



# Proceedings

# 5<sup>th</sup> WORLD TEAK CONFERENCE

GRAND HYATT KOCHI, BOLGATTY, KERALA, INDIA

Sustainable Development of the Global Teak Sector  
Adapting to Future Markets and Environments

*Organisers*



**ITTO**  
INTERNATIONAL TROPICAL  
TIMBER ORGANIZATION



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## **Proceedings of the 5<sup>th</sup> World Teak Conference 2025: Sustainable Development of the Global Teak Sector: Adapting to Future Markets and Environments**

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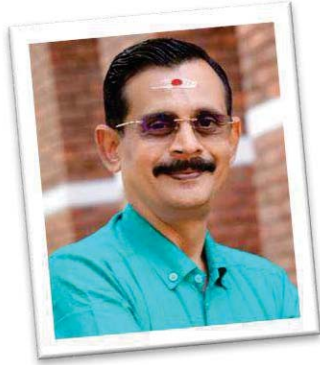
## Preface

The 5<sup>th</sup> World Teak Conference (WTC) brings together people from across the global teak community—policymakers, researchers, forest managers, plantation owners, industry leaders, traders, and other key stakeholders—onto one common platform. Building on the strong foundation laid by previous World Teak Conferences, the 5th WTC creates space for open dialogue, shared learning, and meaningful collaboration, all aimed at supporting the sustainable management, responsible trade, and efficient use of teak resources worldwide.

The Conference explores a wide range of topics that matter to the future of teak, including cultivation practices, silviculture, genetics, plantation management, timber quality, processing, marketing, and policy development. Throughout these discussions, there is a clear focus on sustainability, legality, and value addition. Particular attention is given to emerging issues such as the impacts of climate change, evolving market trends, certification requirements, and the role of new technologies in shaping the teak sector.

Through keynote presentations, technical sessions, panel discussions, and poster displays, the 5th WTC offers an inclusive and interactive forum for sharing research findings, practical experiences, and policy insights. The outcomes of the Conference are intended to inform better decision-making, strengthen connections among stakeholders, and support the long-term sustainability and competitiveness of the global teak sector.

## Message from the conference chair



The 5<sup>th</sup> World Teak Conference 2025 served as a significant international forum for advancing dialogue on teak research, sustainable forest management, value-chain development, and responsible trade in the context of evolving global environmental and economic challenges. By bringing together researchers, policymakers, industry representatives, and development partners from diverse regions, the Conference enabled the exchange of scientific knowledge, policy perspectives, and practical experiences essential for strengthening the resilience and sustainability of the global teak sector.

The deliberations and technical contributions presented during the Conference underscored the growing importance of evidence-based decision-making, innovation, and international cooperation in addressing issues such as climate change, legality and traceability, plantation management, market transparency, and inclusive development. The Conference reaffirmed the role of teak as a strategic resource capable of contributing to sustainable livelihoods, green growth, and long-term forest conservation when managed responsibly.

The outcomes documented in these proceedings reflect the collective commitment of the global teak community to advancing best practices, fostering partnerships, and aligning research and policy efforts toward a more sustainable and equitable future for teak production and utilization. I extend my sincere appreciation to all speakers, delegates, partners, and organizing institutions whose dedication and contributions ensured the success of the 5<sup>th</sup> World Teak Conference 2025 and strengthened the foundation for continued global collaboration.

**Kannan CS Warriar**

Conference Chair

Director

KSCSTE - Kerala Forest Research Institute

Peechi, Kerala, India



## FOREWORD

### **Krishna Bahadur Singh, IFS**

Inspector General of Forests and ITTO Focal Point  
Ministry of Environment Forest and Climate Change,  
Government of India



It is a matter of pride to be associated with the 5<sup>th</sup> World Teak Conference, held in Kochi, Kerala, India. This Conference brings together policymakers, researchers, forest managers, industry representatives and other stakeholders to share insights and deliberate on sustainable paths forward for the teak sector.

Teak (*Tectona grandis*) has a longstanding legacy in India's ecological and cultural context. India's forest ecosystems exhibit rich ecological diversity that supports significant teak resources both within forests and in trees outside forests. The sustainable management of teak forests in the country reflects India's commitment to scientific and adaptive forestry practices developed over many decades. Scientific planning, systematic management, and long-term vision continue to strengthen the country's capacity to meet the future domestic teak wood demands, while maintaining ecological sustainability.

The Government of India, through the Ministry of Environment, Forest and Climate Change, has established a comprehensive framework of legislative and policy instruments to promote forest conservation and sustainable use. These include the Indian Forest Acts, the Biological Diversity Act, the Compensatory Afforestation framework, and the National Forest Policy - together underscoring the nation's dedication to conservation, biodiversity protection, and sustainable development. The Ministry has also taken initiatives to modernize forest governance and improve transparency, including the implementation of the new Working Plan Code, digitalization of the National Forest Inventory, introduction of the National Transit Permit System, and launching of the Indian Forest and Wood Certification Scheme. These efforts reflect India's resolve toward science-based, transparent, and accountable forest management.

I am confident that the 5<sup>th</sup> World Teak Conference will serve as a valuable platform for cross-learning, constructive dialogue, and international cooperation. The Conference provides an opportunity to reinforce the collective responsibility of all stakeholders towards conserving forest ecosystems while meeting the developmental needs. The outcomes of this Conference informing future strategies and partnerships that support a resilient, sustainable, and globally relevant teak sector.

(Krishna Bahadur Singh)

## Welcome Message from ITTO



I am delighted to note the convening of the 5<sup>th</sup> World Teak Conference, held in Kochi, Kerala, India, with the theme "*Sustainable Development of the Global Teak Sector: Adapting to Future Markets and Environments.*" I congratulate the organizers for hosting this important international conference in Kerala—the home of the world's first commercial teak plantations and a historic centre of teak management. The organization of this Conference, in association with other partner institutions, marks a significant milestone of global relevance in strengthening international cooperation and strategic planning for the sustainable management and utilization of teak as a renewable forest resource.

The International Tropical Timber Organization (ITTO) is an intergovernmental organization dedicated to promoting the conservation, sustainable management, use, and trade of tropical forest resources. As the only intergovernmental organization focused exclusively on tropical forests, ITTO's members represent more than 80 percent of the world's tropical forests and account for approximately 90 percent of global trade in tropical timber products. Through its strong mandate, ITTO works closely with member countries, international organizations, and stakeholders to advance sustainable forest management and to enhance the trade and value of legally and sustainably produced timber and timber products.

ITTO continues to serve the international teak community by providing up-to-date statistics, market intelligence, and policy insights. Through its Legal and Sustainable Supply Chains (LSSC) programme, ITTO supports the strengthening of tropical timber value chains—from forest to market—by enhancing capacities for legality, sustainability, business collaboration, and market access.

I trust that participants will find the deliberations of the 5<sup>th</sup> World Teak Conference both productive and forward-looking, and I encourage all delegates to take full advantage of this platform to strengthen partnerships, expand professional networks, and contribute to shaping strategies for a resilient, sustainable, and inclusive global teak sector.

A handwritten signature in black ink, which appears to be 'S. SATKURU'. The signature is stylized and includes a long horizontal line extending to the left.

**Sheam Satkuru**  
Executive Director, ITTO, Japan



## About the conference

The 5<sup>th</sup> edition of the World Teak Conference (WTC 2025) with the theme 'Sustainable Development of the Global Teak Sector – Adapting to Future Markets and Environments' was successfully organized at the Grand Hyatt, Kochi from 17 to 20 September 2025. The 5th WTC 2025 was organized the Kerala Forest Research Institute (KFRI) in collaboration with the International Teak Information Network (TEAKNET), the International Tropical Timber Organization (ITTO), the Kerala State Council for Science, Technology and Environment (KSCSTE) and the Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India. Technical assistance for the Conference was extended by the Food and Agriculture Organization of the United Nations (FAO), the International Union of Forest Research Organizations (IUFRO), the Ministry of Agriculture, Forestry and Fisheries (MAFF), Japan, and the Forestry Commission of Ghana.

The 5<sup>th</sup> World Teak Conference (WTC) served as a premier global platform bringing together policymakers, researchers, forest managers, industry leaders, traders, and other stakeholders from across the teak value chain. Building on the legacy of previous World Teak Conferences, the 5th WTC aims to facilitate knowledge exchange, foster international collaboration, and promote sustainable management, trade, and utilization of teak resources worldwide.

The four-day programme included plenary sessions covering all aspects of teak management, genetics, markets and legal supply chains, smallholder teak plantations and panel discussion on global teak resources assessment and forest landscape restoration. There was one general keynote at the beginning each session by prominent speakers followed by oral presentations. A total of 18 oral presentations together with 9 papers in ITTO session and the FSC session comprise 7 presentations, besides the 21 Posters.

ITTO, Japan organized one thematic Side Event to showcase the outcome of ongoing second phase of ITTO-BMLEH teak project, '*Promoting Quality Timber Production in Smallholder and Community-Based Teak and Other Valuable Species Plantations in the Tropics*'. The Forest Stewardship Council (FSC), India also convened a Side Event on the 'Responsible Sourcing of Teak under the European Union Deforestation-Free Products Regulation (EUDR)'. In addition, the private sector had the great opportunity to meet in Business to Business (B2B) sessions in all the 3 days of the conference.

The conference provides an inclusive forum for sharing scientific research, best practices, and policy perspectives. The Conference outcomes are intended to support informed decision-making, strengthen networks among stakeholders, and contribute to the long-term sustainability and competitiveness of the global teak sector.





