from a 1–1.5-year-old culm, ensuring at least one viable bud. Make a disconnection cut at the bud and another two to three nodes away. Shape the upper cut into a reverse V-form to prevent water from collecting. Plant approximately 30 cm deep in moist, fertile soil at the start of the wet season.

Description: Rhizome cuttings establish quickly as they carry stored nutrients and root systems, producing vigorous new shoots.

Advantages: High survival rate, rapid establishment, and strong early growth.

Limitations: Labour intensive, removing too many rhizomes can weaken the mother clump, transport of heavy rhizomes is difficult.

Use in Fiji: Best suited to wet zones such as Naitasiri and Cakaudrove, where soil moisture is high. Farmers should be trained to limit extraction to no more than one-third of a clump per year to maintain regeneration.

Branch Cuttings:

Method: Select branches from culms that are at least two years old within mature clumps (seven years or older). Cut a T-shaped section with 3–4 nodes of branch and a small part of the culm. Dip the base in wood ash or rooting hormone and plant diagonally so one node is underground and one above the soil under partial shade. These steps are illustrated in Figure 6-11.

Description: Produces consistent plants without disturbing the mother clump and works well with tropical clumping species.

Advantages: Simple, low-cost, and requires only basic tools. Survival rates exceed 70 % under proper shade and watering.

Limitations: Success varies between species and depends on humidity; overwatering can cause rot.

Use in Fiji: The most practical method for small community nurseries. Works well using shade houses made from coconut leaves or shade cloth with daily watering during dry months.

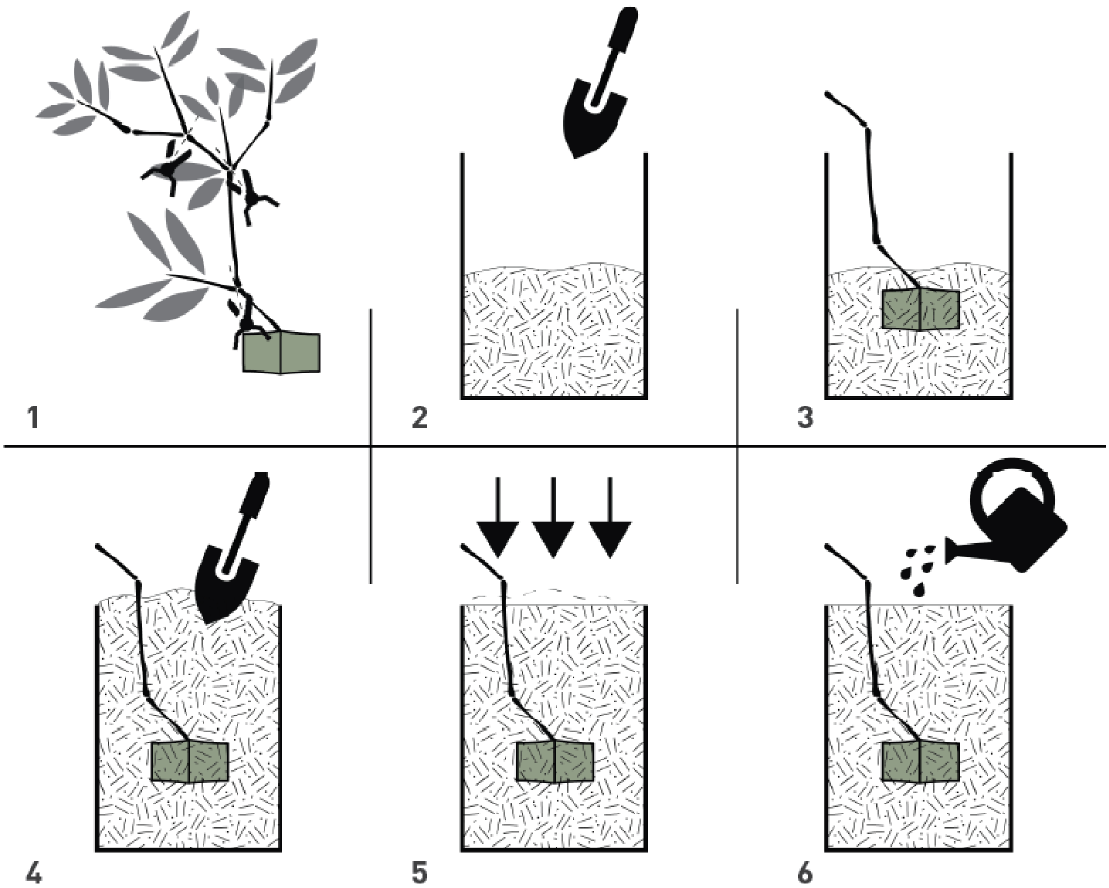

Figure 6-11: Branch Cuttings illustrative diagram (Source BambooU)

Culm Cuttings:

Method: Cut two-node sections from 1–1.5-year-old culms taken from mature clumps. Drill a small hole into each internode to allow for watering or nutrient solution. Plant horizontally with one bud below ground (to form a rhizome) and one above (to form a shoot).

Description: Enables rapid mass propagation from limited mother plants, ideal for expanding nursery stock.

Advantages: High scalability, consistent quality, and faster rooting.

Limitations: Sensitive to fungal infection or waterlogging; avoid heavy rainfall periods.

Use in Fiji: Recommended for establishing pilot nurseries of *Schizostachyum glaucifolium* (Figure 6-12), *Dendrocalamus asper*, and *Bambusa balcooa*, timed just before the wet season for best establishment.

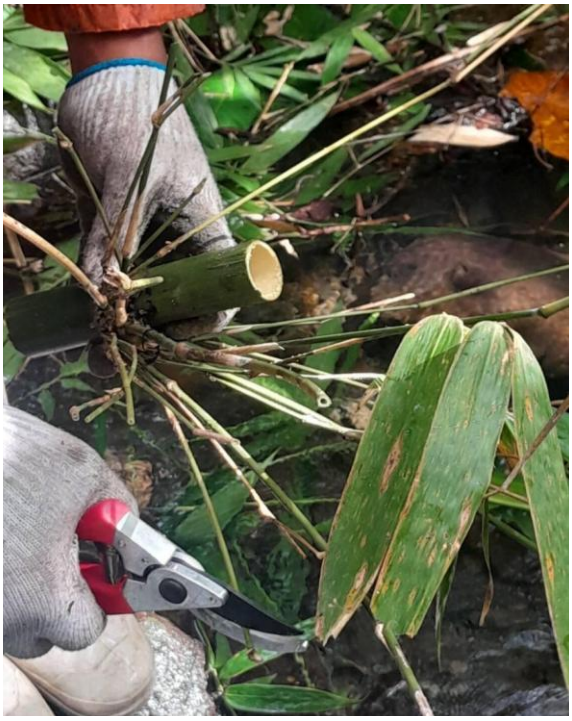

Figure 6-12: Culm cutting of a *Schizostachyum glaucifolium*

Tissue Culture:

Method: Use sterilised shoot tips or meristematic cells grown in nutrient media to produce plantlets, then acclimatise before field planting.

Description: Provides large numbers of disease-free, genetically uniform plants within a short period.

Advantages: Excellent for preserving elite construction species and rapid multiplication once protocols are developed.

Limitations: Requires costly laboratory facilities, skilled technicians, and controlled acclimatisation, high initial cost.

Use in Fiji: Best suited for research and training at institutions such as FNU Koronivia. In the medium term, a national tissue-culture facility could support the bamboo gene-bank proposed.

Comparing different Vegetative Propagation methods

The following Table 5 summarises the different Vegetative Propagation methods and their advantages, limitations, and use in Fijian context.

Method	Reliability	Requirements	Advantages	Limitations	Fiji Context
Seeds	Low	Rare seeds, nursery care	Genetic diversity	Flowering unpredictable, seeds scarce	Limited use
Rhizome offset	Medium	Mature clump, careful handling	Strong establishment	Damages clump if done poorly	Used selectively
Branch cutting	High	Mature clump, simple tools	Easy, minimal stress	Lower success in some species	Most practical
Culm cutting	High	1–2-year culms, soil care	Mass propagation	Needs monitoring, not all species	Scalable option
Tissue culture	Very high	Lab facilities	Uniform, rapid multiplication	Expensive, complex	Not common in Fiji yet

Table 5: Summary of the different Vegetative Propagation methods and their advantages, limitations, and use in Fijian context

6.3.2 Clump Management

Bamboo clump management is essential to ensure healthy growth, sustainable harvesting, and high-quality culms for construction. Poorly managed clumps quickly become overcrowded, reducing productivity and making harvesting difficult. Effective management requires a combination of species identification, inventory, maintenance, and soil care. In Fiji, most naturally occurring *Bambusa vulgaris* and *Schizostachyum glaucifolium* stands are unmanaged, leading to tangled, inaccessible clumps and poor culm quality. Implementing simple management practices can transform these stands into productive, renewable resources.

Species Identification

Accurate species identification is the first step toward effective clump management. Each bamboo species differs in its growth behaviour, wall thickness, and strength, which determines its suitability for structural use or handicrafts.

In Fiji, identification can be done visually using these indicators:

- **Clump type:** All known species are sympodial (clumping) bamboos. No monopodial (running) species are currently recorded.
- **Culm characteristics:** *Bambusa vulgaris* forms tall green or yellow culms (up to 20 m) with thinner walls. *Schizostachyum* glaucifolium has fine, flexible culms used traditionally for weaving. Introduced *Dendrocalamus asper* and *Bambusa balcooa* have thicker walls and higher compressive strength, making them suitable for structural applications.
- **Leaf and sheath traits:** Variations in sheath colour and hair, leaf shape, and size help distinguish introduced from native species.

Recommendation for Fiji:

Develop illustrated field identification cards and mobile photo references for use by Ministry of Forestry field officers and community farmers to reduce misidentification during propagation.

Culm Inventory and Monitoring

Formal bamboo inventory systems are not yet in place in Fiji, but monitoring clumps is essential for planning harvests and maintaining productivity. A simple participatory inventory system can be introduced through the Ministry of Forestry's community forestry programme.

<u>Recommended steps:</u>

- Count the number of culms per clump and classify them by age: new (0–1 year), semi-mature (2–3 years), mature (4–6 years).
- Measure diameters at the base and mid-height using a flexible tape.
- Record culms that are bent, cracked, or diseased for removal.
- Photograph each clump once a year to visually track growth.

Such records will build a national bamboo database over time, helping estimate production potential and guide sustainable harvesting rotations.

Maintaining Clump Health - The B.S.B.O.D. Method

The **B.S.B.O.D. (Bent, Short, Broken, Old, Diseased)** system (Figure 6-13), developed for village-scale bamboo management in Indonesia, is an accessible technique that can be readily applied in Fiji. It encourages farmers to remove unproductive culms annually, improving airflow and shoot regeneration.

<u>Application for Fiji:</u>

- Inspect clumps before the wet season.
- Remove all culms that are bent, broken, shorter than the average height, over seven years old, or showing disease symptoms (e.g., Witches' Broom).
- Burn or compost removed material away from the clump to prevent pest infestation.
- Retain at least two to three mature culms per rhizome to maintain photosynthetic support.

Early observations in Savusavu indicate that cleaning congested *Bambusa vulgaris* clumps increases new shoot production within one rainy season (Figures 6-14 and 6-15). In Fiji's humid climate, this practice also helps reduce fungal growth and termite damage.