### **Scientific organizing committee**

- Chairman : Hugh Brown, Forestry Commission of Ghana, Ghana  
Co-Chairman : S. Sandeep, TEAKNET, India

#### *Session I: Value addition, markets and legal supply chains*

- Tran Lam Dong, Deputy Director General, Vietnamese Academy of Forest Sciences, Hanoi, Vietnam (Session Chair)
- Yongyut Trisurat, Faculty of Forestry, Kasetsart University, Bangkok, Thailand
- Valerie Fumey Nassah, Director of Operations, Forest Plantations Forest Services Division, Forestry Commission, Ghana

#### *Session II: Financial analysis on short rotation teak investments in different teak growing regions*

- Walter Kollert, WaKa-Forest Investment Services AG, Portugal (Session Chair)
- Illias Animon, Forestry Officer, FAO-RAP, Bangkok, Thailand
- Anitha V, Principal Scientist, Kerala Forest Research Institute, India

#### *Session III: Recent advances in teak genetics and stand management of natural and planted teak forests*

- Lars Graudal, University of Copenhagen, Denmark (Session Chair)
- Mauricio Jerez-Rico, Professor Emeritus, University of Los Andes, Venezuela
- Anto Rimbawanto, Professor, National Agency of Research and Innovation (BRIN), Indonesia

#### *Session IV: Management models for smallholder teak plantations and agroforestry systems in Asia, Africa and Latin America*

- Markku Kanninen, Professor Emeritus, University of Helsinki, Finland (Session Chair)
- K.C. Chacko, Scientist F (Rtd.), Kerala Forest Research Institute, India
- Nelly Grace Bedijo, FAO's Sawlog Production Grant Scheme (SPGS), Uganda

#### *Session V: Environmental protection, biodiversity conservation and Forest Landscape Restoration*

- Michael Kleine, Senior Advisor, IUFRO HQ, Vienna, Austria (Session Chair)
- Kenichi Shono, Forestry Officer, FAO HQ, Rome, Italy
- John Alvin Stanturf, Visiting Professor, Estonian University of Life Sciences, Estonia



*Sustainable Development of the Global Teak Sector: Adapting to Future Markets and Environments*

## ***Keynote and Thematic Sessions***

## *Session I & II (combined)*

### *Financial analysis, value addition, markets and legal supply chains*



**Session Chair:** Walter Kollert, WaKa-Forest Investment Services AG, Switzerland.

The combined Session I & II focused on the economic, technological, and regulatory dimensions shaping the global teak sector. The session brought together researchers and practitioners to examine trade dynamics, wood properties, plantation management strategies, and emerging technological applications in forestry. The thematic keynote presented an evaluation of global teak trade flows using new customs classifications, providing improved insights for policymakers, investors, and forest managers. Subsequent presentations explored wood characteristics from plantation-grown teak, optimized financial and silvicultural scenarios for timber production, and the transformative potential of artificial intelligence in plantation volume estimation.



## **Thematic Keynote**

### **Analysis and evaluation of global trade flows in major teak-producing countries**

**Walter Kollert<sup>1</sup> & Arvydas Lebedys<sup>2</sup>**

<sup>1</sup> WaKa Forest Investment Services AG, Portugal, <sup>2</sup> Food and Agriculture Organization of the United Nations (FAO), Rome

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#### **Abstract**

From 1 January 2022, international trade in teak roundwood and sawntimber is reported in the Harmonised System Nomenclature 2022 Edition (HS 2022) under the new customs codes 4403.42 (roundwood) and 4407.23 (sawntimber). The data are based on official customs records and are published, for example, in the UN Comtrade database (<https://comtradeplus.un.org/TradeFlow>). This has significantly improved the assessment of the importance of the international teak trade, providing policy and decision makers, investors and managers with more reliable data and a better understanding of the important role that teak resources play in providing wood products for the national economies of many countries.

Although the HS 2022 customs codes for teak are still a relatively new tool for exporting and importing countries, and the resulting data show some inconsistencies, the paper will analyse, graphically present and evaluate the global teak trade flows of major teak-producing countries based on official customs records for the period 2022 to 2024.

**Keywords:** Teak Trade, Teak Importers, Teak Exporters



## **Wood characteristics of teak (*Tectona grandis*) cultivated in Kaptai, Bangladesh**

**Md Sarwar Jahan<sup>1</sup>, M Tushar Uddin<sup>1</sup>, MNA Likhon<sup>1</sup>, Sharmin Islam<sup>1</sup>, M. Mostafizur Rahman<sup>1</sup> & ASM Jahir Uddin<sup>2</sup>**

<sup>1</sup> Bangladesh Council of Scientific and Industrial Research, <sup>2</sup> Bangladesh Forest Department  
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### **Abstract**

Teak (*Tectona grandis*) is not native to Bangladesh; it was introduced from Myanmar (formerly Burma) in 1871 at Sita Pahar Range, Kaptai forests of the Chittagong Hill Tracts, initially covering only 4 hectares. The species remained confined to the Chittagong region until 1920, when its cultivation spread to the districts of Chittagong, Cox's Bazar, and Sylhet. Today, teak is the dominant plantation species in both the hill forests and other parts of the country. The total area covered by teak plantations has been widely debated, with estimates ranging from 40,000 to 216,994 hectares. This study assessed the wood properties of 16-year-old *Tectona grandis* planted in the Kaptai forests of the Chittagong Hill Tracts. Results indicated an increasing trend in lignin and  $\alpha$ -cellulose content from pith to bark, while fiber length was shorter at the pith and progressively increased toward the bark. Teak, a tropical tree species, has been utilized for construction and structural purposes for centuries. Consequently, understanding its Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) is essential in the timber production process. Both MOE and MOR showed a gradual increase from the area of pith to the area of bark at various radial levels. These insights contribute to optimizing teak utilization in the timber industry.

**Keywords:** Plantation, Chemical Properties, Fiber Length, Strength Properties



## **Optimal technical and financial management scenarios for timber production in planted teak stands in Venezuela**

**Mauricio Jerez-Rico<sup>1</sup>, Carlos J. Jerez-Rico<sup>2</sup>, María A. Quintero-Méndez<sup>1</sup>, Ana M. Quevedo-Rojas<sup>1</sup>**

<sup>1</sup> School of Forestry and Environmental Sciences, University of The Andes, Mérida, Venezuela, <sup>2</sup> School of Mechanical Engineering, University of The Andes, Mérida, Venezuela  
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### **Abstract**

For planted teak (*Tectona grandis* L. f.) in Venezuela, we utilized available national information on growth and yield from permanent plots, stand management, costs, and market prices to build and feed a stand growth and yield simulator-optimizer to find the optimal combination of spacings, thinnings, and harvest schedules and financial variables (interest rates, timber prices, production costs) that maximized stand net present value (NPV) and soil expectation value (SEV). We used information from 112 permanent plots (2-45 yr.-old) managed under a set of silvicultural regimes. The simulator employs a state-space approach, with site index, basal area, and mortality as stand-growth drivers generating growth and yield estimates by tree/log categories penalized by losses from tree quality and harvest operations. A Genetic Algorithm-based optimizer was used to determine optimal management scenarios. A sensitivity analysis assessed the effects of changes in the main biological and financial variables. The best scenario had a PV = 9,481, NPV = 805, and LEV = 967 USD ha<sup>-1</sup> (interest rate = 10%), with a planting spacing of 625 trees ha<sup>-1</sup>, final harvest age of 18 years, and one thinning at 7.4 years, removing 40% of the stand basal area. The sensitivity analysis revealed that optimal schedules are most sensitive to interest rates and the price differential across log categories. Lower interest rates and a significant increase in the differential price between large- and medium-diameter logs are needed to delay rotation age and favor a larger proportion of volume in larger logs, rather than producing larger total stand volume concentrated in smaller logs with lower quality.

**Keywords:** *Tectona grandis*, Heuristics, Financial Analysis, Stand Management, Forest Planning, Growth and Yield Models



## **Artificial Intelligence (AI) powered framework for plantation volume estimation: a case study in teak (*Tectona grandis*)**

**Ani A. Elias<sup>1,2</sup> & Anusiya Kumari M<sup>3</sup>**

<sup>1</sup> ICFRE - Institute of Forest Genetics and Tree Breeding, <sup>2</sup> HelixOmics Analytics LLP, <sup>3</sup> ICFRE - Institute of Forest Genetics and Tree Breeding  
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### **Abstract**

Teak (*Tectona grandis*), an economically important wood is renowned for its exceptional timber quality and resilience. However, traditional manual methods for estimating the volume of wood from teak plantations are labor-intensive, time-consuming, lack repeatability, and are prone to errors. These challenges necessitate innovative, technology-driven approaches to enhance efficiency, precision, and sustainability in volume estimation.

We introduce an artificial intelligence (AI)-powered framework to revolutionize teak plantation volume estimation. Using advanced object detection algorithms such as YOLO, we developed an innovative system capable of accurately identifying teak trees in diverse plantation settings. The algorithm also considers commonly co-occurring species in teak plantations such as *Xylia xylocarpa*, *Terminalia tomentosa*, and *T. bellirica*, reflecting real-world forest dynamics. This innovative step enables forest managers to identify and localize teak trees directly from imagery, eliminating the dependency on exhaustive ground surveys and paving the way for automated ecological analyses. Building on the detection framework, we incorporated tools to calculate essential metrics such as girth at breast height (GBH) and diameter of the detected teak trees. These measurements were subsequently used alongside the NR Nair volume table to estimate individual tree volumes. This hybrid AI approach minimizes human intervention, reduces the potential for measurement inconsistencies, documents the sampling area as images, and ensures scalable data collection across extensive plantations.

The findings of this study underscore the transformative potential of AI-driven forestry management by streamlining routine tasks. By automating tree detection, measurement, and volume estimation, this framework offers plantation managers actionable insights to optimize operations. This research not only addresses critical gaps in teak plantation management but also sets a precedent for integrating AI technologies into broader forestry and ecological conservation efforts. By reducing dependence on manual labor and enhancing the reliability of data-driven decision-making, this work demonstrates how AI can revolutionize sustainable forestry practices globally.

**Keywords:** Teak, Plantation, Artificial Intelligence, Identification, Volume Estimation



## **Application of TLC and UV-visible spectroscopy for differentiating between *Tectona grandis* and *Acacia auriculiformis* woods**

**Rakesh Kumar & Rohit Sharma**

Wood Properties and Processing Division, Institute of Wood Science and Technology, Malleswaram  
18th Cross, Bangalore, Karnataka-560003  
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### **Abstract**

Teak (*Tectona grandis*) is highly sought after in India for its superior properties and aesthetic value, but the country depends largely on imports to meet the growing demand. As a result, some traders try to pass off Auri (*Acacia auriculiformis*) wood as Teak, owing to their similar appearance, which leads to fraudulent trade practices. This situation highlights the need for reliable methods to distinguish between the two species, particularly in finished products, where identifying the wood is difficult because it involves destructive sampling. Despite their visual similarities, Teak and Auri differ in their chemical composition, offering a clear opportunity for scientific differentiation. This study presents a simple and rapid solution to this issue by utilizing Thin Layer Chromatography (TLC) and UV-Visible spectroscopy to distinguish between Teak and Auri timber, as well as their finished products. The analysis identifies distinct peaks in UV-Visible spectroscopy and separate spots with varying retention factors (RF) in TLC, enabling reliable species identification. These findings provide a practical and scientifically grounded method for distinguishing Teak from Auri, ensuring that consumers receive authentic products and helping to combat the unethical trade of Acacia wood as Teak. This approach not only improves customer satisfaction but also promotes sustainability and fairness within the timber market.

**Keywords:** Teak Wood, Acacia Wood, Trade, Thin Layer Chromatography and UV-Visible Spectroscopy.



## **Enabling traceability in the teak value chain for adapting to future market regulations**

**Anuj Sharma**

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### **Abstract**

Teak is found in Southeast Asia, Africa, and Latin America. Coincidentally, these regions have experienced high deforestation rates, driven by illegal logging, land conversion, and weak governance. Deforestation is linked to significant socio-environmental risks, including biodiversity loss, violations of community rights, and exploitation of workers. The increasing demand for teak, coupled with its high market value, further incentivizes unsustainable harvesting and illegal logging practices.

While Geographic Information System (GIS) tools can help sourcing countries map deforestation hotspots and identify high-risk regions, a critical gap will persist in tracing semi-finished and finished timber products. Without product-level traceability, consumers cannot distinguish sustainably sourced teak from unverified, high-risk timber.

In this context, integrating traceability tools into the timber value chain is important to enhance compliance with emerging market regulations, such as the EU Deforestation Regulation (EUDR). A traceable supply chain offers multiple advantages: it enables the verification of deforestation and degradation-free supply chains while also providing transparency on the involvement of marginalized stakeholders, including indigenous communities and woodworkers. Such assessments are crucial for ensuring compliance with international labour and environmental standards, including the International Labour Organization's (ILO) Core Labour Requirements (CLR) and the Free, Prior, and Informed Consent (FPIC) framework.

As a global leader in responsible forest management, FSC is developing blockchain-based traceability solutions to strengthen transparency in the timber trade. This paper explores the benefits of traceability, evaluates the effectiveness of existing technological solutions such as FSC Trace (blockchain) and the FSC Regulatory Module, and assesses their role in mitigating socio-environmental risks in the wood-based commodity sector.

**Keywords:** Traceability, EUDR, Ethical Sourcing, CLR, Blockchain



## **Bridging the financial gap for teak smallholders: a review of financing models in South Asia, Southeast Asia and West Africa**

**Temesgen Zana Jaffo, Eliza Zhunusova & Sven Günter**

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### **Abstract**

Teak (*Tectona grandis*) is a high-value and strategic commodity for major teak-producing countries in the tropics. Smallholders are a significant player in the sector - by managing approximately one quarter of the world's planted teak forests, which is about 1.2 million ha. However, they face significant barriers, including limited access to finance, which is a real problem on its own, and also is often a symptom of other difficulties such as insecure tenure, inadequate technical capacity, lack of business and market know-how and limited cost efficiencies and bargaining power. Teak plantations, particularly, often require a longer maturity period, creating tough cash flow constraints for smallholders who mostly depend on immediate financial returns. Different financial mechanisms have been introduced at various scales and regions that not only address the cash flow problems but also enhance the economic and ecological benefits through long-rotation practices and high-quality timber production for smallholder and community-based teak plantation owners. This review synthesizes the existing literature and ongoing initiatives related to such financial mechanisms, to describe their implementation practices, looking into respective key success factors and constraints to their sustainability and replicability across the selected six major teak-producing countries in the tropics - Thailand, India, Indonesia, Cambodia, Vietnam and Togo. The review also highlights selected case studies to draw good practices that support successful smallholder teak systems, emphasizing the importance of integrating policy instruments with appropriate/tailored financial support and value chain coordination mechanisms. Comparative review of regional differences in legal and institutional policy frameworks, land use, market access, and financial infrastructure, shows how tailored finance innovations can bridge the smallholders' limitations and help successfully integrate into the high-value timber market.

**Keywords:** Teak, Smallholders, Finance, Tropics



## **An analysis of teak demand in the Japanese market**

**Honda Tomoyuki**

Forestry Agency of Japan, Tokyo, Japan

### **Abstract**

Teak is recognized in Japan as one of the three major precious woods, mainly used for flooring, furniture, and luxury interior materials. However, statistical data on teak products are limited. This study examines the demand structure for teak using import data from 2008 to 2024 by estimating own- and cross-price elasticities with the Rotterdam demand model. Oak and mahogany were included as comparison timbers to assess cross-price effects. Results indicate that teak demand is price inelastic, suggesting limited sensitivity to price changes. Teak demand is slightly influenced by oak prices, and when income effects are considered, teak and oak behave as minor complements rather than substitutes. Mahogany prices have almost no effect on teak demand. These findings suggest that teak maintains relatively stable demand in the Japanese wood market, though its consumption can be modestly affected by oak market conditions.

**Keywords:** Teak Demand, Rotterdam Model, Price Elasticity, Wood Imports

### *Session III*

## *Recent advances in teak genetics and stand management of natural and planted teak forests*



**Session Chair:** Olman Murillo, Professor, Instituto Tecnológico de Costa Rica

The session on contemporary developments in Teak genetics and stand management, focused on emerging scientific and technological developments supporting teak genetic improvement and sustainable forest management. Presentations covered advances in clonal propagation, the development of new cultivars, genetic mechanisms underlying drought tolerance, genomic adaptation to local climatic conditions, and progress in regional breeding programmes, collectively highlighting the role of biotechnology and genomics in enhancing plantation productivity, resilience, and long-term sustainability.



### **Thematic Keynote**

## **Development and management of teak genetics through clonal propagation**

**Doreen Goh**

YSG Bioscape Sdn Bhd., Yayasan Sabah Group, Voluntary Association Complex, Mile 2 ½, off Jalan Tuaran, P. O. Box 11623, 88817 Kota Kinabalu, Sabah, Malaysia  
*Email: dorngoh@hotmail.com*

### **Abstract**

The importance of teak as one of the world's most valuable timber species is evidenced by the extensive research publications and projects undertaken over the past two decades by international organizations such as FAO, IUFRO, ITTO, and TeakNet. The erosion of genetic diversity resulting from the decline of natural teak forests, coupled with the increasing reliance on planting materials derived from narrow genetic bases, is a matter of serious concern. Over the years, various biotechnological tools, spanning from marker-assisted selection to genome sequencing and genetic improvement, have been developed to support teak breeding, enhancement, and conservation efforts. At YSG Bioscape, the development of a simple, efficient, and cost-effective tissue culture protocol has enabled, within a short time frame, the mass propagation of mature teak trees and elite high-quality seed sources that are otherwise scarce or exhibit poor germination. This technological advancement has facilitated the large-scale multiplication and distribution of millions of clonal teak plants across countries in four continents, supporting the enrichment of local germplasm, the establishment of clonal seed orchards and gene banks, and the development of plantations with genetic uniformity and more predictable productivity. Together with other complementary strategies, micropropagation continues to play a vital and sustainable role in the advancement and management of teak genetic resources.

**Keywords:** High-Value Timber, Clonal Propagation, Genetic Improvement, YSG Bioscape



## **Revolutionizing teak production: 19 new cultivars driving genetic and technological innovation in Brazil**

**Ligório de Jesus Ximenes<sup>1</sup>, Maria do Socorro Bezerra de Araújo<sup>1</sup>, Fausto Hissashi Takiwaza<sup>2</sup>, Joamir Barbosa Filho<sup>2</sup>, Gilcianny Pignata Cavalcante<sup>1</sup>, Antonio Marcos Chimello<sup>1</sup>, Kaliane Zaira Camacho Maximiano Cruz<sup>1</sup>, Sabrina Cassaro<sup>1</sup>, Antonio André da Silva Alencar<sup>1</sup>, Dalcirlei Pinheiro Albuquerque<sup>1</sup>, Leonarda Grillo Neves<sup>1</sup>**

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### **Abstract**

Teak (*Tectona grandis* L.f.) is a highly valued forestry species, with its cultivation in Brazil expanding since the 1970s due to advances in management, genetic improvement, and local adaptation. By mid-2024, only three teak cultivars were officially registered for commercialization with the Brazilian Ministry of Agriculture and Livestock (MAPA). Genetic characterization is crucial for ensuring cultivar authenticity, traceability, and legal protection. Microsatellite (SSR) fingerprinting has proven to be an effective tool for genotype discrimination and genetic diversity assessment, enhancing security and innovation in the forestry sector. This study analyzes the genetic diversity and discriminates 19 elite teak cultivars registered by UNEMAT-TRC with MAPA using microsatellite markers. The genetic profiles of these cultivars were characterized, confirming their distinctiveness for legal protection and certification. Optimized DNA extraction and PCR amplification protocols were applied, followed by genetic and statistical analyses, such as Gower's genetic distance estimation, UPGMA clustering, and Bayesian population structure analysis via STRUCTURE software. The results revealed high levels of genetic diversity and enabled clear genotype discrimination. This approach supports intellectual property protection, cultivar traceability while promoting sustainable and legal teak commercialization. The registration of these 19 cultivars represents a milestone for the Brazilian teak industry, offering farmers access to genetically improved, disease-resistant, and high-yielding planting material. Overall, the study underscores the essential role of genetic fingerprinting in ensuring authenticity and traceability, fostering trust and transparency in the teak value chains. The adoption of these cultivars is expected to boost productivity, reduce illegal logging, and contribute to the sustainable development of Brazil's teak sector.