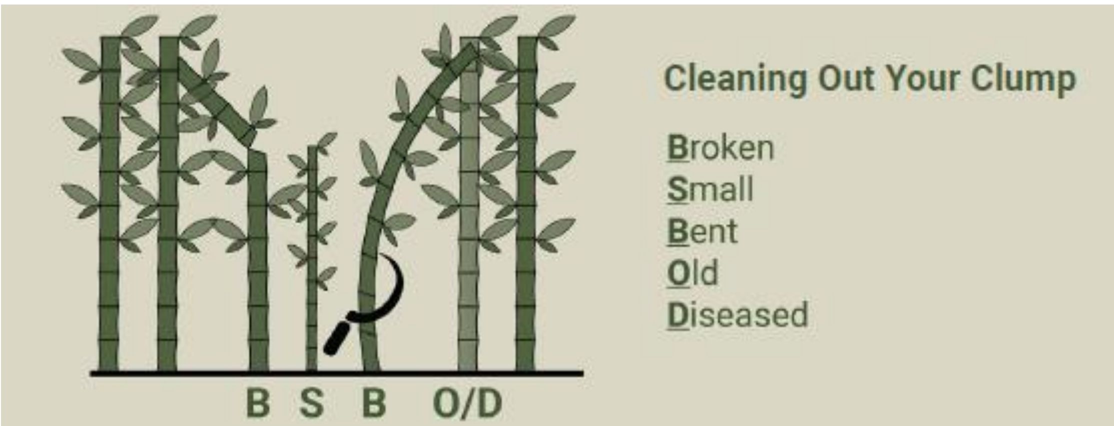

Figure 6-13: B.S.B.O.D. (Bent, Short, Broken, Old, Diseased) system (Source: BambooU)

Figure 6-14: Before clump management

Figure 6-15: After clump management

Determining Culm Age and Generations

Knowing the age of culms ensures harvesting at the right maturity (3–6 years), when mechanical strength and durability are highest. Although formal ageing techniques are not used in Fiji, several simple indicators can be taught through farmer training (Figure 6-16):

- **Branch whorls:** Each wet season produces one ring of branches. Counting three to five whorls indicates a 3–5-year-old culm, ideal for harvesting.
- **Surface appearance:** Younger culms are smooth and glossy; older culms dull and often covered in lichen or moss.
- **Resonance test:** Tapping the culm with a wooden stick produces a clearer sound in older, hollow culms due to lower moisture content.

Recommendation for Fiji: Future demonstration farms should include labelled clumps of different age classes to train farmers in quick visual age identification and link this to mechanical testing results under Fiji's climatic conditions.

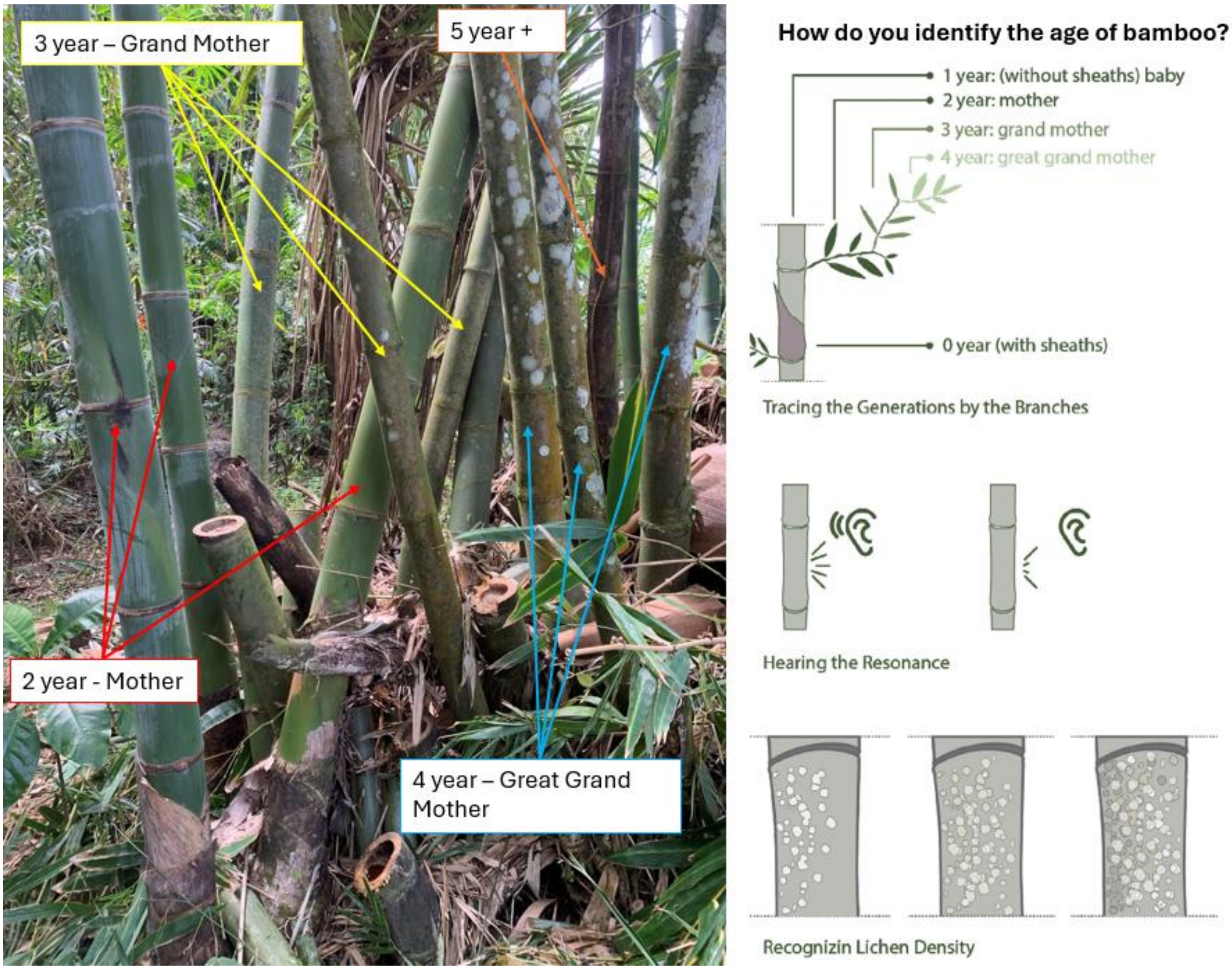

Figure 6-16: Identifying culm age (Photo and identification soure: Arno Roös; Diagram source: BambooU)

Tracking and Coding Clumps

In established bamboo industries, culm coding helps regulate harvesting. In Fiji, where formal systems are new, a simplified clump-level coding system is more practical. Instead of marking every culm, label each clump with the planting year, estimated first harvest year, and farmer initials, using painted stakes or wooden tags. This provides an immediate visual reference and introduces the concept of rotational harvesting without overwhelming farmers.

Mounding and Fertilisation

Mounding is already a familiar agricultural practice in Fiji for crops such as yams and ginger and can be adapted for bamboo management. The technique strengthens root systems, enhances nutrient uptake, and promotes new shoot emergence (Figure 6-17).

<u>Method (adapted for Fiji):</u>

- Collect fertile topsoil mixed with compost, mulch, or decomposed coconut husk.
- Build a mound 20–30 cm high around the clump base, covering exposed rhizomes.
- Apply organic fertiliser (e.g., compost, poultry manure) once per year at the start of the wet season.
- Maintain thick mulch cover to conserve moisture during the dry months.

This method has shown visible improvement in shoot emergence and culm thickness within a single year on farms in Cakaudrove and Bua (Figure 6-18).

Figure 6-17: Application of compost and mulch to strengthen rhizomes (Source: BambooU)

Figure 6-18: Application of compost and mulch to strengthen rhizomes in Cakaudrove and Bua

Benefits and Relevance to Fiji

When properly managed, bamboo clumps maintain productivity for decades. The combined practices above — cleaning, thinning, and fertilisation — can transform neglected wild groves into structured bamboo farms supplying high-quality poles for construction. The below summarises the different clump management methods that can be applied in Fiji and their benefits.

Clump management in Fiji	Benefit
Regular thinning increases shoot growth and allows consistent supply of poles.	Higher Productivity
Selective harvesting ensures only mature, strong culms are used for structural work.	Improved Quality
Clean, ventilated clumps deter termites and fungal infection common in humid coastal zones.	Reduced Pest Pressure
Open clumps reduce labour time and risk of injury during harvest.	Ease of Harvesting
Converts unmanaged stands into productive assets aligned with MoF's 30-Million-Trees and community livelihood programmes.	Supports national forestry goals

Table 6: Different clump management methods that can be applied in Fiji and their benefits

6.3.3 Bamboo agroforestry, plantations and gene banks

This section outlines the current cultivation and management practices in Fiji and explores how bamboo can be integrated into agroforestry and plantation systems to enhance productivity, livelihoods, and ecological resilience. It also highlights the importance of establishing national gene banks to ensure access to high-quality planting material and preserve long-term species diversity.

Current Cultivation and Propagation Initiatives in Fiji

Efforts were made in the past by the Fiji Bamboo Association (FBA) to propagate species like *Dendrocalamus asper*, and *Gigantochloa apus* through partnerships (e.g. with Indonesia), however these were disrupted by COVID[51]. The FBA does not manage any plantations or cultivation sites directly, nor does it conduct any harvesting[52].

Major propagation and nursery development and gene pool work is currently being led by Pacific Ark, which is establishing pilot bamboo nurseries and trial plots in Vanua Levu. These initiatives focus on the propagation and treatment of priority construction species such as *Bambusa Vulgaris*, *Bambusa balcooa*, and the native *Schizostachyum glaucifolium*. Pacific Ark's approach links propagation with applied research and training for community farmers, supporting the development of future bamboo supply chains for construction and agroforestry use.

Smallholder farmers such as W. Nimbalka are also expressing growing interest in participating, forming informal clusters that will benefit from future training and access to propagation material through Pacific Ark's programs and government partnerships. These combined initiatives mark the first coordinated steps toward establishing a sustainable bamboo propagation network in Fiji, forming the foundation for future agroforestry and plantation development.

Bamboo Agroforestry

Bamboo agroforestry goes beyond simply planting bamboo, it integrates bamboo into diversified farming systems that simultaneously enhance livelihoods, improve food security, and build ecological resilience. Unlike monocultures, agroforestry systems with bamboo combine short-term crops, companion trees, and bamboo as a long-term perennial resource. This approach provides communities with multiple income streams and reduces vulnerability to market or climate shocks.

Bamboo is especially suited for agroforestry because of its ecological niche:

- Acts as a pioneer species that rapidly establishes on degraded land.
- Forms a thick canopy that shades soil, conserves moisture, and suppresses weeds.
- It has a shallow root system that complements deeper-rooted trees.
- Provides habitat for insects, pollinators, and micro-bats that support farm biodiversity.

Evidence shows that diversified cropping systems can yield 10–60% more than monocultures, while also providing greater food and income security[53]. Farmers can earn from intercrops while bamboo matures, and harvested bamboo shoots themselves provide additional nutrition and market value.

Bamboo can be integrated into different agroforestry models for meeting diverse needs of farmers. Pacific Ark is demonstrating integrated bamboo cultivation and mixed-crop systems as part of its 10 Acre Green Hill Bamboo

[51] M. Borg, personal communication, 19 Jun 2025
[52] M. Borg, personal communication, 19 Jun 2025
[53] Thomson et al., 2021

Farm agroforestry initiative (Figure 6-19). Some of the recommended bamboo-based agroforestry systems for Fiji are as follows:

1. **Bamboo home gardens -** Home gardens are a common feature of the agricultural landscape in rural and urban localities of Fiji. This presents an incredible opportunity to integrate bamboo for subsistence and sale. In North-east India *Bambusa cacharensis*, *B. vulgaris*, and *B. balcooa*, are commonly planted by villagers either in a distinct area of home gardens or in a bamboo grove, which is an area of land where bamboo is either grown as a pure stand or in combination with other trees like *Lagerstroemia* sp. and *Erythrina* sp. Bamboos are mostly grown for domestic use in home gardens and for commercial purposes in bamboo groves. In home gardens, bamboo culms are selectively felled to meet subsistence needs of households for construction, fishing and agricultural implements. Bamboo groves are managed on felling cycles of 5-6 years and are clear-felled for meeting the raw material demands of the pulp and paper industries (Nath et al., 2009).

2. **Bamboo windbreaks**: To protect agricultural fields and orchards from strong winds, bamboo can be utilized to build windbreaks along their margins. Bamboo should be planted in a linear pattern in this agricultural technique. Non-clumping bamboo species like *Bambusa oldhamii* are suitable for windbreaks.

3. **Bamboo alley cropping**: In this agroforestry system, crops such as beans and maize are cultivated in the alleys or spaces between rows of managed bamboo. The bamboo can be pruned three or four times a year at a height of fifty centimeters above the ground. The pruned material can be added to the soil as a source of organic manure. The width of the alleys depends on the slope of the ground ranging from 2 m on steep slopes to 4 m on level ground. On steep slopes, bamboo-based alley cropping systems can help in mitigating soil erosion. The recommended planting distance for bamboo is 50–100 cm (FODER, 2019)

4. **Bamboo-based intercropping:** Bamboo can be intercropped with shade bearing crops such as vanilla, ginger and turmeric. In this model, bamboos are planted at various spacings, ranging from 5 m × 5 m for small to medium sized bamboos to 10 m x 10 m for giant bamboos (PARDI, 2021).

5. **Bamboo with cash crops:** In countries such as the Philippines and Indonesia, bamboo is integrated with cash crops such as cocoa and coffee which require partial shade for their growth and development. Shade improves the microclimate and protects these crops from high soil temperature and low relative humidity. In cocoa plantations, bamboo can be planted at a spacing of 12m x 12m, and in coffee plantations, the recommended spacing is 10m x 10m (FODER, 2019).

Environmental benefits of bamboo agroforestry

Bamboo in agroforestry systems contributes to multiple ecosystem services and offers both environmental protection and livelihood resilience for farming communities.

Soil stabilisation: Dense rhizome and root networks bind the soil and reduce erosion, particularly on steep slopes where crops such as cassava, dalo, and ginger often accelerate sediment loss. In Fiji's wet zones, clumping species like *Bambusa vulgaris* and *Schizostachyum glaucifolium* play a valuable role in stabilising road embankments and degraded hillsides.

Water regulation: Bamboo clumps act as living water reservoirs, storing and releasing moisture gradually into the soil system. During dry periods, they help sustain surrounding crops, especially in areas with shallow groundwater tables such as Savusavu and Bua. This capacity is increasingly important as Fiji faces more frequent droughts and erratic rainfall patterns linked to climate change.

Wind barriers: Stands of bamboo protect sensitive crops like cocoa, vanilla, and banana from strong winds and salt-laden gusts, reducing cyclone-related damage. Well-designed windbreaks of clumping bamboo have proven more durable than timber or synthetic fencing, regenerating naturally after damage.

Biodiversity: Bamboo supports beneficial species such as pollinators, small mammals, and birds while suppressing invasive trees such as African tulip (*Spathodea campanulata*). The dense canopy and leaf litter also improve soil biodiversity by supporting fungi and microorganisms essential for nutrient cycling.

Disaster Resilient Crop: Bamboo's deep root system and rapid regeneration make it one of the most cyclone, and flood-resilient plants in tropical ecosystems. Even after Category 4–5 cyclones, most bamboo clumps recover quickly, new shoots often appear within weeks, while mature culms remain structurally usable for temporary shelter and reconstruction. In contrast, timber trees and fruit orchards may take years to recover. This regenerative capacity positions bamboo as a critical species for post-disaster rebuilding and community resilience in Fiji, where cyclones are expected to increase in intensity. Bamboo's flexibility and tensile strength allow it to withstand strong winds without snapping, while its distributed root network reduces landslide risks in high-rainfall areas[54].

Economic and livelihood benefits of bamboo agroforestry

Intercropping opportunities: Short-term crops (vegetables, cassava, ginger) can be cultivated during the first years while bamboo is gradually establishing.

Companion tree crops: Bamboo can enhance the growth of other valuable species — for example, mahogany develops straighter, stronger trunks when planted alongside bamboo, while sandalwood thrives in bamboo-associated systems[55].

Shoots as a food source: Bamboo shoots are highly nutritious and can be sold in domestic and export markets.

Long-term value: Once established, clumps provide annual harvests of construction-grade poles, creating stable livelihood streams for up to 50 years.

Bamboo Plantation Systems

Bamboo plantations have immense potential to prevent deforestation and forest degradation[56]. Incorporating bamboo into plantation programs could help restore degraded areas to productive use, while diverting pressure from natural forests for timber and fuel. It would give communities stable incomes through alternative livelihoods, mitigating the smaller-scale pressures that drive ongoing degradation[57].

Bamboo can be utilised for subsistence and industrial purposes such as furniture and construction as well as a source of renewable energy in place of conventional forest tree species. Countries such as China, India, and Indonesia have established bamboo plantations because of the plant's special ability to produce bioenergy in addition to other ecological benefits such as soil and water conservation. Fiji's commitment to national initiatives like the 30 million trees in 15 years and the Reforestation of Degraded Forests (RDF) programs, and international agreements like the Bonn Challenge and the New York Declaration on Forests call for restoring deforested and degraded lands. Bamboo matures in three to seven years and can be harvested annually thereafter with proper management. In addition, it can grow on marginal land where most native tree species, especially in tropical

[54] Thomson et al., 2021
[55] Thomson et al., 2021
[56] Akwada and Akinlabi, 2018
[57] Rebelo and Buckingham, 2015

regions, find it difficult to grow and establish[58]. Under such environments, bamboo uses less water and fertiliser than conventional sources of biomass[59]. Consequently, bamboo plantations on marginal lands can help achieve restoration objectives in an economically viable manner and within a realistic time frame while revitalizing local livelihoods.

Environmental benefits of bamboo plantations on marginal land

1. Bamboo can improve soil fertility in nutrient-depleted soil. Its dense canopy mitigates the effect of wind and rain on exposed soils, while its root system creates a strong underground network that helps in binding soil particles. A study reported lower soil erosion in Moso bamboo (Phyllostachys pubescens) forests compared to adjacent evergreen broadleaved and Japanese cedar forests[60]. Owing to its dense foliage and rapid growth rates, bamboo can quickly create a thick layer of litter on the forest floor. This litter layer improves the soil microclimate in addition to conserving soil moisture[61].
2. The dense canopy, abundance of culms, and evergreen leaves make bamboo an ideal species for rainwater interception as well as moisture retention[62]. A study reported that the water retention ability of Moso bamboo forests in South China was around 30% higher than Chinese fir (*Cunninghamia lanceolata*) plantations[63]. Another study found higher infiltration and saturated hydraulic conductivity in Moso bamboo forests compared to adjacent broadleaved forests[64]. This was attributed to the higher fine root biomass and density in the Moso bamboo forests.
3. Bamboo plantations have a high capacity of carbon sequestration due to their quick growth rate and high rate of regrowth following harvest. Over a long-term, the average carbon sequestration in bamboo is a static line rather than the typical bell-shaped curve encountered in timber plantations. This is because, despite the fact that some bamboo biomass is harvested annually, it quickly regenerates in a single growing season[65]. Studies have reported higher carbon sequestration in Moso bamboo forests compared to natural forests and plantations[66].

Plantations are suitable for large-scale supply of construction-grade bamboo. Productivity is highly variable depending on species and site conditions:

- **Species differences:** Over 1,600 species exist, each with different yields per hectare. Clumping bamboos (sympodial) are generally more productive than running types.
- **Environmental factors**: Rainfall, altitude, soil type, and fertility strongly influence productivity.
- **Yield estimates:**
  - A healthy clump can produce up to 200 poles in 5 years[67]
  - In Bali, one hectare with ~700 clumps can yield 3,500–12,600 poles per year, based on 10–18% selective harvesting[68]
  - A typical model: 50 clumps per hectare with 36 poles each could yield 300–500 poles per year.

[58] Rebelo and Buckingham, 2015
[59] Sharma et al., 2018
[60] Shinohara et al., 2019
[61] Rebelo and Buckingham, 2015; Paudyal et al., 2022
[62] Rebelo and Buckingham, 2015
[63] Wang and Liu, 1995
[64] Ide et al., 2010
[65] Rebelo and Buckingham, 2015; Paudyal et al., 2022
[66] Zhou and Jiang, 2004; Kuehl et al., 2013
[67] Environmental Bamboo Foundation
[68] BambooU

For Fiji, plantation potential is constrained by access to quality planting material, water availability, and land tenure systems (e.g., *Mataqali* traditional customary land that is communally owned by clans). These factors have both direct and indirect effects on the production and annual yield of bamboo poles. Limited access to quality planting material means that propagation often relies on wild or poorly managed clumps, resulting in uneven growth rates, mixed species stands, and lower culm quality. Without reliable nurseries or gene banks, plantation establishment is slow and inconsistent, directly reducing the number of mature poles available for harvest each year.

Water availability, particularly during the dry season in northern and western divisions, influences shoot emergence and culm thickening; inadequate irrigation or prolonged drought can reduce annual production by up to 30–50% depending on species.

Furthermore, Fiji's complex land tenure system, where most land is owned by *Mataqali* (clan groups), creates indirect barriers to scaling plantations. Lengthy lease negotiations, fragmented land parcels, and differing community priorities delay investment, reduce continuity of management, and discourage private-sector engagement. Collectively, these constraints limit Fiji's ability to achieve the productivity benchmarks seen in countries like Indonesia or India, where standardised propagation, irrigation, and tenure systems support annual yields exceeding 3,000–10,000 poles per hectare. In Fiji, current yields are likely to remain well below these levels until these foundational systems are addressed.

Gene Banks and Planting Material

Developing gene banks is critical to support Fiji's bamboo sector. Gene banks conserve different species and provide farmers with access to high-quality, disease-free planting material. They also safeguard genetic diversity, ensuring resilience against pests, diseases, and climate variability. A national bamboo gene bank would:

- Support agroforestry initiatives and plantations with reliable propagation material
- Provide training hubs for clump management and propagation techniques
- Contribute to research on which species are best suited to Fiji's soils, rainfall, and construction needs

6.4 Bamboo Treatment and Processing for Use in Construction

Bamboo is naturally strong, lightweight, and fast-growing, yet its durability in humid tropical climates such as Fiji is limited without proper treatment and preservation. The high starch and sugar content in bamboo makes it particularly vulnerable to insect attack (especially borers and termites) and encourages fungal decay. If used untreated, construction grade bamboo may last only 2-5 years, compared to up to 50 years when treated and depending on exposure and design.

Treatment is therefore a critical step in ensuring bamboo viability as a sustainable building material and an alternative to imported timber, concrete, or steel. In Fiji, most current treatment practices remain informal and traditional, with no standardised facilities or government regulated systems in place. This section outlines the primary natural, chemical and advanced treatment methods used internationally and locally, and evaluates their relevance and scalability for Fiji's growing bamboo construction sector.

6.4.1 Natural treatment methods

Natural or traditional preservation techniques are long practiced across Asia and the Pacific and are typically used in contexts where access to specialised equipment or chemicals are limited. In Fiji, these include smoking, heating, and water leaching. These remain the most common low-cost practices at Village level.

Smoking

It is one of the oldest preservation methods and holds cultural significance in Fijian traditional construction. Small fires are kept burning continuously inside a bure (traditional thatched house) for several weeks, allowing smoke to permeate the bamboo. The process reduces starch content, darkens the culm, and provides limited protection against insect attack. However, studies in Indonesia and India show that smoking offers only short-term durability, providing surface level protection that diminishes within a few years. It remains effective as a supplementary pre-treatment but should be followed by chemical preservation for structural use.

Heat Treatment

Often applied with a torch or open flame, is another traditional method used to reduce moisture content, straighten poles, and sterilise the surfaces. In Fiji, this technique is common for small construction projects or temporary structures, like veranda extensions and sheds, where treated poles are easier to handle and shape. While it enhances surface hardness and reduces moisture, heat treatment alone does not prevent decay or insect infestation and should be combined with boron-based treatment for structural grade bamboo.

Figure 6-20: Heat Treatment in Fiji

Water Leaching

Involves submerging freshly harvested culms in flowing water, lagoons, or tanks to dissolve sugars and starches. The method, common in Asia, is suitable in Fiji where clean sources of water are accessible. However, extended soaking may weaken fibres or reduce mechanical strengths if not monitored. It is therefore recommended only as a pretreatment step before chemical preservation and controlled drying.

Figure 6-21: Water Leaching in a stream in Fiji

Overall, while these natural methods are environmentally friendly, culturally relevant, and affordable, they provide limited protection in Fiji's humid and pest-prone environment. Combining them with boron-based preservation and proper drying procedures offers the best balance between accessibility and long-term performance.

6.4.2 Boron-based treatment and preservation methods

Boron-based preservatives, most commonly a mixture of borax and boric acid or disodium octaborate tetrahydrate (DOT), are widely regarded as the most suitable eco-friendly preservation for bamboo. These chemical treatments are water soluble, low in toxicity, and effective against termites, borers, and fungi without compromising the bamboo's structural strength. International Standards (ISO 22156, Annex B) recommend a boron retention of approximately 4kg/m3 to ensure long term protection.