**Keywords:** *Tectona grandis*, Microsatellite Markers, Genetic Diversity, Cultivar Discrimination, Legal Commercialization



## **Genetic insights into drought tolerance through QTL mapping and SNP discovery in plus trees of *Tectona grandis* L.f.**

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### **Abstract**

The study investigates drought tolerance and recovery potential in selected plus trees of *Tectona grandis* L.f., utilizing Genotyping by Sequencing (GBS) to identify Single Nucleotide Polymorphisms (SNPs) and map Quantitative Trait Loci (QTLs) associated with drought resilience. Eight-month-old ramets from ten selected teak accessions were evaluated across two seasons for morphological, physiological, and biochemical traits under three water stress conditions; normal irrigation, drought stress, and post stress recovery. Multivariate analysis including cluster analysis and principal component analysis (PCA) classified the accessions into four drought tolerance categories: highly susceptible (A8), susceptible (A4, A6), moderately tolerant (A1, A3, A7, A9), and highly tolerant (A2, A5, A10). Genotyping using Illumina-assembled sequences generated 7,518,960 variants, from which variant calling detected 3,665 SNPs across ten genomes. Genome-wide Association Study (GWAS) pinpointed 19 significant SNPs associated with drought tolerance, which were validated through quantile-quantile (QQ) and Manhattan plots. Functional annotation via BLASTX and UniProt databases identified stress-responsive genes associated with organ development and metabolic pathways. Key QTLs were mapped on Chromosome 1 (BLH9, POX), Chromosome 4 (DXS, TKL), and Chromosome 11 (MFS, MIK2), influencing critical physiological functions such as xylem development, chlorophyll biosynthesis, stomatal regulation, and root activity. Notably, DXS is associated with chlorophyll and terpenoid biosynthesis, MFS regulates stomatal closure, and MIK2 plays a role in cellular and root activity. Overall, this study provides valuable insights into the genetic basis of drought tolerance in teak, supporting breeding programs aimed at enhancing climatic resilience and sustainable forest management strategies.

**Keywords:** Drought tolerance, Genotyping by sequencing, SNPs, QTL mapping, Teak



## **Genomic adaptation in teak (*Tectona grandis* L.f.) associated with local climatic conditions and insights for planting strategies to achieve higher resilience on Java Island**

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### **Abstract**

Teak (*Tectona grandis* L.f.) is a valuable tropical tree species that has been extensively planted across its native ranges, including large-scale plantations on Java Island, Indonesia. Despite its economic importance, comprehensive assessment of genetic diversity and local adaptation using genome-wide sequencing data across its natural distribution and Indonesian landraces remain limited. Genome-wide analysis of genetic structure and local adaptation can elucidate genetic origin and adaptive capacity, thereby formulate strategies for establishing climate resilient teak plantations under future climate change scenarios. In this study, we analyzed genetic structure and local adaptation in eight natural teak populations from India, Thailand, Laos and Myanmar, together with nine Indonesian landraces, using genome-wide SNP datasets comprising 3,132 and 8,948 SNPs, respectively. Our objectives were to (1) characterize genetic structure of natural origin teak and determine the genetic origin of landraces and (2) assess genomic signatures of environmental adaptation to guide future teak planting strategies in Java. Population structure analysis identified five genetic clusters, with Indonesian landraces showing close affinity to populations from Myanmar and Laos. Evidence of local adaptation was detected in the Malabar and Central Provenance in India, which exhibited allele frequency shifts along climatic gradients. These populations exhibited low genetic offset between present and future projected climatic conditions. Notably, the climatic conditions of central and eastern Java closely resemble those of the Malabar and Central Provenance in India, indicating that these populations represent useful genetic resources for future teak planting in Java.

**Keywords:** *Tectona grandis*, Genome-Wide Environmental Interaction, Genetic Structure, Climate Change



## **Teak breeding in Latin America: where do we stand?**

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### **Abstract**

Teak breeding efforts in Latin America started in the 1980s, from small seedling stands to well-developed breeding programs based on clonal plantations, and are now moving towards more advanced breeding generations. Improved clones have achieved more than 25% gains in commercial volume and about 35% gains in commercial value, while rotation age has been reduced from 20-22 years to 16-18 years. GENFORES, an International Tropical Tree Improvement Cooperative governed through the School of Forestry Engineering of the Technological Institute of Costa Rica, was established 23 years ago. Currently, it has a collection of more than 400 teak plus trees distributed across nine breeding programs in Nicaragua, Colombia, Ecuador, Brazil and Costa Rica. A second breeding generation is being developed in conjunction with small-scale monoclonal plantations, targeting an expected 15% gain and further reductions in rotation length. Wood properties are becoming essential in genetic testing. Ten validated gene markers (ISSRs) organized into two multiplexes, are currently employed for clonal identity verification, genotyping, and other breeding applications. Additionally, more than 20 SNPs linked to economic traits are undergoing development and validation, with the aim of becoming novel genetic markers for selection. Over the last three years, the Double Tree Plot has been developed as a new design for genetic testing and selection, with the aim of shortening breeding cycles. GENFORES' new breeding strategy emphasizes open and controlled pollination through clonal deployment, for high performance teak clones with improved growth.

**Keywords:** Teak, Breeding, Economic Trait, Genetic Improvement



## **Variability in heartwood content of tissue culture raised *Tectona grandis* L.f.**

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### **Abstract**

*Tectona grandis* L.f. (teak) is one of the most important tropical hardwood species globally, with heartwood characteristics determining its commercial value. Tissue culture based clonal propagation has emerged as a strategy to enhance productivity and wood quality; however, variation in heartwood formation among clonally propagated trees remains poorly documented. The present study quantified heartwood development in an eight-year-old plantation of tissue-culture raised teak established under uniform site and management conditions in Andhra Pradesh, India. A total of forty-two trees were evaluated for bole height, diameter, bark and sapwood thickness, heartwood radius, heartwood proportion, and heartwood volume. Despite relatively uniform growth performance, substantial variability was observed in heartwood traits. Bole height and diameter exhibited low-to-moderate variability (CV = 12.2 % and 16.9 %, respectively), whereas heartwood radius, heartwood area, and heartwood volume showed markedly higher dispersion (CV = 32.5 %, 63.1 %, and 66.4 %, respectively). Relative heartwood proportion under bark ranged from 15.93 % to 76.77 %, indicating that trees of similar dimensions differed by more than four-fold in heartwood content. Heartwood volume was strongly correlated with heartwood area ( $r \approx 0.97$ ) and diameter ( $r \approx 0.84$ ), while bole height showed only a weak relationship. These findings demonstrate that diameter alone is an unreliable indicator of heartwood yield in young teak and highlight the necessity of direct wood-quality assessments in selection programs. Several superior individuals with high heartwood proportions and volumes were identified as promising candidates for future clonal deployment. The study establishes baseline information on heartwood variability in tissue-culture teak and emphasizes integrating heartwood traits into improvement and certification frameworks to enhance economic returns from short-rotation teak plantations.

**Keywords:** *Tectona grandis*, Power Increment Borer (PIB), Growth Traits, Tissue Culture, Heartwood Content.



## **Exploring genetic diversity and population structure of India's national teak (*Tectona grandis* L.F.) germplasm bank**

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### **Abstract**

For the conservation of teak genetic resources, a National Teak Germplasm Bank (NTGB) was established by the Maharashtra State Forest Department at Lohara, Chandrapur, and is considered as the largest existing field gene bank in the country. NTGB was established in seven phases, i.e., in 1979, 1982, 1983, 1984, 1989, 1991, 1991, over a total area of 5.09 hectares. Currently, a total of 238 accessions, each represented by three ramets, collected from eleven different states across the country, are maintained in the germplasm bank. In this study, the genetic diversity of teak conserved in this field gene bank was assessed using SSR markers. Analysis of molecular variance showed 85% of the genetic variation occurred within populations, while 15% among populations. Estimates of the total number of alleles, Nei's gene diversity ( $h$ ) and Shannon's information index ( $I$ ) showed high level of genetic variation across geographical regions. The entire collections were clustered into two groups, which was further confirmed by Bayesian model-based structure analysis. Analysis of population Q matrix revealed that several accessions exhibited mixed ancestry. Accessions from Odisha, Madhya Pradesh, Uttar Pradesh and Gujarat constituted one cluster, whereas Tamil Nadu and Kerala formed the second cluster. Accessions from Andhra Pradesh, Karnataka and Maharashtra displayed admixture between both clusters. The influence of human mediated movement of planting materials and environmental factors might have played a major role in observed genetic clustering. High levels of within population genetic diversity and heterozygosity may be attributed to predominant cross pollinating mating system, woody perennial nature, etc. The results of genetic structuring have established that introduction of genetic materials from diverse sources across the country would be effective than localized sampling in broadening the genetic base and long-term conservation strategies at NTBG.

**Keywords:** Premier timber, Field Gene Bank, Genetic resources, Microsatellite, Conservation



## **Unravelling the genetic diversity of teak (*Tectona grandis* L.f.) in central India, a premier timber species of tropical forests**

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### **Abstract**

*Tectona grandis* L.f., a premier tropical timber species, is facing significant threats in its natural populations due to overexploitation and habitat degradation. This study aimed to evaluate the morphological and molecular diversity in natural populations across central India, providing critical information to support its conservation and management. A total of thirteen natural teak populations in thirteen different agro-climatic zones were selected for the study from central India. From each population, twenty trees were sampled using controlled random sampling for morphological and molecular analysis. Morphological traits, including tree height, clear bole height, and girth at breast height exhibited substantial variation across populations, with tree height ranging from 7.62 to 38 m, with the highest mean value recorded in populations from Jagdalpur. Similarly, clear bole height ranged from 2.21 to 32.0 m, with the highest mean values observed in Jagdalpur (17.25 m), followed by Seoni (17.20 m) and Balaghat (17.00 m). Girth at breast height ranged from 70.0 to 265.0 cm with an average of 121.0 cm. The highest average girth at breast height was also observed in Jagdalpur (169.55 cm), followed by Jabalpur (153.0 cm), Khandwa (135.7 cm) and Betul (125.35 cm). Wood density also varied significantly, ranging from 401.51 to 792.96 kg/m<sup>3</sup>, although its variability was lower compared to the morphological traits. Molecular diversity analysis, based on 22 microsatellite markers, revealed high levels of genetic diversity across populations. Bayesian clustering (STRUCTURE) analysis identified three distinct genetic clusters. Analysis of molecular variance showed that 74.5% of the total genetic variation existed within populations, indicating strong local adaptation. This study underscores the importance of preserving genetic diversity within teak populations in central India, to ensure long-term ecological sustainability and improve genetic resource management. The findings provide critical insights for the development of conservation strategies and genetic improvement programs for teak in this region.