In Fiji, boron-based systems are the most practical and scalable solution because they are safe for community use, cost effective and adaptable to various project scales. The following methods are recommended:

Vertical Soak Diffusion (VSD)

This low-cost technique involves piercing freshly cut bamboo's internal nodes with a reinforcing bar (leaving the bottom node intact) and filling them with a 4-5% boron solution. The preservative gradually diffuses through the vascular bundles over 10-14 days. Trials by Pacific Ark in Vanua Levu have demonstrated its simplicity and effectiveness, making it suitable for "backyard" and village level treatment option (Figure 6-22).

Figure 6-22: Vertical Soak Diffusion (VSD) setup for trials by Pacific Ark in Savusavu, Vanua Levu

Hot Immersion

The boron solution is heated to around 60°C, reducing treatment time to 24 hours, further studies now show if you heat it consistently to 100°C, this time can drastically be reduced to 8-12 hours, while also improving penetration. This process requires heat sources, metal tanks, and temperature monitoring. It is best suited for institutional / commercial treatment hubs. Trials of this method have been carried out by Pacific Ark as seen in Figure 6-23 and 6-24.

Figure 6-23: Dissolving boron mixture, prior to lacing bamboo into mixture (Pacific Ark)

Figure 6-24: Placing bamboo into hot immersion tanks keeping it submerged at all times (Pacific Ark)

Cold Immersion

Culms are fully submerged in tanks containing a boron solution for 10-14 days. allowing even diffusion through perforated nodes. This method is simple, low risk and ideal for small to medium scale enterprises. It's widely used across Asia (notably in India and Indonesia) and is highly adaptable to Fiji's community and training centre environments.

All three boron-based systems are environmentally safe, cost effective, and compliant with international best practices. It is recommended that Fiji adopt boron treatment as the national preservation standard, supported by training at vocational, forestry and community level.

6.4.3 Emerging and advanced treatment methods

Beyond traditional and boron-based approaches, several advanced methods are emerging internationally to improve treatment efficiency and penetration. The most relevant to Fiji include the Modified Boucherie method and carbonisation treatment.

Modified Boucherie Method

This method uses low pressure pumps to inject preservatives solution through freshly cut bamboo culms. The process replaces natural sap with boron solution within hours, providing deep penetration along the vascular bundles. This approach is efficient, portable and ideal for processing large and lengthy bamboo. It has been used successfully in India and Indonesia and could be adopted for Fiji with portable field rigs or at centralised treatment hubs. Pacific Ark is currently trialling this method as part of its applied research into eco-friendly bamboo boron solutions (Figure 6-25).

Figure 6-25: 1st trial of Modified Boucherie setup using portable low-pressure pump by Pacific Ark

Carbonisation (or Decarbonation) treatment

This method involves heating the bamboo's outer surface to create a thin carbonised layer. This seals the pores, drives out sugars, and adds moderate water and insect resistance. It also enhances appearances and durability, making it suitable for external applications such as fencing, signage, laminated flooring and furniture.

While fumigation and chemical spray can be effective for temporary pest control, they are not recommended for community or village settings in Fiji due to their toxicity and environmental risks. These should only be used under professional supervision for export quarantine or restoration purposes.

6.4.4 Comparing different treatment methods

Table 7 below compares the different treatment methods presented from section 6.4.1 to 6.4.3.

Method	Category	Typical Duration	Effectiveness	Cost Level	Infrastructure Required	Suitability for Fiji
Smoking, Heat Treatment, Water-Leaching	Traditional / Natural	2–8 weeks	Low–Medium (2–5 yrs)	Very Low	Minimal (firewood, water access)	High for rural use, small structures
Vertical Soak Diffusion (VSD), Cold Immersion, Hot Immersion	Boron-based (Standard)	1–3 weeks	High (15–30 yrs)	Low	Simple tanks or sealed culms	Highly suitable for Fiji; scalable
Modified Boucherie Method, Pressure Injection	Advanced / Mechanical	Hours–2 days	High (20–40 yrs)	Medium	Requires pressure pump and fittings	Medium–High
Industrial Carbonisation (pyrolysis)	Industrial Thermal Treatment	1-3 days	Very High (30–50 yrs)	High to Very high	Cylindrical kilns or sealed reactors	Low current feasibility / future R&D potential
Fumigation, Synthetic Preservatives (CuN, etc.)	Chemical / Industrial	Hours–days	High (short-term)	Medium	Controlled chambers, PPE	Not recommended for Fiji

Table 7: Comparison of different treatment methods presented from section 6.4.1 to 6.4.3

The analysis in Table 7 shows that boron-based systems, particularly Vertical Soak Diffusion, Cold Immersion, and Hot Immersion, are the most practical, safe, and scalable solutions for Fiji's conditions. Traditional methods remain culturally relevant but provide limited durability. Emerging technologies such as carbonisation and the Modified Boucherie Method offer promising opportunities for innovation. A national bamboo treatment strategy integrating these methods will ensure both ecological integrity and structural performance, enabling bamboo to become a cornerstone of Fiji's climate-resilient construction future.

6.4.5 Drying, storage and handling after treatment

Proper drying after treatment is critical to achieving long term structural stability. Once treated, bamboo should be air dried in shaded, well-ventilated areas for four to 6 weeks, until moisture content falls below 20%. Direct sun exposure can cause splitting, while poorly ventilated drying spaces can promote mould and fungal growth.

Raised drying racks, spaced stacking, and covered sheds are the most effective drying arrangement in Fiji's humid climate. End sealing bamboo culms with paint, wax or natural oils reduces cracking during drying. Treated bamboo must be stored on the ground, on timber slats, or platforms, to prevent reabsorption of soil moisture.

Workers should use gloves and eye protection when handling treated materials, and all used boron solutions should be disposed of responsibly to prevent contamination of waterways. Establishing a simple record keeping system, noting species, harvest dates, treatment method, concentration and drying period, will greatly assist in maintaining consistency, traceability and construction quality assurance.

7 Pacific Ark Case Study: Species Performance and Cost Analysis

Pacific Ark has undertaken end-to-end practical trials demonstrating the full bamboo construction value chain in Fiji from propagation and harvesting to treatment, processing, and construction. The organisation's fieldwork, led by A. Roös, has been carried out across the Savusavu region, testing locally available species such as *Bambusa vulgaris*, *Bambusa balcooa* and Schizostachyum *glaucifolium* through every production stage under real conditions as seen in Figure 7-1.

Figure 7-1: Pacific Ark trials from Bamboo Harvesting > Treatment > Prepping > Curing & storing

7.1 Harvesting and Resource Access

Most bamboo utilised by Pacific Ark originates from unmanaged wild clumps rather than structured plantations. Harvesting therefore presents both logistical and technical challenges including dense growth, steep terrain, and limited access to mature culms, increased labour time and handling difficulty. Since bamboo is widely perceived as a low value or nuisance plant, communities have generally welcomed Pacific Ark's initiatives and readily granted permission to harvest, once informed of the purpose and sustainable methods being applied. In several cases, small financial exchanges or community contributions were offered as appreciation for access, establishing fair and transparent engagement with landowners, often providing goodwill payments of FJD$2 per pole (9m) or in-kind contributions. These experiences highlight that sustainable harvesting is socially feasible in Fiji but will require structured management, training, and compensation systems as the industry scales.

The work confirmed that community access and social licensing for bamboo harvesting are feasible in Fiji, provided there are clear agreements on benefit-sharing and sustainable cutting practices. Labour teams of two to three workers can harvest roughly 20 poles (3.5 m each) within six hours, averaging $45 per day per worker. Transport of a full truckload costs approximately FJD $100, depending on terrain and access conditions.

7.2 Agroforestry and Cultivation Systems

Pacific Ark's bamboo agroforestry and plantation initiative forms the foundation of its long-term sustainable supply model (Figure 7-2). Established across pilot sites in Savusavu and Valelawa, the program integrates bamboo within mixed cropping systems to restore degraded lands, stabilise slopes, and enhance farm resilience.

The initiative combines bamboo with crops such as dalo, eggplant, mahogany, banana, small fruit trees, and cocoa, creating multi-layered, productive landscapes that improve soil structure and biodiversity while generating both short- and long-term income streams for landowners. Bamboo's extensive root system enhances water retention and erosion control, while its rapid regrowth provides a renewable source of biomass for construction and community energy use.

Pacific Ark's field trials focus on *Bambusa balcooa* propagation and early growth performance under varying soil, shading, and irrigation regimes. Each planting is managed through selective harvesting to ensure long-term productivity without soil depletion. Data are being collected on shoot regeneration, culm density, and intercropping performance, establishing Fiji's first local baseline for bamboo agroforestry and plantation site performance using a single high value construction species. These trials are providing critical insights into growth rates, yield potential, and management requirements under Fijian conditions, forming the scientific foundation for future large scale bamboo plantations and regenerative land use planning.

The program also functions as a live demonstration for community training, where farmers and youth groups participate in planting, maintenance, and early harvesting activities. This model has proven effective in increasing rural engagement by linking livelihood opportunities directly to climate adaptation and land restoration. In the long term, Pacific Ark's agroforestry initiative aims to supply a consistent flow of mature bamboo poles to feed treatment and construction operations while regenerating degraded landscapes across Vanua Levu and the wider Pacific.

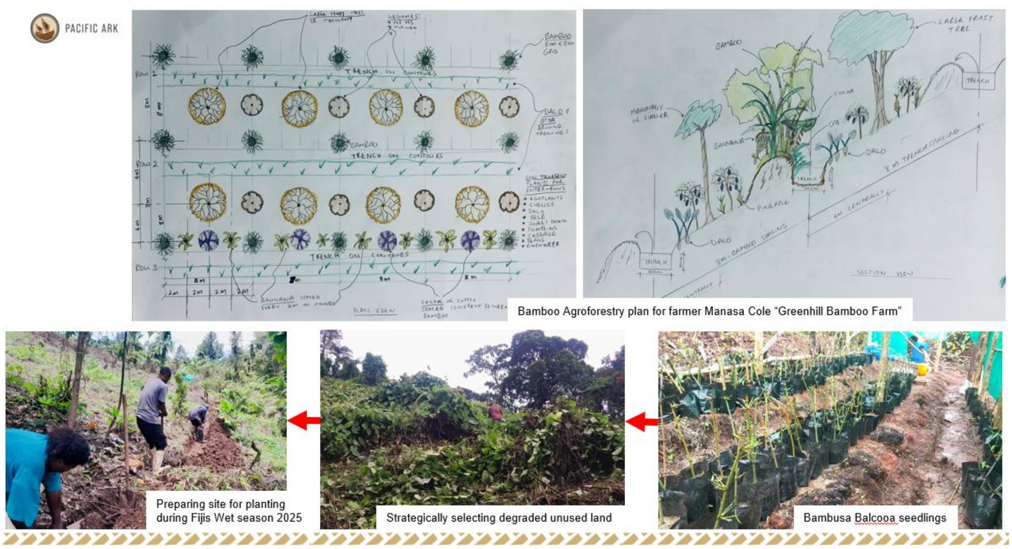

Figure 7-2: 10 Acre Green Hill Bamboo Farm agroforestry initiative, demonstrating integrated bamboo cultivation and mixed-crop systems under Pacific Ark's registered sites

7.3 Treatment Trials and Cost Analysis

Pacific Ark established two pilot treatment systems to evaluate cost, labour, and performance under local conditions as seen in the following sections.

7.3.1 Case Study 1: Village Harvesting & Vertical Soak Diffusion (VSD)

Bamboo poles were harvested from community clumps and treated using a VSD system assembled from locally available materials.

- **Setup cost:** ~ FJD $750 (including burners, hoses, and tools).
- **Labour:** FJD $90–180 per cycle (2 staff × 2–3 days).
- **Cycle output:** ~ 20 poles (3.5 m each).
- **Total cost per cycle:** FJD $1,000–1,200 → ~ FJD $50–60 per pole.
- **Drying period:** 4–5 weeks in solar-covered racks.
- **Chemical inputs:** Borax (FJD $200–250 / 25 kg) and Boric acid (FJD $280–450 / 25 kg). Supply remains inconsistent, requiring import coordination.

Lessons learnt

Boron solution can be reused indefinitely with filtration and concentration monitoring, greatly reducing recurring costs. Treated culms achieved markedly lower termite and fungal damage after six months of field exposure.

7.3.2 Case Study 2: Hot Immersion Method (Initial Trials)

A temporary steel-trough system (cost ~ FJD $2,500) was fabricated to test rapid hot-immersion treatment.

- **Labour:** 4 staff over four months.
- **Output:** ~ 500 poles (9 m each).
- **Total cost:** ~ FJD $20,000 → ~ FJD $40 per pole .

Lessons learnt

Inconsistent heating and uneven boron concentration caused variable quality and discoloration, indicating that temperature control and uniform agitation are essential for scale-up. Nevertheless, the system achieved higher penetration rates than cold soaking.

By comparison, established industries in Indonesia produce treated poles for USD $0.50–2.00 each, illustrating the current cost gap due to Fiji's small scale and import dependence.

Boron solution was reused across five consecutive treatment cycles without measurable decline in performance. When disposal is necessary, the solution can be safely diluted with water, as boron acts as a plant micronutrient at low concentrations.

The following Table 8 summarises the treatment trials carried out by Pacific Ark:

Parameter	Indicative Cost (FJD)	Notes / Fiji Context
Community culm access	$2 per 9m pole	Informal payments to landowners (Mataqali)
Harvest Labour	$45 per day x 2-3 workers	~20 poles (3.5m) in 6 hours
Truck Transport	$100 per day	Distance and access dependant
Treatment setup (small scale)	$750-$2,500	Locally sourced and manufactured
Chemical Inputs	$200-$450 per 25kg bag	Inconsistent supply, imported
Treatment Labour	$90-$180 per cycle	Skilled handling required
Total Cost / 20 Poles Cycle	$1,000 to $1,200	~ $40-$60 per pole
Hot Immersion System	~$40 per Pole	Higher efficiency, higher setup costs

Table 8: Summary of treatment trials carried out by Pacific Ark

7.4 Construction and Joinery

Pacific Ark has constructed Fiji's first bamboo market store at Da Roko Settlement (Figure 7-3), a bamboo-based playground at Urata Primary School (Figure 7-4), shade shelters, and eco-tourism prototypes in Savusavu, using locally processed poles and hand-crafted joinery. These builds have proven bamboo's load-bearing strength, versatility, and aesthetic potential when combined with modern connection systems, reinforced footings, and appropriate design detailing. They also revealed practical constraints such as irregular supply of mature poles, limited availability of treatment facilities, and the absence of engineer approved structural templates for any type of certification.

Figure 7-3: Da Roko Settlement Market Stall: Step-by-step construction of demonstration bamboo build, from framing to finished structure

Figure 7-4: Urata Kindergarten bamboo playground: Step-by-step construction of demonstration bamboo build, from testing the bamboo's bending limits, framing to finished structures

7.5 Training and Community Engagement

Pacific Ark's team has delivered hands-on training and awareness programs in collaboration with the Ministry of Forestry, reaching over forty participants across multiple villages, for example Naloaloa Village (Figure 7-5). These sessions covered bamboo propagation, selective harvesting, treatment methods, and basic construction joinery. The participatory approach, learning by doing, proved the most effective model for community skill transfer and long-term adoption.

Figure 7-5: Community engagement in Naloaloa Village on bamboo harvesting, clump management, and awareness of bamboo's ecological and cultural significance by Pacific Ark (Oct 2023)

7.6 Field Research and Data

Pacific Ark has documented every stage of the process, collecting empirical data on treatment retention, processing waste ratios, curing times, and construction performance. This evidence base provides the first locally verified technical inputs for bamboo's performance under Fijian conditions. The findings directly support the development of national treatment guidelines, processing standards, and training modules under the Ministry of Trade's ISO adoption framework.

Key Insights and Lessons Learned

- **Supply:** Need for structured species propagation, clump management, and sustainable harvesting cycles
- **Treatment:** Standardised boron diffusion and VSD methods can deliver long term durability with local materials
- **Processing:** Absence of mechanised facilities limits scaling; semi-mechanised tools are essential for consistency
- **Construction:** Bamboo performs well structurally but requires engineered designs and certification pathways
- **Market:** Early demand is emerging from schools, resorts, and rural community projects for low-cost, climate-resilient infrastructure

Together, these demonstrations position Pacific Ark as Fiji's leading field laboratory for bamboo construction, translating research into built evidence and validating bamboo's potential in real-world conditions, and informing both national policy and community practice (Figure 7-6).

Figure 7-6: Completed bamboo works, from artifact and construction in Indonesia to prototypes in Fiji, demonstrating cross regional knowledge transfer and craftmanship by Pacific Ark

8 Sustainability Analysis

The following section presents a sustainability analysis of bamboo cultivation, harvesting, treatment, and processing for construction in Fiji. It considers the environmental, social, and economic strengths and challenges.

8.1 Environmental Sustainability

8.1.1 Environmental strengths

Bamboo offers significant environmental benefits that align closely with Fiji's sustainability and climate resilience goals. These include its widespread availability, ability to restore degraded lands, substitute for conventional timber, rapid growth, carbon storage in harvested products, and its potential to replace energy-intensive materials like steel and concrete.

Fiji's abundant bamboo resources represent a significant yet underutilised opportunity for meeting the demands from the construction sector. Out of all bamboo species *Bambusa vulagris* is the most widespread, typically found growing along streams and rivers in forest environments. A recent bamboo inventory in the Naitasiri province revealed 4,992,678 culms of *Bambusa vulagris* with a clump density of 30 clumps/ha (GGGI, 2025). If managed under a sustainable rotation of 506 years, this volume could equate to an estimated 800,000 to 1 million harvestable poles per year, enough to meet local demand for community infrastructure, small housing and furniture production. While a national inventory would offer a more comprehensive understanding of the resource's extent, this study gathered critical insights into the availability and distribution of bamboo clumps. Harvesting bamboo from forests will help in preventing resource degradation since overmature culms are prone to drying out, turning brittle, dying, and decomposing.

In addition to natural forests, planting bamboo on degraded lands including *talasiga* grasslands and riparian zones can not only help in meeting industrial demands but also facilitate ecological restoration by improving soil, water and biodiversity functions of landscapes. It can also be used for restoring degraded mining areas because of its shallow root system, which stabilises soil and enhances fertility by increasing the amount of organic carbon and nutrient cycling[69].

Globally, over 25% of timber harvested from forests is consumed by the construction sector. Rising human populations across Fiji has fuelled the demand for construction materials including timber for which may accelerate natural resource depletion. Bamboo has emerged as a sustainable and innovative building material since it is a viable substitute for timber, with a sustainability profile that is over 20 times higher than that of wood[70]. Bamboo has many benefits as a building material, such as affordability, strength, and availability along with a smaller environmental impact. It is one of the most versatile renewable materials due to its remarkable tensile strength (28,000 pounds /square inch), which is even greater than that of steel (23,000 pounds/square inch)[71]. Diverting construction demands from timber and energy intensive materials like concrete and steel to bamboo can help in forest conservation while reducing the carbon footprint.

Bamboo's fast growth rate, short rotation, and ease of establishment make it an ideal candidate for afforestation and reforestation programmes which aligns well with Fiji's 30 million trees in 15 years and the RDF programmes. Typically, culms can reach their maximum height in one growing season though they need five growing seasons to reach full maturity. Consequently, bamboo is considered among the fastest growing plants on earth with

[69] FAO and INBAR, 2018
[70] Xu et al., 2022
[71] Adebowale and Agumba, 2024

growth rates ranging between 30 to 100 cm in most species. However, Moso bamboos can reach growth rates exceeding 1m/day in their fast growth stage which is hundreds of times faster than that in timber trees[72]. Bamboo also has high biomass productivity ranging between 22 to 44 Mt/ha/year which is higher than fast growing trees such as pine (25 to 30 Mt/ha/year) and comparable to eucalyptus (30 to 40 Mt/ha/year)[73].

Bamboo's high carbon sequestration capacity allows it to act as a long-term carbon sink including when used as a durable construction material. A global review of 184 studies covering 70 bamboo species estimated ecosystem carbon stocks ranging between 94 to 392 tC/ha. This includes an aboveground, belowground and soil sequestration of 16-128, 8-64, and 70-200 tC/ha respectively[74]. While these values are below that for most natural forest ecosystems, they are comparable to managed tree plantations, and higher than those for agroforests, oil palm, swidden fallows, grasslands, and pastures.

In addition, bamboo contributes to emissions reductions through 'product displacement' wherein it can be used as a substitute for energy-intensive construction materials such as steel and concrete. While carbon stored in the durable products pool ranges between 30-134.7 tC/ha, product displacement avoids the emissions of 24.5-109.9 tC/ha over a 30-year period[75]. Although these aspects of bamboo are currently not a part of existing mechanisms under the Paris Agreement (CDM and REDD+), there is immense potential for inclusion in future emission reduction protocols. Bamboo could also be integrated into existing emissions reduction pathways under Fiji's Low Emission Development Strategy (LEDS) which aims to decarbonise the economy by 2050.

8.1.2 Environmental challenges

Despite the environmental advantages, several challenges impede the large-scale utilisation of bamboo resources in Fiji. These include inconsistent supply chains, informal propagation practices, lack of sustainable harvesting guidelines, environmental risks of chemical treatment, and methodological and institutional gaps.

Sourcing raw materials for meeting industrial demands remains a major concern, largely due to the limited availability of species suitable for the construction sector and the absence of bamboo cultivation practices. This has resulted in inconsistent supply chains with variations in species, maturity, and quality which can affect product reliability and performance.

Current bamboo propagation practices in Fiji rely on informal exchanges of culms, and rhizomes, often of mixed or unidentified species. There are no dedicated bamboo nurseries or genetic repositories ensuring quality planting stock. This limits large scale planting and reduces the ability to match species to site conditions. Without proper gene banks and certified nurseries, farmers will struggle to access reliable, construction grade varieties.

Despite widespread bamboo availability in and around forests, the absence of sustainable harvesting guidelines makes it challenging to meet environmental outcomes. Without clear information regarding when, how, and how much to harvest, there is a risk of overexploitation. Unsustainable harvesting practices such as cutting immature culms or damaging the rhizomes can impede regeneration rates while diminishing the quality and durability of bamboo.

While traditionally species such as *B. vulgaris* which are highly vulnerable to insect damage are treated by smoking, heating, and water leaching, meeting commercial demands for large scale construction projects may

[72] Jin et al., 2021
[73] Rathour et al., 2022
[74] Yuen et al., 2017
[75] INBAR, 2018

require the application of non-traditional methods such as chemical treatment. These chemicals often pose environmental and health risks, especially if not handled properly during and post-treatment[76].

Bamboo remains globally underrepresented in carbon certification frameworks owing to its categorisation as a NTFP, and the lack of recognised carbon methodologies, and standardised measuring, reporting, and verification (MRV) standards[77]. In Fiji, inadequate documentation of bamboo species and mapping of their distribution, lack of silvicultural techniques, species-specific allometric models for biomass estimation, and institutional and policy gaps are key challenges to including bamboo within national carbon frameworks such as REDD+.

8.2 Social Sustainability

8.2.1 Social strengths

Bamboo holds cultural significance in Fiji where it is used for meeting the subsistence needs of communities related to farming, fishing, and medicine. It is used for constructing traditional bures which are relatively more cyclone-resilient than modern housing structures[78]. Beyond traditional use, bamboo now represents a bridge between heritage and innovation, offering both cultural continuity and new livelihood opportunities in rural Fiji.

It is used for light housing and construction, fencing, tools, rafts, and crafts[79]. Species such as *Bambusa vulgaris* are also valued in traditional medicine. Local communities possess valuable traditional knowledge on bamboo harvesting and utilisation. Strengthening the traditional utilisation of bamboo would support local craftsmanship while enhancing cultural resilience. Incorporating traditional knowledge into modern practices would offer locally adapted solutions for resource management and construction.

In Navala, the last remaining Fijian village with traditional *bures*, bamboo has been used for constructing cyclone resilient housing with bamboo walls and thatching have been found to withstand multiple Category 4-5 cycles, including Winston (2015) and Yasa (2020)[80]. Its innate flexibility and elasticity ensure efficient absorption and distribution of impact energy allowing it to withstand environmental stresses such as strong winds more effectively compared to conventional timber structures[81]. In countries vulnerable to climate change such as Fiji, treated and engineered bamboo can further enhance the durability and safety of such buildings allowing them to withstand natural disasters more efficiently. Promoting bamboo for affordable and resilient housing would not only preserve cultural heritage but also contribute towards climate adaptation and disaster risk mitigation.