**Keywords:** Sagon, Centre Of Diversity, Population Structure, Variation, Genetic Resources



## **New insights into the pathosystem of *Ceratocystis fimbriata* and teak**

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### **Abstract**

Ceratocystis wilt of teak (*Tectona grandis* L.f.) is a destructive fungal disease caused by *Ceratocystis fimbriata*, posing a significant threat to teak plantations in tropical and subtropical regions, leading to substantial economic losses. Developing effective resistance strategies requires an understanding of disease dynamics under conditions that closely mimic the natural environment. This study presents recent research findings aimed at improving resistance to *C. fimbriata* in teak. Accurate inoculation methods are critical for simulating natural disease processes of soil-borne pathogens. A soil based inoculation method was developed to achieve a more realistic reproduction of symptoms and pathogen behaviour under near-natural environment. In addition, pathogen translocation within host plants following soil inoculation was investigated to better understand systemic infection pathways. Field and experimental observations further revealed that new shoots emerging from the stumps of infected and dead trees can become infected with *C. fimbriata*. Additionally, vector-mediated transmission was elucidated, showing that bark beetles can act as carriers and facilitate pathogen spread to other plants. In teak plantations, disease management is particularly challenging due to considerable environmental and genetic variability of the *Ceratocystis* isolates. The study emphasizes the importance of exploiting 'polyresistance' which reflects a plant's capacity to withstand multiple *C. fimbriata* isolates. The findings offer future directions for managing *Ceratocystis* wilt, as the pathogen's persistence in the environment and its ability to infect new growth present significant challenges.

**Keywords:** *Tectona grandis*, Polyresistance, Emerging technologies, Ceratocystis wilt



## **Genomic resources of teak**

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### **Abstract**

The interest of smallholders in the cultivation of teak fuels the infusion of modern technologies to expedite the process of tree improvement. Genetic improvement of teak for its timber quality and quantity demands an in-depth understanding of its biology, wood parameters, genetics and comprehensive execution of modern cultivation and silvicultural practices. ICFRE-Institute of Forest Genetics and Tree Breeding, along with KSCSTE - Kerala Forest Research Institute, initiated genomic studies by including the most popular provenances of teak in India. Recent recognition of distinct population structure within Indian teak has opened up opportunities for precision breeding. Harnessing this diversity for genetic improvement requires exploration of genomic variations to precisely target the genomic regions governing wood colour, sapwood to heartwood ratio, grain pattern, biotic and abiotic stress tolerance. Genomic information has also been utilised for seed zonation by including bioclimatic variables to identify suitable seed collection zones vis-a-vis planting areas. Additionally, genome-wide simple sequence repeat (SSR) markers generated are routinely utilised for genetic fidelity testing of mass propagated tissue culture teak seedlings, as well as in illegal timber tracing and legal certification. More recently, the genomic selection (GS) strategy is introduced by developing 50,39,445 single-nucleotide polymorphism (SNP) markers from 150 teak genotypes representing the entire diversity of India. This curated pseudomolecule level information serves as a comprehensive genomic resource for teak improvement. The database will be updated to include teak structural genomic variations, including insertions, deletions, and chromosomal rearrangements. Further, accelerating the GS and genetic resources management of teak can benefit from cost-effective and efficient SNP array genotyping platforms, which have revolutionized genomic improvement in annual crops. The increasing availability of genomic information in teak is poised to facilitate the establishment of high-quality, productive and resilient teak plantations globally.

**Keywords:** Genomic Resources, Population Genomics, Timber Tracing, Genetic Fidelity



## **Genetic improvement of teak in Brazil: advances and contributions from UNEMAT and TRC**

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### **Abstract**

Teak (*Tectona grandis* L.f.) is among the most valuable tropical hardwood species, prized for its high-quality timber. In Brazil, significant advancements in teak genetic improvement have been driven by the partnership between Teak Resources Company and the Universidade do Estado de Mato Grosso (UNEMAT/TRC). This paper highlights the scientific and technological advancements achieved through this collaboration that have contributed significantly to teak genetic improvement in Brazil. The UNEMAT/TRC breeding program focuses on selecting superior genotypes with higher yield, wood quality, and resistance to biotic stresses. Notable achievements include the development of teak cultivars resistant to wilt caused by *Ceratocystis fimbriata* and canker caused by *Lasiodiplodia theobromae*. The establishment of mycotheques, pathogenicity tests, standardized inoculation protocols, and resistance evaluation in teak germplasm, combined with advanced genotyping techniques, optimized the identification of resistant clones. Molecular tools, such as qPCR, were employed for rapid pathogen detection in teak wood. Microsatellite and SNP markers enabled assessment of genetic diversity, traceability, and elite clone discrimination. High-throughput genotyping revealed substantial genetic diversity within the germplasm bank, strengthening conservation and breeding strategies. Elite genotypes were evaluated for cultivar registration and protection, ensuring traceability and commercial integrity. Ongoing research investigates protein expression and genome-wide association mapping to identify molecular markers linked to wood yield traits and resistance to multiple isolates of *C. fimbriata*, *L. theobromae*, and *Fusarium* spp. These technological advances significantly enhance the sustainability of teak cultivation in Brazil, positioning the sector to meet future market demands and environmental challenges, while boosting the national forest economy.

**Keywords:** *Tectona grandis* L.f., *Ceratocystis fimbriata*, *Lasiodiplodia theobromae*.



## **Evaluation of elite teak genotypes: a comparative analysis of two 15-year-old plantations**

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### **Abstract**

KFRI has been engaged in the genetic improvement of Teak (*Tectona grandis* L.f.) over the past few decades through plus tree selection, successfully providing high-quality planting stock via stump propagation, seedlings, and asexual propagation using branch cuttings. The present paper reviews KFRI's ongoing Teak genetic improvement program, with particular emphasis on evaluating previously selected plus trees from earlier studies for their potential use in identifying elite genotypes for future breeding and clonal development. Clonal plantations established at Vellikulangara (Thrissur) and Karimankode (Thiruvananthapuram) were assessed to examine growth variation and adaptability across contrasting geographical locations. Although both regions fall within a tropical monsoon climatic zone, Karimankode region experiences conditions closer to a tropical savanna climate, characterized by hot summers and pronounced seasonal dryness. In contrast, Vellikulangara located in the south-western coastal region of Kerala, exhibits relatively stable temperature regimes with minimal diurnal and annual variation. In 2000, the pioneering efforts by KFRI led to the establishment of a pilot-scale, true-to-type teak clones from superior mother trees originating from Nilambur (T1, T3, T4, T5, T6, T10), Konni (T11, T16), Arienkavu (T24), and Anchumukku (T36, T46, T47). Evaluation of growth parameters and wood characteristics revealed site specific performance among clones. At Vellikulangara, clone T16 exhibited superior height and girth at breast height, while clone T47 performed well in terms of clear bole length. At Karimankode, clone T36 showed comparatively better height. Comparative analysis between Vellikulangara and Kariamkode further indicated that overall clone performance was superior at Vellikulangara.

**Keywords:** Teak, Plus Tree, Selection, Clones, Comparison



## **Outcomes of the Camcore international teak provenance trials conducted in Proteak, México, at early growth stages**

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### **Abstract**

With over 6,000 ha of planted teak forests in México, Proteak is a leading producers of Latin American teakwood. As a CAMCORE member, Proteak participates in the global teak (*Tectona grandis* L.f.) genetic improvement program. Between 2014 and 2015, Proteak established four provenance/progeny trials aimed at identifying superior provenances, families, and individual trees, to widen its genetic pool, enhancing stand productivity and resilience. The trials included 29 provenances and 109 half-sib families from Asia/Oceania (India, Myanmar, Thailand, Laos, Indonesia, Bangladesh, Australia); Africa (Tanzania, Mozambique); and America (México, Venezuela, Costa Rica, Panamá, Colombia, Guatemala). Experiments were conducted at three sites in Tabasco, SE México (17°36'15"N, 92°50'34"W, 28–100 m.a.s.l.), with excellent site conditions for teak growth. Each trial followed a complete randomized block design with four replicates and six trees per family, planted in 6-tree-row-plots at 3.8x2.6m spacing. Site preparation included weeding, subsoiling, and plowing. The trials were evaluated at 2, 3, 5, and 8 years of age to estimate provenance performance, genetic parameters, and genotype x environment (GxE) interactions. At age eight, survival ranged from 57-76%, total height from 12.6-16.8 m, dbh from 18.9-23.0 cm, and tree volume from 0.1413-0.2154 m<sup>3</sup>. Substantial provenance differences were found, with volume variation ranging from +16% to -10%. Genetic analyses revealed moderate provenance effects ( $P^2 = 0.04$ ) and low but expected heritability ( $h^2 = 0.09$ ) for a 20-year rotation species. GxE interactions were moderate at both the provenance ( $rbp=0.33$ ) and family(provenance) level ( $rbg=0.46$ ). Nevertheless, notable genetic gains can be made, with the best performing families exhibiting volume gains of 10% to 30%, while superior individual trees exhibited potential gains of 20% to 40%. The results demonstrate excellent potential for increasing teak genetic diversity in México through breeding and elite clone selection, ensuring more productive and pest-climate resilient teak plantations.

**Keywords:** *Tectona Grandis*, Latin America, Genetic Gains, Progeny Tests, Volume



## **Genome-wide association study of teak (*Tectona grandis* L.f.) growth and leaf traits in Ngawi progeny trial**

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### **Abstract**

Teak is one of the important tropical timbers that is grown and traded worldwide. Future climate challenges necessitate the development of strategies to identify climate resilient individuals, without compromising growth performance. Genome Wide Association studies (GWAS) provides a means to identify markers associated with key traits, such as growth and leaf hysiological traits. In this study, 7,156 SNP markers were extracted from sequences of 764 individuals, and linkage disequilibrium was detected up to 60 kb. A mixed model (Q+K), accounting for population structure and kinship, was conducted using a 3.0 LOD score threshold. The analysis revealed SNP markers associated with growth and leaf traits. For growth trait, two SNPs were linked to diameter and height, and one SNP to crown area and volume. For leaf traits, four SNPs were associated with specific leaf area, three with leaf density, two with leaf phosphorous content and one with leaf nitrogen content. These findings highlight that while growth and leaf traits are potentially influenced by underlying genes, the relative small number of markers and weak association, indicate that genomic selection (GS) approaches may be more effective than marker assisted selection for teak breeding.