Bamboo can provide viable opportunities for community empowerment among rural and marginalised communities including women and youth groups across Fiji. The sector can contribute towards social sustainability by strengthening community cohesion, promoting inclusive participation, and enhancing livelihoods. Owing to its accessibility and widespread availability, it can be utilised as a raw material for micro, small and medium enterprises (MSMEs) based on handicraft and furniture making. Community-based projects can encourage collaboration and skill-sharing while technical training can empower individuals by enhancing their ability to generate viable income streams. Local craftsmen such as S. Soko have been running value-adding training for women and youth groups to enhance livelihood opportunities. Supporting local trainers while

[76] Gauss et al., 2021
[77] Ayer, 2025
[78] Elkharboutly & Wilkinson, 2022
[79] Elkharboutly & Wilkinson, 2022; Kasanawaqa et al., 2024
[80] Elkharboutly & Wilkinson, 2022
[81] Adier et al., 2023

facilitating the exchange of knowledge and skills with international bamboo experts would foster inclusive growth and strengthen community networks across Fiji.

8.2.2 Social challenges

Bamboo holds immense potential for driving widespread inclusive community development across Fiji, offering opportunities for income generation, employment and cultural revitalisation. However, realising the social sustainability of bamboo faces several challenges. These include a lack of awareness, insecurity of land tenure, and inadequate technical capacity for cultivation, harvesting and treatment.

Across Fiji, bamboo is still widely viewed as a “wild grass” or “bush material” rather than as a valuable non-timber forest product. There is also a misconception that bamboo products typically only last short term up to 6 months, which stems from the lack of exposure to modern yet simple treatment methods. Limited education, research and public campaigns implies that communities, policymakers, and investors remain largely unaware of bamboo’s modern applications in handicrafts and construction sectors. The absence of demonstration models contributes to poor public understanding of bamboo's potential. Weak institutional and policy frameworks discourage investment in the sector while impeding technology transfer from bamboo producing countries. Changing perceptions will require stronger awareness programmes, demonstration models, and practical examples of bamboo being used successfully in houses, resorts, and community infrastructure.

Fiji's land tenure system presents both an opportunity and a challenge. Over 84% of the land is communally owned under *Mataqali* (clan) systems, which can make leasing or long-term investment complex. Since bamboo is a long-lived crop (20-50 years lifespan), investors and communities require clearly defined benefit-sharing and lease models to ensure fairness and long-term sustainability. Where tenure arrangements are transparent and inclusive, Fiji’s communal land ownership can foster shared responsibility, social cohesion, and sustainable livelihoods. However, insecurity of land tenure can hinder long-term investments and the adoption of sustainable practices. This is particularly true for land under agricultural leases where concerns over non-renewal of lease terms have long driven unsustainable land use practices[82].

While there is growing interest in bamboo, few farmers or builders have the technical capacity for cultivation, harvesting, and treatment. Lack of knowledge and skills in clump management, spacing, treatment, or post-harvest handling, may lead to poor quality construction poles reducing their market value. However, training programmes are sporadic and lack integration into extension services. Consequently, even after years of introduction into Fiji, value chains are practically non-existent with bamboo remaining a largely underutilised resource.

8.3 Economic Sustainability

8.3.1 Economic strengths

Bamboo can contribute towards economic sustainability in Fiji through its affordability, versatility, and capacity to support local livelihoods. It can be used for lost cost affordable housing, reducing dependence on imported construction material, and employment generation. As the sector matures, it could form part of Fiji’s emerging green economy, creating local value chains in plantation establishments, treatment, processing and construction.

[82] Harrison and Karim, 2016

Several studies have established the construction potential of bamboo as a sustainable low-cost renewable material[83]. In terms of economic benefits, bamboo-based houses demonstrate significant cost efficiency, requiring approximately 25.5 m3 less wood and incurring only half the construction cost of timber houses[84]. In Ethiopia, the cost of constructing bamboo houses in towns is higher than that in rural areas where bamboo is harvested from communal lands and houses constructed using communal labour[85]. A similar dynamic may be applicable to Fiji, where bamboo is abundant on native lands and the traditional practice of *solesolevaki* (collective community effort) could substantially reduce construction costs while enhancing access and affordability of bamboo housing.

The development of a bamboo-based construction sector has the potential to significantly reduce dependence on imported building materials such as timber, steel, and cement. According to the Fiji Bureau of Statistics (2024), the construction industry imports over FJD $500 million worth of building materials annually. Even partial substitution of 10% with locally produced bamboo could retain more than FJD $50 million within the domestic economy, while creating new green employment opportunities. Promoting the cultivation, harvesting, processing, and utilisation of local bamboo resources will enable Fiji to strengthen its domestic supply chains while generating and retaining economic value within the country. Such a transition will support local self-sufficiency and enhance rural livelihoods while reducing carbon footprints associated with the import of construction materials.

Utilising bamboo in the construction sector can create skilled and semi-skilled jobs at multiple stages along the value chain, from planting, harvesting and treatment to design, prefabrication, and on-site building. Decentralising the production process can foster the growth of bamboo-based MSMEs providing sustainable livelihoods to producers, processors, and construction workers. Through such initiatives the bamboo sector can become a driver of green growth, social inclusion and economic resilience in Fiji.

8.3.2 Economic challenges

Bamboo has significant potential for driving economic sustainability across rural communities in Fiji. However, the absence of standards and codes, and policy and financial support are major limitations that hinder economic progress.

Countries such as China, India, Peru, Colombia, and Ecuador have put in place bamboo construction standards and codes. However, in Fiji the absence of such frameworks remains a major limitation for mainstreaming bamboo in the construction sector. Without these regulatory frameworks, designers, builders, and architects face uncertainty regarding quality, safety, and compliance which restricts the application of bamboo as a construction material. Most bamboo builders continue to rely on traditional knowledge and personal experience rather than standardised guidelines. A global review of bamboo standards and codes revealed that existing bamboo standards and codes are based on ISO standards which may be inadequate and should be updated to reflect advances in testing methods, material characterisation, and novel engineered products[86]. Any future guidelines for Fiji should take into account new knowledge generated from testing local bamboo species, ensuring that standards and codes are relevant and applicable to the country's specific context.

Another key limitation to valorising the country's bamboo resources is the lack of policy and financial support. While bamboo has high potential for construction, handicrafts, and carbon sequestration, the lack of formal

[83] Boity et al., 2022; Adebowale & Agumba, 2024
[84] INBAR, 2017
[85] Kibwage et al., 2011
[86] Amede et al., 2021

recognition in national policies, remains a key challenge for producers and investors. In the absence of microcredit or support for certification programs, bamboo growers and entrepreneurs face high upfront costs with uncertain returns discouraging investment in the sector. This policy gap coupled with weak inter-agency cooperation, tenure complexities, and poor public awareness impede the sustainable development of Fiji's bamboo sector.

8.4 Overall sustainability analysis of Fiji's bamboo sector

The following Figure 8-1 summarises the environmental, social and economic sustainability analysis of Fiji's bamboo sector detailed in sections 8.1 to 8.3.

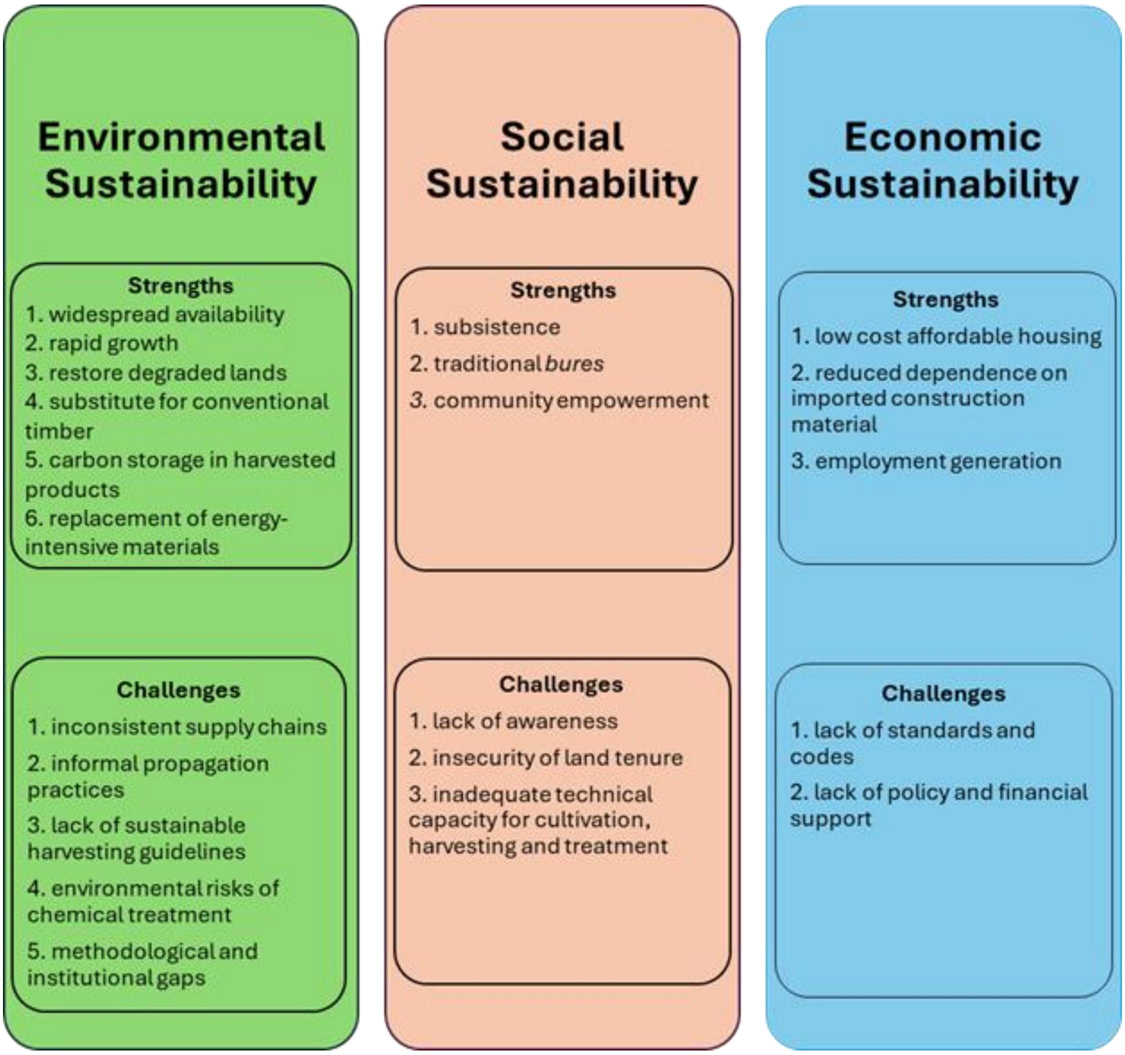

Figure 8-1: Sustainability analysis of Fiji's bamboo sector

9 Guidelines for Sustainable Methods for Cultivating, Harvesting, Treating and Processing Bamboo for use in Construction in Fiji

The following section presents the recommended guidelines for Cultivating, Harvesting, Treating and Processing Bamboo for use in Construction in Fiji. The details of the recommended methods are in Section 6.

9.1 Cultivating

The four species exhibiting the highest potential for structural applications in Fiji are *Bambusa balcooa*, *Bambusa vulgaris*, *Dendrocalamus giganteus*, and *Dendrocalamus asper*. Among these, *Bambusa balcooa* and *Dendrocalamus asper* show the greatest potential for high-strength structural applications based on global experience. *Bambusa vulgaris* remains the most widespread species and serves as the primary local resource for community-scale construction and pilot testing.

Utilising native or naturalised bamboo species can lower transportation costs, promote ecological adaptation, and uphold cultural continuity. Species selection should consider local rainfall, soil fertility, and access to markets or treatment facilities, ensuring that each site species combination supports both ecological and logistical efficiency.

Bamboo should ideally be cultivated in the high rainfall windward zones of Fiji which is conducive for shoot emergence and rhizome expansion. Practices such as mulching, biochar application, contour bunding, water harvesting, or intercropping with shade plants can retain soil moisture and maintain active root growth in the drier leeward zones, where long dry spells may suppress young culms and reduce clump vigour. Alluvial soils along streams and rivers are the most appropriate for bamboo cultivation while clay loams and lateritic soils require organic amendments such as crop residues and poultry manure. Bamboo is vulnerable to excessive waterlogging which can cause rhizome rot and culm mortality. Adequate drainage can be achieved through raised planting mounds (30–50 cm), contour drains, or vegetative barriers using vetiver grass or lemon grass on steep slopes.

Ensuring a consistent supply of raw material for the bamboo industry calls for enhancing local production. The establishment of bamboo agroforestry and plantations on degraded lands, riparian zones, and steep slopes therefore becomes critical. For quality assurance, gene banks should be established for conservation of elite species, provide high quality planting material, and enable training in propagation techniques, including public awareness, and capacity building. Vegetative propagation techniques such as rhizome, branch or culm cuttings will be the most appropriate and cost-effective for establishing nurseries owing to uncertainties associated with bamboo flowering and seed supply.

Clump management prevents overcrowding ensuring the production of high-quality clumps. It should involve a combination of approaches including identification of species, inventory, maintenance, and soil care. Clump type, culm characteristics, and leaf and sheath traits serve as visual indicators for species identification. Inventory includes counting the number of culms, classifying culms by age, coding culms, and measuring culm diameters.

The B.S.B.O.D. (Bent, Short, Broken, Old, Diseased) system can help in monitoring clump health (see section 6.3.2). Regular cleaning and removal of these culms improve airflow and shoot regeneration. Mounding and fertilisation can strengthen root systems, enhance nutrient uptake, and promote new shoot emergence.

9.2 Harvesting

Knowing the age of the culms ensures that they are harvested when their mechanical strength and durability are at their peak, which is typically between three and six years. Harvesting too early reduces density and strength, harvesting too late results in brittleness.

Culm age can be determined by counting branch whorls (each representing a rainy season), examining surface colour and lichen density, or using the resonance test (a clear, ringing sound indicates a mature culm, see section 6.3.2).

In Fiji, where rainfall varies regionally, harvest schedules should be adjusted based on observed regeneration cycles and seasonal humidity. For example, coastal lowlands may yield harvest-ready culms within three years, while higher altitude clumps in the interior may take up to five.

To support community harvesting, simple field coding should be encouraged. This can be done by marking culms or stakes with paint to indicate planting year, estimated harvest year, and farmer initials. Colour-coded systems (e.g. green for 1-year-old, blue for 3-year-old, red for 5-year-old) are effective for managing multiple clumps and preventing overharvesting.

Harvesting must follow selective cutting principles, removing only mature culms while preserving younger generations and rhizome health. Cuts should be made 2–3 nodes above ground level, just above a node to prevent water accumulation and decay. Training programs led by the Ministry of Forestry and local partners should focus on these good harvesting practices, including tunnel or horseshoe methods for accessing mature culms.

9.3 Treatment and processing

Treatment is a critical step in ensuring bamboo's long-term durability and structural reliability, particularly in Fiji's humid tropical climate where untreated bamboo typically degrades quickly. Proper treatment can extend the material's lifespan to over 25 years, allowing it to compete with conventional timber in strength and resilience.

Natural treatment methods are widely practiced and culturally significant, often considered more economical and environmentally friendly than chemical alternatives. In Fiji, traditional methods such as smoking, water leaching, and open-air drying are most common in rural areas. While these techniques provide short-term protection against insects, they are unsuitable for structural applications because they fail to penetrate the inner culm and achieve uniform preservation.

For construction-grade bamboo, Fiji should progressively transition toward controlled, low-cost, non-traditional treatment systems that are scalable for community and commercial use. Considering cost, effectiveness, eco-friendliness, and ease of setup, the most appropriate methods for Fiji are Cold Immersion, Hot Immersion, Vertical Soak Diffusion (VSD), and potentially the Modified Boucherie method.

Trials conducted by Pacific Ark in Savusavu (2024–2025) confirmed that the VSD method achieved full boron penetration within 10–14 days using locally built setups costing around FJD $750, while Hot Immersion systems using borax-boric acid solutions showed similar protection with faster processing but higher setup costs (around FJD $2,500).

The use of environmentally friendly preservatives such as boric acid, borax, and polycarboxylic acid is recommended, as they provide effective protection against fungi, borers, and termites while remaining non-toxic to humans and the environment. These methods align with ISO 22156:2021 guidelines, which recommend a minimum boron retention of 4 kg/m³ of bamboo tissue to ensure resistance to biological degradation.

Following treatment, processing methods such as sizing and straightening, splitting and slivering, planing, sanding, lamination, and joinery should be applied to prepare bamboo for construction or prefabrication. Community treatment hubs or small-scale cooperative facilities could significantly reduce processing costs and improve quality consistency, providing a foundation for Fiji's emerging green building industry.

10 Recommendations for Sustainable Bamboo Sector in Fiji

10.1 Enhancing local production to meet industrial demand

Meeting rising demand for cyclone-resistant, sustainable building material calls for enhancing local production through the establishment of bamboo agroforestry and plantations on degraded lands, riparian zones, and steep slopes. This would divert pressure on existing forests for meeting timber demands, lower import bills, and generate employment opportunities in rural areas.

Bamboo is a valuable component of agroforestry systems due to its rapid growth, coupled with its potential to generate a suite of ecological and economic benefits. In Fiji, bamboo can be integrated into home gardens, windbreaks, and alley cropping systems. Other viable land use options include bamboo-based intercropping with shade-bearing crops such as vanilla, ginger, and turmeric, and bamboo with cash crops such as cocoa and coffee. Bamboo plantations on degraded and marginal lands will contribute towards ecological restoration while meeting the raw material demands of the construction sector. This is in line with international agreements like the Bonn Challenge and the New York Declaration on Forests, as well as national initiatives like the 30 million trees in 15 years and the Reforestation of Degraded Forests (RDF) programs.

10.2 Establishing nurseries and gene banks to ensure good quality planting stock

In Fiji, setting up community bamboo nurseries of species such as *Dendrocalamus asper*, *Dendrocalamus giganteus*, and *Bambusa Balcooa*, supported by the MoF and relevant development partners, would be a crucial step towards addressing the lack of quality planting material. They could be managed by women and youth groups registered as cooperatives to ensure access to government schemes and incentives. These facilities would serve as the foundation of a national bamboo propagation and distribution network, ensuring the availability of genetically superior, high-yielding, and locally adapted species. These could also serve as training hubs and demonstration sites, offering capacity-building programs for land managers and extension officers. In the long term, a coordinated nursery network would facilitate the establishment of community-based plantations, agroforestry systems, and restoration projects on degraded and marginal lands.

Gene banks would be a strategic intervention to conserve the country's bamboo genetic resources and support long-term sectoral development. Currently, the diversity, distribution, and genetic characteristics of Fiji's bamboo resources are poorly documented. This poses a risk of genetic erosion, limiting the country's capacity to identify species suitable for different ecological zones. Establishing a national bamboo gene bank coordinated by the MoF in collaboration with research organizations like FNU and The Pacific Community (SPC) would enable the systematic documentation, collection, and preservation of native and introduced bamboo germplasm.

10.3 Developing a sustainable bamboo harvesting code of practice

Although Fiji has the Forest Harvesting Code of Practice 2013, which provides species-specific diameter limits for harvesting timber trees, there is very limited information on NTFPs. In order to avoid the overexploitation and degradation of resources, there is a strong need for a Sustainable Bamboo Harvesting Code of Practice tailored towards Fiji's ecological conditions, socio-economic contexts, and policy frameworks. A national harvesting code could be developed by the MoF in collaboration with research organizations, local communities, and the private sector to provide scientific guidelines on key aspects of bamboo management. This includes specifying harvest maturity thresholds to ensure good quality culms, harvesting intensity and frequency for sustained natural regeneration, rhizome protection to minimize soil disturbance, selective harvesting to maintain productivity and clump health, and post-harvest management practices such as thinning, cleaning, and fertilization to sustain long-term yield.

The code should include monitoring mechanisms to systematically track culm age, number of culms harvested, and regeneration rates within each stand. Communities should be trained to submit annual reports outlining harvest volumes, stand conditions, and regeneration success. Compliance should be ensured through periodic field inspections and cross-checking the reports with actual on-ground field conditions. In order to enhance adherence to the code, a certification mechanism similar to Fiji Pine's Forest Stewardship Council (FSC) certification should be developed. Compliant harvesters could be rewarded with access to niche markets, while non-compliance could trigger corrective actions or suspension of certification.

10.4 Developing treatment and processing facilities

Collaboration with Fiji Pine and the MoF's Timber Training and Utilization Division offers a practical way to jumpstart the bamboo sector by leveraging existing kilns, drying and processing spaces, along with technical expertise in preservation and processing. Partnerships could include technical exchange, R&D, and training programs, helping communities, entrepreneurs, and MSMEs gain early-stage capacity. Over time, these shared facilities could evolve into dedicated bamboo treatment and processing centers near major bamboo growing areas, equipped with eco-friendly treatment systems and modern machinery for splitting, drilling, pressing, and molding. These centres could serve as innovation and training hubs, while mobile treatment units extend services to remote localities, reducing costs and ensuring equitable access. Collectively, such an approach would enhance bamboo durability, promote local entrepreneurship, and support the sustainable growth of Fiji's bamboo industry.

10.5 Linking bamboo with carbon markets

Bamboo directly supports Fiji's REDD+ goals, national adaptation plans, and climate change commitments. It ensures high rates of carbon sequestration in plantations, emissions reductions through product displacement, and carbon storage in durable product pools. In addition, it regenerates degraded land while creating opportunities for sustainable income. Bamboo becomes more than just a building or agricultural material when it is positioned inside these frameworks; it becomes a strategic, nature-based solution. By incorporating bamboo into policy and rural development programs, several obstacles can be overcome by gaining institutional support, finance, and research.

Developing a bamboo blockchain carbon credit system in Fiji is an inclusive and transparent approach to monetise bamboo's high carbon sequestration potential while empowering landowners. By combining blockchain technology with bamboo-based agroforestry systems, each stand could be digitally registered, monitored, and verified for carbon capture, allowing the issuance of traceable digital carbon tokens on a secure ledger. Smart contracts would automate benefit-sharing among landowners, investors, and developers, ensuring fair and transparent revenue distribution while preventing double-counting[87]. This approach aligns with Fiji's communal land ownership structure, National Carbon Market Strategy, and inclusive green growth principles.

Fiji can learn from both local and international initiatives. Drawa's Rainforest REDD+ project provides an exemplary example, where eight *Mataqalis* have committed their lands to forest conservation and ensuing REDD+ carbon payments for over 18,000 carbon credits annually. The Drawa Block Forest Community Cooperative administers member dividends, promotes income-generating opportunities, and enhances village infrastructure as part of its community development initiatives[88]. This model can be adapted for bamboo-based production systems. In the Philippines, InfraBlocks Technologies, in partnership with the Asian Development Bank (ADB) and Rhizome, recently launched a digital platform for bamboo carbon credits for engineered bamboo plantations based on satellite imagery, blockchain, and MRV systems. In Uganda, Timeless Bamboo is collaborating on a bamboo-based carbon pilot project with Fedrok AG, a Swiss blockchain company. The initiative combines a transparency-focused digital infrastructure layer with a community-led rehabilitation effort. While Fedrok's system will document discussions, surveys, and planting programs on a secure digital ledger, women's and youth groups will spearhead mobilisation and planting operations. By leveraging these examples, Fiji could establish blockchain bamboo carbon projects that ensure digital verification through smart contracts, enhancing transparency and efficiency in emissions trading.

10.6 Capacity building through training, demonstration, and awareness programs

To address the misconceptions and underutilisation of bamboo in Fiji, a multi-pronged approach focused on training, demonstration, and awareness is needed. In collaboration with community-based organisations, vocational schools, the private sector, and NGOs, a nationwide network of bamboo training and demonstration facilities with an emphasis on technical and entrepreneurial skills should be established. By merging traditional Fijian practices like bure construction and farming methods with contemporary structural and treatment approaches, these centers would offer practical, technical, and entrepreneurial training on sustainable harvesting, low-cost treatment techniques, processing, and climate-resilient design.

Training should emphasize safety, durability, and creative design while fusing traditional craftsmanship with contemporary building techniques. Collaborations with Pacific Ark, FNU, and CATD can ensure curriculum delivery that is compliant with emerging bamboo certification processes and standards. To ensure that women, youth, and people with disabilities have fair access to resources, training, and entrepreneurial possibilities, training infrastructure should be inclusive and gender responsive. Demonstration projects can focus on production systems, including bamboo agroforestry, plantations, and gene banks, alongside their construction applications, such as bamboo houses, resort features, and community infrastructure. Community workshops, school programs, and media campaigns can educate the public, policymakers, and investors about bamboo's durability and versatility in construction and handicrafts.