**Keywords:** Teak, Breeding, GWAS, Plantation, Progeny, Genome, Leaf-Traits



## **Improved techniques to enhance germination rate and shelf-life of teak seed (*Tectona grandis* L.f.)**

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### **Abstract**

Teak (*Tectona grandis* L.f.), a member of Verbenaceae family is one of the most well-known, multi-purpose timber species worldwide. Teak seeds generally exhibit poor germination due to their thick pericarp and limited shelf-life under ambient conditions. This study was undertaken to improve both germinability and shelf-life of teak seeds using modern techniques. Seeds of teak were collected during March, 2022 from the Teak Seed Production Area, Nedumkayam -1973 Nilambur, Kerala, India (11° 16' 57.1" N: 76° 20' 33.2" E). A portion of the seeds was subjected to de-pericarping (removal of pericarp) using a seed scarifying machine. Both scarified & un-scarified seeds were stored in air-tight containers in the cold storage room (4°C temperature with 45±5% relative humidity) at Kerala Forest Seed Centre, KFRI, Peechi, Thrissur, Kerala, India. Regular viability tests were conducted over multiple years (2022–2025) to assess the shelf-life and seed viability. The study evaluated the performance of un-scarified and scarified seeds with varying treatments including control (no additional treatment), weathering (un-scarified seeds only), water soaking for 24 hours, and gibberellic acid (GA<sub>3</sub>) applications at 100, 225, 500, and 1000 ppm. The study revealed that mechanical scarification significantly enhanced germination rates, and GA<sub>3</sub> treatments further improved seed performance. These results highlight the effectiveness of seed scarification, combined with GA<sub>3</sub> application, in improving germination and extending the shelf-life of teak seeds.

**Keywords:** De-Pericarping, Teak Seed Germination, Shelf-Life, Pre-Sowing Treatments, Seed Viability.



## **Diameter reduction in teak (*Tectona grandis* L.f.) during the dry season**

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### **Abstract**

Teak plantations in some years have exhibited temporary diameter reductions during dry periods, creating challenges for the handling of inventory data. Although this phenomenon is not widely documented in the literature, teak growers from other regions confirmed its occurrence. This study analyzes monthly basal diameter at breast height (BDH) data from 2013 to 2024, within Norteak's plantations in central Nicaragua, where the wet season lasts 6-9 months and annual rainfall ranges from 1,400 and 2,500 mm. A severe diameter decrease in 2019 notably affected the commercial volume predictions, with younger stands yielding about half of model estimates due to logs falling below commercial diameter thresholds. Logging intensity was also reduced due to lower basal areas. Across years, average diameter decreases ranged from 0 - 5 mm, with individual tree showing 0 to 10mm diameter reductions. Observations suggest that the bark thickness responds rapidly to changes in moisture content and the temporary diameter decrease likely reflects limited water transport during the dry periods. This explains a relatively lower decrease in older trees with a lower bark to wood ratios. Severe reductions were associated with low rainfall from January to April, while wet years caused smaller declines. High-yielding clones exhibited greater decreases, though 70-85% of the trees recovered diameter within 40 days of rainfall. Overall annual growth was not compromised with no significant diameter loss, a unique response in teak, particularly in clones selected for semi-humid climates.

**Keywords:** Teak, Diameter-decrease, Inventory



## **Monitoring adaptation and productivity of teak plantations in Guinean Zone of Togo: a comparative study of historical and newly introduced provenances**

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### **Abstract**

Teak (*Tectona grandis* L.f.) is the most important commercial tree species in Togo, yet plantation productivity remains low due to limited genetic diversity and suboptimal silvicultural practices. This study aimed to assess the growth performance of seven teak provenances (Avétonou, Indian, Tanzanian, Ivorian, Perlis, Taliwas, and Luasong) planted in 2016 at the Zogbépimé Forest Station in southern Togo and to provide recommendations for the first thinning. Dendrometric parameters, including diameter, height, basal area, and the Hart-Becking spacing factor (S%) were measured before and after thinning, and data were analyzed using ANOVA at a 5% significance level. Results revealed significant differences in growth among provenances ( $P < 0.05$ ). Prior to thinning, the Indian provenance showed the best growth performance (diameter 12.87 cm; height 11.74 m; basal area 16.83 m<sup>2</sup>/ha), followed by Luasong and Avétonou. Two years after thinning, the Indian provenance maintained its superiority with a mean diameter of 17.91 cm, height of 16.52 m, and basal area of 23.38 m<sup>2</sup>/ha, while Luasong and Tanzanian provenances also showed good performance. Thinning effectively reduced stand competition, decreasing the spacing factor from 21–24% to 14–20%, depending on provenance. These findings highlight the influence of genetic variability on growth and response to silvicultural management. Selecting high-performing provenances and applying appropriate thinning regimes can substantially improve teak plantation productivity, contributing to sustainable forest management in Togo's Guinean ecological zone.

**Keywords:** Teak Provenances, Silvicultural Practices, Thinning Effects, Growth Performance, Plantation Productivity, Togo.



## **Unveiling nature's blueprint: the intricate relationship of site factors and teak plantation productivity in Kerala**

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### **Abstract**

Site quality is a crucial determinant of plantation productivity and plays a key role in species selection, rotation age, thinning regimes, and overall silvicultural decisions for sustainable forest management. The suitability of a site for a given species is largely influenced by biophysical factors, necessitating research to establish site-growth relationships for commercially important species like teak (*Tectona grandis*). This study examined the correlation between biophysical attributes and teak site productivity across Kerala using of 51 sample plots (24 m × 24 m) were established in even-aged teak plantations. The site index, represented by the top height (mean height of the five largest trees per plot), was used as a productivity indicator. Topographic attributes were recorded in the field, while nineteen bioclimatic variables were retrieved from WorldClim and multiple soil physicochemical parameters, including texture, bulk density, pH, electrical conductivity, total phosphorus (P), and total potassium (K), were analysed for different depths up to 1m. Results indicated significant correlations between most climatic factors and site index, whereas only a few soil properties exhibited strong associations. Stepwise linear regression, Random Forest, and XGBoost algorithms were employed to model site index variation., Machine learning models struggled to capture site variability due to the limited sample size, with XGBoost performing better than Random Forest. Multiple linear regression model achieved the highest predictive accuracy, with an adjusted R<sup>2</sup> value of 0.65 and an RMSE of 1.735. Significant predictor variables included soil depth, isothermality, silt percentage (30-60 cm), electrical conductivity (15-30 cm), total phosphorus (15-30 cm), bulk density (60-100 cm), and slope position (top, middle, or bottom). Further investigations incorporating additional soil properties are required to fully explain site index variability in teak plantations.

**Keywords:** Site Index, Top Height, Machine Learning, Site Factors, Site Productivity, Linear Regression

## *Session IV*

### *Management models for smallholder teak plantations and agroforestry systems in Asia, Africa and Latin America*



**Session Chair:** Markku Kanninen, Research Director & Professor Emeritus, University of Helsinki, Viikki Tropical Resources Institute (VITRI), Finland

This session, examined innovative management approaches for smallholder teak plantations and agroforestry systems, highlighting their growing contribution to sustainable timber production and rural livelihoods across tropical regions. It brought together case studies and empirical research to explore scalable, inclusive, and productivity-oriented plantation models.



## **Thematic Keynote**

### **Smallholder teak plantations in Africa-KVTC's experience**

**Irvine Kanyemba**

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#### **Abstract**

Tanzania is one of the leading teak-producing countries in Africa, supported by favourable agro-climatic conditions, expanding plantation area, and increasing private sector investment. The present case study examines the development of Tanzania's teak industry through a detailed study of the role of Kilombero Valley Teak Company (KVTC), Africa's largest privately owned teak plantation enterprise, in the development of Tanzania's teak industry. Established in 1992, KVTC manages 28,132 ha of land in central Tanzania that comprises of commercial teak plantations, conservation areas and supporting infrastructure. In addition to operating an integrated sawmilling and timber processing facility, KVTC has played a significant role in employment generation, research and development, and community engagement. A key component of this engagement has been the company's out-grower support programme (OSP), designed to integrate smallholder farmers into commercial teak production.

The initial phase (first model) of KVTC's OSP was implemented between 2011 and 2020 which was characterized by high quality inputs and extension services by KVTC, cost-sharing for establishment and maintenance and guaranteed markets for the logs at open market prices. A revised model was introduced in 2022 wherein KVTC provided quality planting material and technical guidance, but emphasized on farmer autonomy and no financial incentives. The revised model also proposed open-market competition for KVTC with others to buy logs. Performance outcomes from both models were compared in terms of farmer participation, plantation survival, land-use commitment, and programme sustainability. While the earlier model achieved rapid enrolment and plantation establishment, it faced challenges related to governance, incentive alignment, and high farmer exit rates. On the other hand, early results from the revised OSP indicate improved long-term farmer commitment, lower attrition, and more sustainable integration of teak into smallholder farming systems. The OSP model being implemented by KVTC provides key lessons in designing inclusive, scalable, and commercially viable private-smallholder partnerships in teak forestry, with broader relevance for plantation development across Africa and other tropical regions.