10.7 Strengthening tenure security for sustainable bamboo production

Strengthening tenure security, particularly for agricultural leaseholders, through longer lease terms or community-based joint ventures can encourage investment in sustainable bamboo plantations. Extension officers and traditional leaders can facilitate confidence-building measures while building local capacity. Developing benefit-sharing models with clearly defined stakeholder roles and responsibilities, transparent accounting systems, buy-back prices, environmental and social safeguards, replanting commitments, and provisions for training and technical support are crucial.

[87] Merlo et al., 2025
[88] Shah and Race, 2024

Agroforestry contracts can provide price incentives and risk-sharing mechanisms, enabling more sustainable land uses supporting poverty reduction in developing economies like Fiji. Research on communities' willingness to accept (WTA) agroforestry contracts on abandoned sugarcane leases in Fiji found a strong preference for denser, long-duration production systems with higher carbon sequestration potential, as these configurations offer more secure revenue streams compared to less dense and shorter duration contracts[89].

Introducing "Community Contractor" or "Farming Contractor" models, such as those piloted by Pacific Ark in Vanua Levu, can offer a practical pathway, allowing communities to supply bamboo poles under guaranteed buy-back schemes with private investors or government programs while retaining ownership of the resource base. This approach creates employment, builds trust, and aligns directly with Fiji's inclusive green growth principles. By empowering landowners to act as contractors rather than as passive leaseholders, this model promotes employment creation, trust-building, and equitable benefit-sharing, while supporting Fiji's inclusive green growth principles.

10.8 Developing bamboo standards and codes

Fiji should establish national bamboo construction standards and guidelines that ensure safety, durability, and quality compliance. These standards would enable engineering certification, insurance coverage, and access to funding, all of which are critical for scaling bamboo-based construction. The codes should be locally relevant, drawing from international standards like ISO 22156 and related standards, as well as cyclone performance models from the USA, Philippines, and ICC. To ensure relevance to Fiji's natural conditions and social reality, such standards must be tailored to the country's geography, culture, and climate rather than being adopted from foreign contexts. In parallel, Fiji should establish a streamlined and formalized material approval pathway to replace the current bureaucratic processes. This would allow faster evaluation and certification of bamboo products, encourage innovation, and use in both public and private construction.

Collaboration among government agencies, engineers, academic organisations, and international experts will be essential to developing and testing these codes. Together, these measures would strengthen public trust, attract investment, and position bamboo as a legitimate, safe, and sustainable construction material in Fiji. Additionally, the current material approval procedures are bureaucratic and dispersed. Therefore, creating a formalized approval process is crucial.

10.9 Policy interventions for scaling the bamboo sector

Bamboo should be incorporated as a strategic species in Fiji's upcoming Planted Forest Policy, which emphasises the role of nature-based solutions (NbS) for the restoration of degraded landscapes. As a fast-growing plant, bamboo can play a critical role in rehabilitating eroded or abandoned lands, reducing erosion, protecting water catchments, and sequestering carbon. Any future Agroforestry Policy[90] should also recognise the potential of bamboo-based production systems as pathways to support rural livelihood development, strengthening community resilience, and diversifying income streams.

Inclusion in policy would provide guidelines for cultivation, management, tenure arrangements, benefit-sharing, and market development. Policy interventions may include financial incentives such as access to microcredit, tax rebates, small grants, public procurement preferences, as well as support for certification programs that enhance market credibility and access. Integration across ministries and agencies can address implementation silos,

[89] Santos et al., 2025
[90] Shah, 2023

improve coordination between market development, policy, and research, and create an environment that is conducive to a resilient bamboo industry.

11 Conclusion

Bamboo represents one of Fiji's most promising renewable resources, capable of advancing sustainable construction, rural livelihoods, and climate resilience when cultivated, harvested, treated, and processed responsibly. This research demonstrates that with targeted interventions, inclusive governance, and technical innovation, bamboo can transition from an underutilised resource into a cornerstone of Fiji's green economy.

The findings confirm that Fiji's climate and soil conditions are well-suited for high-performance species such as *Bambusa balcooa* and *Dendrocalamus asper*, which outperform the commonly available *Bambusa vulgaris* in both strength and durability. Field trials conducted by Pacific Ark validated that bamboo can be successfully integrated into agroforestry systems, contributing to soil restoration, water regulation, and diversified income generation. Improved propagation methods, particularly vegetative techniques, and the establishment of nurseries and gene banks are critical to ensuring consistent quality and supply of planting materials.

Sustainable harvesting and treatment practices are equally essential to the sector's credibility. The adoption of selective harvesting protocols and simple monitoring systems such as the B.S.B.O.D. method enhance both clump productivity and ecological health. Likewise, the use of boron-based Vertical Soak Diffusion and Hot Immersion treatment methods has proven effective and economically feasible, extending bamboo's lifespan to over two decades while remaining environmentally safe. Developing regional treatment and processing hubs will help standardise quality, lower costs, and empower communities to participate in every stage of the value chain.

The research also emphasises that social inclusion and traditional knowledge must be embedded throughout the bamboo lifecycle, from cultivation and harvesting to design and processing. Women, youth, and local artisans play a vital role in bamboo craftsmanship and innovation; thus, capacity-building and training programs must remain accessible, gender-responsive, and culturally grounded. Integrating traditional construction techniques, such as *bure* building, with modern engineering and treatment standards provides an opportunity to bridge Indigenous knowledge with technical excellence.

A sustainable bamboo sector requires an enabling policy and institutional environment. This includes the formal integration of bamboo into Fiji's building codes, national climate adaptation strategies, and sustainable land-use frameworks. Strengthened land tenure arrangements under the *Mataqali* system (traditional communal land ownersip by clans), financing support for smallholders, and linkages to carbon markets will further incentivise bamboo cultivation and restoration.

Ultimately, this report establishes a technical and practical foundation for scaling bamboo-based construction in Fiji. By aligning species selection, propagation systems, harvesting protocols, and treatment infrastructure within a coherent national framework, bamboo can evolve into a trusted, low-carbon construction material and a driver of inclusive green growth.

In doing so, bamboo becomes more than a plant, it becomes a regenerative solution linking ecosystems, economies, and communities. When cultivated and managed sustainably, bamboo can restore degraded lands, sequester carbon, support rural entrepreneurship, and symbolise Fiji's commitment to a climate-resilient and circular future built on both innovation and tradition.

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Appendices - Appendix A: Bamboo and Rattan Species in Fiji

	Latin name	Height (M)	Culm diameter (CM)	Status	Common English name(s)	Local names in South Pacific	Brief description	Main uses	Notes / Source
	Native species								
1	*Schizostachyum glaucifolium*	3-15	3.5-6	Native	Polynesian bamboo	Bitu dina (Fiji); 'ofe Samoa (Samoa)	Slender, thin-walled bamboo of forest margins	Weaving, crafts, musical instruments	Native to Fiji, Samoa, Tonga
	Naturalised species								
2	*Bambusa vulgaris*	10-25	10-12.5	Naturalised	Common bamboo	Bitu vavalagi (Fiji); Fi'i kako (Solomon Is.)	Medium bamboo; green or yellow culms	Construction, furniture, crafts, paper	Adaptable, common
	Introduced Species in Fiji								
3	*Bambusa lako*	12–21	3–10	Introduced	Timor black bamboo	Bitu loaloa (Fiji)	Glossy dark culms, tight clumps	Ornamental, furniture, construction	INBAR, GuaduaBamboo, Wikipedia
4	*Bambusa multiplex*	3–14	2–4	Introduced	Hedge bamboo		Dense, small, ornamental species	Ornamental, hedge	NParks, FAO
5	*Bambusa oldhamii*	10–20	5–10	Introduced	Green / Giant timber bamboo		Straight, thick-walled culms, fast-growing	Construction, shoots, crafts	Wikipedia, BambooLand
6	*Bambusa textilis var. gracilis*	6–10	2–4	Introduced	Weaver's bamboo		Fine, smooth, high-strength culms	Weaving, ornamental	BambooLand, Palmco
7	*Bambusa tuldoides*	10–20	5–8	Introduced	Verdant punting-pole bamboo		Erect, dense clumps, straight culms	Fishing rods, poles	FAO, INBAR
8	*Bambusa ventricosa*	3–8	3–6	Introduced	Buddha belly bamboo		Swollen internodes; ornamental	Ornamental, potted	Wikipedia, Tropical Plants
9	*Bambusa vulgaris 'Wamin'*	3–5	4–8	Introduced	Dwarf Buddha belly bamboo		Swollen short nodes; dwarf	Ornamental	Nursery listings
10	*Bambusa vulgaris 'Vittata'*	8–15	8–10	Introduced	Yellow stripe bamboo		Yellow culms with green stripes	Ornamental, fencing	FAO, INBAR
11	*Bambusa balcooa*	5–30	2.5–10	Introduced	Strong bamboo		Very strong, thick-walled culms	Construction, scaffolding, laminated boards	ProSEA, INBAR
12	*Dendrocalamus asper*	15–30	8–20	Introduced	Asper bamboo	Bitu levu (Fiji)	Large, thick-walled, multi-purpose bamboo	Construction, furniture, shoots	FAO, INBAR
13	*Dendrocalamus giganteus*	20–35	10–30	Introduced	Giant bamboo		Very large bamboo, thick-walled	Construction, pulp, crafts	Wikipedia, FAO
14	*Dendrocalamus latiflorus*	14–25	8–20	Introduced	Taiwan giant bamboo		Medium-large, glossy culms	Shoots, furniture, pulp	FAO, INBAR
15	*Dendrocalamus brandisii*	20–30	8–15	Introduced	Thai / Brandis bamboo		Straight, thick culms, large nodes	Construction, crafts	ProSEA, INBAR
16	*Gigantochloa apus*	15–25	5–10	Introduced	String / Tashbir bamboo		Straight, flexible culms	Furniture, weaving	FAO, Tropical Plants
17	*Gigantochloa atter*	15–25	5–10	Introduced	Black bamboo		Dark brown-black culms	Furniture, weaving	ProSEA, Tropical Plants
18	*Thyrsostachys siamensis*	7–13	2–6	Introduced	Monastery bamboo		Tight clumps, straight pale green culms	Construction, crafts, shoots	BambooInfo, INBAR
19	*Bambusa pervariabilis × D. latiflorus*	10–20	6–12	Introduced	Beema bamboo (hybrid)		High-biomass hybrid bamboo	Biomass, carbon sequestration	INBAR, Bioenergy trials
20	*Pogonatherum paniceum*	0.5–1.5	-	Introduced	Bamboo grass		Small, ornamental grass-like bamboo	Ornamental	Nursery data
	Potentially in Fiji (TBC)								
21	*Bambusa nutans (possible TBC)*	8–20	5–10	Trial (possible)	Nodding bamboo		Culms nodding at tips	Construction, crafts	SPC trials
22	*Bambusa blumeana (possible TBC)*	15–25	8–15	Trial (possible)	Thorny bamboo		Very thorny clumps, thick-walled	Construction, fencing	FAO Pacific record
23	*Gigantochloa levis (possible TBC)*	15–30	8–12	Trial	Philippine giant bamboo		Smooth internodes, tall, strong	Construction, pulp	FAO Pacific record
	Rattan Species in Fiji								
24	*Calamus vitiensis*	10–30	—	Native	Fiji rattan	Wa ni gasau (Fiji)	Climbing palm with spiny sheaths and flexible stems	Weaving, furniture, handicrafts	Most common native rattan; poor survival in coastal lowlands (Smith, 1979; MoF 2024)
25	*Calamus erinaceus*	10–25	—	Introduced	Australian rattan		Climbing palm with long, durable canes; thrives at lower elevations	Furniture, binding, handicrafts	Observed in Savusavu; better coastal survival than C. vitiensis (Pacific Gene Pool 2025)

ABOUT THE GLOBAL GREEN GROWTH INSTITUTE

The Global Green Growth Institute was founded to support and promote a model of economic growth known as "green growth", which targets key aspects of economic performance such as poverty reduction, job creation, social inclusion, and environmental sustainability.

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