**Keywords:** Teak Plantations, Out-Grower Schemes, Private - Smallholder Partnership, Smallholder Integration, Sustainable Plantation Management



## **Evaluating growth performance and volume of teak coppice management systems- case of intermediate zone, Sri Lanka**

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### **Abstract**

Coppice management is an alternative reforestation technique for Teak (*Tectona grandis*) grown in tropical regions. This study investigated the growth performance and volume of even-aged teak coppice under four coppice management systems (A: 1 coppice, B: 2 coppices, C: 3 coppices, D: >3 coppices) established in the Intermediate Zone of Sri Lanka. Each system covered 1 hectare land with 250 trees. Data on tree height and diameter at breast height (DBH) were collected from all trees at 8 years old. The coppices having a DBH greater than 9.5 cm was included in the analysis. Descriptive statistics was used to summarize the results, and the Kruskal-Wallis test was used to determine differences in total volume among the systems. Consider the maximum DBH growth, the highest DBH (26 cm) was recorded in System C, while System A had the lowest (20 cm). Systems B and D showed similar DBH values (23 cm). System B achieved the maximum tree height (17 m), while System A had the lowest (16 m). Systems C and D recorded intermediate heights (16.5 m). At 8 years, System A produced 22.54 m<sup>3</sup>/ha timber volume, System B 45.09 m<sup>3</sup>/ha, System C 66.83 m<sup>3</sup>/ha, and System D 95.28 m<sup>3</sup>/ha. The Kruskal-Wallis test revealed significant differences in timber volumes among the systems ( $p < 0.001$ ). Post-hoc pairwise comparisons with Bonferroni correction confirmed that all systems differed significantly ( $p < 0.0083$ ). System A had the smallest volumes, while System D had the largest. Growth parameters (height and DBH) indicated that managing multiple coppices did not significantly influence tree height or DBH at younger stages. However, managing multiple coppices per stump at age 8 significantly increased volume per unit area. These findings suggested that managing more than one coppice can serve as a silvicultural guide to enhance teak plantation yields in short rotation.

**Keywords:** Teak (*Tectona grandis*), Coppice Management, Growth, Timber Volume, Sri Lanka



## **Managing small holder teak plantations through the modified taungya system for landscape restoration and climate change mitigation, and adaptation**

**Hugh C.A Brown, Valerie L. Fumey Nassah and Kwame Agyei**

Forestry Commission Ghana

### **Abstract**

Smallholder teak plantations play a vital role in landscape restoration and climate change mitigation and adaptation in Ghana. The revised Ghana Forest Plantation Strategy 2016 - 2040 highlights the Modified Taungya System (MTS) as one of the best strategies for landscape restoration as it integrates food crop production with tree planting and has a unique benefit sharing model that ensures fair share of final matured produce to government, farmers, traditional authorities and fringe communities. This presentation outlines the potential of MTS for smallholder teak plantations, focusing on its benefits for landscape restoration, climate change mitigation, and adaptation as well as impact on livelihoods of farmers. Our findings from implementation for over 20 years indicates MTS is an effective strategy for smallholder teak plantations, enhancing ecosystem services, improving rural livelihoods through short-, medium- and long-term benefits and contributing to climate resilience. Insights for improvement in implementation of MTS is shared for policymakers, practitioners, and researchers seeking to promote sustainable land use and climate-resilient development.

**Keywords:** Smallholder Teak Plantations, Modified Taungya System, Landscape Restoration, Climate Resilience, Sustainable Land Use, Equitable Benefit Sharing.



## **Site management models for optimum yield of *Tectona grandis* L.F. plantations in Southern Nigeria**

**Ige P. O**

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### **Abstract**

Depletion of tropical rainforest is on the increase and plantation forest has been identified as a quick fix measure. Sustainable management of plantation forest for optimum productivity is therefore essential. Hence, this study was carried out to develop site management models (site index) for *Tectona grandis* plantations in Gambari, Oluwa, Omo and Sakpoba Forest Reserves, Nigeria. The data for the study were collected from six (6) age series (6, 8, 10, 12, 14 and 16 years old) in each location. Five (5) sample plots (25m x 25m) were randomly selected per age series (making a total of 120 sample plots) and two-third of the data were used for calibration, while the remaining one-third was used for validation purpose. Based on the index age of 10 years, the selected site index model constructed using regression models approach in Gambari, Oluwa, Omo and Sakpoba were  $SI = \exp [\ln(Hd) - 8.65 (A-1 - 0.1)]$ ,  $SI = \exp [\ln(Hd) - 5.77 (A-1 - 0.1)]$ ,  $SI = \exp [\ln(Hd) - 9.31 (A-1 - 0.1)]$  and  $SI = \exp [\ln(Hd) - 4.35 (A-1 - 0.1)]$ , respectively. Using the graphical approach and proportional curve method, the plantations were stratified into five site quality classes I to V (I = the best site and V = poor site). A 10 year-old Teak stand from this study attained average dominant height (m) of 16.2, 14.1 and 9.8 (Gambari); 19.5, 16.0 and 12.3 (Oluwa); 21.8, 16.2 and 10.5 (Omo) and 15.5, 11.4 and 8.9 (Sakpoba) on site classes I, III and V, respectively. This implied that, the stand height development pattern similar to curve I is growing on the best site and has higher volume production than a stand with height development pattern similar to curve V. It is recommended that site classes I to III should be used for Teak plantations in this study areas.

**Keywords:** Forest Soil, Index Age, Management Models, Site Quality Classes and *Tectona grandis*



## **Allometric equation for estimating the wood volume of *Tectona grandis* growing in agroforestry systems in Brahmaputra valley, India**

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### **Abstract**

Teak (*Tectona grandis* Linn. F.) is one of the most prevalent tree species known for its commercial timber production. It grows in dense clusters and compact blocks in natural and adaptive forests. Most of the allometric equations developed for teak have been based on observations in natural forests, and interestingly, these same equations are being applied to assess teak growing in agroforestry systems. This generates an uncertainty in accurate estimations of wood volume and biomass as growth of trees varies across different natural and managed systems. Therefore, this study was conducted to develop statistically valid volume equations to estimate the total wood volume for teak trees growing in distinct agroforestry systems practiced in northeastern India. A total of 312 trees of teak were measured with the help of Criterion RD1000® Basal Area Factor Scope. The evaluation process involved testing 11 models that relied solely on DBH and 14 models that considered both DBH and height. The identified best-fit equations were validated by applying paired t-test, MAPE and 45-degree line test. There was no significant difference ( $p > 0.05$ ) between the calculated and predicted total wood volumes by the best-fit equations. Additionally, there was a significant difference between total wood volume estimated by the best-fit equations of this study and the equations available for teak of natural forests. Our study suggest that the volume equation developed in this study can provide precise estimate of biomass storage in teak over the commonly used equations for this species.

**Keywords:** Teakwood, Volume equation, Assam, Model validation, Criterion RD1000



## **Smallholder teak plantations: bridging the demand and supply gap in India**

**Rekha R Warriar<sup>1</sup>, Animesh Sinha<sup>2</sup>, Ajay Thakur<sup>3</sup>, Bilas Singh<sup>4</sup>, Fatima Shirin<sup>5</sup>, Yasodha Ramasamy<sup>1</sup>**

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### **Abstract**

India, though, possesses the highest levels of genetic diversity in teak, and remains the world's second-largest importer of tropical logs. One of the major challenges in teak cultivation is its long rotation period, which discourages smallholder participation. Short-rotation plantations, popular in Thailand, Brazil, and Indonesia, offer a viable alternative.

Tissue culture technology effectively addresses the challenges of mass propagation of genetically superior teak clones. Its commercial adoption is limited due to high costs, lack of demonstration trials, and awareness among farmers. The ICFRE-Institute of Forest Genetics and Tree Breeding (ICFRE-IFGTB) has been working to bridge this gap by developing protocols and supplying quality planting material to small holders.

ICFRE-IFGTB has partnered with commercial tissue culture labs and trained stakeholders to enhance production. Since 2016, over 10 lakh tissue culture teak plants have been distributed, showing promising early growth and increasing interest in clonal teak plantations.

Field trials indicate that clonal teak plants exhibit superior performance compared to seedlings. The tissue culture-derived clones have faster growth, better bole formation, and higher survival rates in well-maintained settings. Under proper irrigation and management practices, the harvest cycle can be reduced to 15-20 years, significantly shorter than traditional rotations. The initiative has gained strong support from Forest Departments and private sector investors.

With growing farmer interest and government support, tissue culture teak plantations can boost productivity, sustain livelihoods, and strengthen India's forestry economy. With proper management and silvicultural practices, smallholder teak plantations can significantly contribute to closing the demand-supply gap, offering economic benefits to farmers. The success of clonal teak plantations highlights their potential for a thriving, sustainable teak industry with significant financial benefits for farmers.

**Keywords:** Teak, Smallholder, Tissue Culture, Commercial Production, Quality Planting Stock



## **Dendroclimatic signature on radial growth of teak (*Tectona grandis* L.f.) in South Gujarat, India: an approach for plantation management**

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### **Abstract**

The tree growth and climate relationship of teak has been extensively analysed due to its dendroclimatic potential to extract past climate. The objective of the current investigation was to utilize its dendroclimatic potential in plantation management for teak growers. A total of thirty-seven core samples from 29 teak trees at three different locations, namely Ahwa, Valsad and Navsari of South Gujarat, were collected to study the effect of climatic factors, viz., rainfall and temperature, on the radial growth of teak. The study revealed that the pre-monsoon showers, monsoon rainfall during June–July and September of the current year and high temperature during March have a positive association with radial growth of teak at Ahwa. However, the radial growth of teak at the Navsari site showed a positive association with the previous and current year's September–November rainfall. Considering the Valsad site, the preceding year's August rainfall and current year's June rainfall were negatively correlated with radial growth of teak, while the October–December temperature of the preceding year and temperature of the current year's July and September–November months were also negatively correlated with teak radial growth. It is concluded that the radial growth of teak is influenced by the locality factors, especially the rainfall patterns, topography and moisture availability. The rainfall of March shows a positive influence on the radial growth of teak at three locations. Interestingly, the carryover effect of moisture from the previous year's monsoon and post-monsoon rainfall has a visible change in the radial growth of teak. Hence, by understanding the teak growth and climate relationship in a particular locality, the management of teak plantation can be planned to curtail its mortality rate and meagre growth by water management in the form of irrigation.

**Keywords:** Monsoon, Plantation, Teak, Water Management and Climate



## **Effect of nitrogen and phosphorus levels on growth and biomass production of *Tectona grandis* l. stump in nursery**

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### **Abstract**

A study was conducted to assess the initial growth performances of teak (*Tectona grandis* Linn.) stump under different levels of nitrogen and phosphorus as inorganic fertilizer. One-year-old stumps of 2.5 cm shoot and 12.5 cm root were planted in the polybags of 6" × 12" in size, comprising nursery soil. After one month of growth of teak stump, three treatments of nitrogenous fertiliser in the form of urea i.e. 50, 100 and 150 mg/plant and three treatments of phosphorus in the form of Single Super Phosphate i.e. 25, 50 and 100 mg/plant were applied as sole and their combination following complete randomised block design with four replications comprising 16 treatments including a control. The growth attributes and biomass were recorded up to 240 days at an interval of 60 days. The combined application of 150 mg N and 25 mg P/plant showed highest collar diameter, height, shoot fresh weight, shoot dry weight, total biomass, DQI, chlorophyll a, chlorophyll b and total chlorophyll while the sole application of 150 mg N/plant showed the best in leaf area, leaf fresh weight, root fresh weight, leaf dry weight, root dry weight and leaf weight ratio. The sturdiness quotient for the seedlings ranged from 3.42 to 4.52 among the treatments, with no significant difference over the initial 3.37 to 3.59. The initial mean values of soil pH, OC, available N, available P and available K (7.43, 0.35%, 156.02kg/ha, 89.70kg/ha and 102.47kg/ha) shifted to (7.21, 0.41%, 131.36kg/ha, 62.12kg/ha and 85.44kg/ha), respectively.

**Keywords:** Teak, Stump, Collar Diameter, Biomass, Sturdiness Quotient



## **The role of smallholder teak plantations in Indonesia's forestry sector: models for sustainable development**

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### **Abstract**

Smallholder teak plantations play a significant role in Indonesia's forestry sector, contributing to the local economies and livelihoods of the rural people. In Java, Indonesia, approximately 1.5 million small-scale farmers cultivate nearly 500,000 hectares of tree-based agroforestry systems, with teak serving as the predominant tree species. Up to 80% of small-diameter logs (under 30 cm DBH) supplied to small- and medium-sized industries in Java originate from smallholder plantations. These plantations have the potential to yield as much as 8.2 million m<sup>3</sup> of teak per annum.

While teak dominance underscores its economic value, it simultaneously faces challenges related to productivity and sustainability, owing to suboptimal silvicultural practices, limited access to markets, and inadequate policy support. This paper examines the status of smallholder teak plantations in Indonesia, identifies key constraints, and explores opportunities for improvement. Through a review of best management practices and case studies of successful interventions, this study provides recommendations for enhancing smallholder productivity and economic returns. Government policies and support mechanisms are crucial for the promotion of sustainable teak production. A combination of improved silvicultural techniques, enhanced market access, and enabling policy frameworks is essential to unlocking the full potential of smallholder teak plantations in Indonesia, contributing to both economic development and environmental conservation.

**Keywords:** Smallholder Plantations, Sustainability, Silviculture Practices, Teak



## **Teak in India: a national perspective**

**Jitesh Kumar**

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### **Abstract**

India has a long and well-established tradition of scientific forest management, supported by a robust policy, legal, and institutional framework that emphasizes conservation, sustainability, and community participation. The National Forest Policy, 1988 envisages one-third of the total land area of the country under forest or tree cover. Currently more than 25 per cent of the geographical area of the country is under forest and tree cover. As per FAO's Global Forest Resource Assessment (GFRA) 2025, India continues to maintain third position worldwide in terms of net annual forest area gains and moved up to 9th position globally in terms of total forest area since last decade. As per India State of Forest Report (ISFR) 2023, the Forest and Tree Cover expanded from 7,89,979 sq km to 8,27,357 sq km for the period ISFR 2013 to ISFR 2023. India possesses substantial teak resources both within recorded forest areas and outside forests. Current estimates, as per India State of Forest Reports 2023, indicate that approximately 994 million teak trees occur within forests, representing an estimated growing stock of 199.61 million cubic metres. In addition, around 320 million teak trees are found in trees outside forests (TOF), contributing 36.58 million cubic metres of timber volume. Despite its large teak resource base, India remains a net importer of teak wood. India plays a dominant role in international teak trade. The country accounts for approximately 87 percent of global teak log imports by quantity and about 67 percent by value, reflecting the high demand for quality timber in the domestic market.

Government of India has introduced several regulatory reforms to promote tree cultivation and improve the ease of doing business in the timber sector. Model Rules for Agro-Forestry Rules for felling of trees in agriculture circulated for adoption by the States/Uts. A major governance reform in this sector is the National Transit Pass System (NTPS), which provides a digital platform envisioned with "One-Nation One Pass" for the issuance of transit permits and No Objection Certificates for the movement of timber and other forest produce across states. In addition, India has introduced the Indian Forest and Wood Certification Scheme (PRAMAAN) to promote sustainable forest management and improve traceability and sustainability assurance for timber and wood products in domestic and international markets. The ICFRE-IFGTB has developed a tissue culture protocol for large scale multiplication of selected teak genetic resources. Government initiatives also support the distribution of high-quality planting material to farmers and state forest departments, encouraging teak plantations on private lands and agroforestry systems. Challenges include long rotation periods of teak, limited availability of high-quality planting material, and productivity gaps. Addressing the demand–supply imbalance in teak requires a strategic combination of policy support, technological innovation, and market reforms. Strengthening the expansion of teak plantations in agroforestry systems would offer significant potential to enhance domestic timber production while generating additional income for farmers. Improving access to quality planting material, promoting clonal forestry, and strengthening research on improved genetic varieties will be essential for enhancing productivity and reducing rotation cycles. Further simplification of felling and transit regulations, wider adoption of digital governance platforms such as NTPS, and greater integration of certification systems such as PRAMAAN will help strengthen transparency, traceability, and international competitiveness of Indian teak products.

## *Session V*

### *Environmental protection, biodiversity conservation and forest landscape restoration*



**Session Chair:** Michael Kleine, Senior Advisor, IUFRO HQ, Vienna, Austria

This session addressed the critical role of teak plantations within broader environmental protection frameworks, biodiversity conservation strategies, and forest landscape restoration initiatives. The session brought together researchers, policymakers, and practitioners to examine how planted teak forests can contribute to resilient landscapes while maintaining ecological integrity.



## **Thematic Keynote**

### **Potential benefits of diversification of monoculture plantations – state of knowledge and ways forward**

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#### **Abstract**

The diversification of monoculture plantations is increasingly recognized as a critical pathway toward enhancing both ecological integrity and socio-economic resilience at local and global scales. While monoculture plantations remain predominant within the timber sector due to their relatively high productivity and operational simplicity, they are inherently susceptible to biotic and abiotic stresses, including pest outbreaks, disease proliferation, diminished biodiversity, and narrow ecosystem functioning. These vulnerabilities not only threaten sustainability but also results economic risk due to an exclusive reliance on a single species. Recent advances in plantation management highlight the potential of structural and compositional diversification—through strategies such as polycultures, interplanting with short-rotation species, integrating understory crops, and alley cropping—to create heterogeneous habitats, thereby supporting greater wildlife diversity and enhancing the provision of ecosystem services. Diversified plantation systems are further improves local employment opportunities and income stability, although their socio-economic and environmental outcomes remain context-dependent and hinge upon the development of viable value chains and adaptive market mechanisms. Diversified plantations may also be well-positioned to capitalize on emerging biodiversity credit markets by aligning production with growing demand for environmental co-benefits. This review synthesizes the current state of knowledge concerning diversification interventions within monoculture plantations and critically evaluates pathways forward for optimizing both their ecological and economic potential.

**Keyword:** Climate Resilience, Biodiversity, Sustainable Forestry, Socio-Economic Resilience, Plantation Management



## **Evaluating the environmental resilience of teak (*Tectona grandis* L.F.) plantations: a geospatial analysis of carbon storage in the Western Ghats, India**

**Aswathy K Vijayan<sup>1,2</sup>, Athira Saleevan<sup>2</sup>, Sandeep S<sup>2</sup>, Wable Pawan Shyamrao<sup>2</sup>, Pramod G. Krishnan<sup>3</sup>, K. P. Sudheer<sup>4</sup>,**

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### **Abstract**

Teak (*Tectona grandis* L.f.) plantations serve as critical carbon reservoirs within tropical forest ecosystems, contributing significantly to economic sustainability, global climate change mitigation, and sustainable resource management. Despite their importance, spatially explicit assessments of carbon storage remain scarce, especially across heterogeneous plantation systems. This study applied a multi-decadal remote sensing data and GIS tools to measure spatiotemporal changes in carbon storage and ecological resilience across ten stations of teak plantations in the Palakkad Forest Division, Western Ghats, India. Vegetation indices such as Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), Soil Adjusted Vegetation Index (SAVI), Modified Soil Adjusted Vegetation Index (MSAVI), and Green Normalized Difference Vegetation Index (GNDVI) were derived from multi-temporal Landsat imagery (1988–2024), along with field-based measurements, to estimate aboveground biomass (AGB) and carbon stock using validated empirical models. The results on the NDVI–age relationship ( $R^2 = 0.93$ ) confirmed NDVI as an effective nondestructive measure for estimating biomass and carbon accumulation. Carbon density varied from 1.5 to 67.5 tC ha<sup>-1</sup>, with resilient plantations (Dhoni, Elival, Poolampara) showing higher carbon storage, while degraded sites (Walayar, Puthussery) exhibited lower productivity due to soil and fire stress. This study introduced Carbon Sequestration Efficiency (CSE) as a new measure of stand age and carbon productivity, indicating that sequestration rates decrease with age.

**Keywords:** Teak Plantations, Carbon Sequestration, Remote Sensing, Vegetation Indices, Ecological Resilience



## **Landscape restoration using teak: practices and experiences from Uganda**

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### **Abstract**

Uganda lost vast areas of forest land majorly due to anthropogenic factors such as wildfires, unsustainable agricultural practices, driving land use land cover change (LULC), illegal logging, and a high dependence on biomass energy, amongst others. The highest rates of deforestation (at 3% annual loss) occur on private and communal lands due to indiscriminate cutting of trees for charcoal production. The 2015 FL-ROAM (Forest Landscape Restoration Opportunities Assessment Methodology) identified close to 8 million hectares of degraded areas available for landscape-level restoration.

Teak landscapes occur within the severely deforested North Moist farmlands, characterized by open dry forests that experience frequent and uncontrolled wildfires, invasive, encroaching plant species and the large human settlements cascading the process of deforestation. Restoration of teak landscapes with assisted natural regeneration through enrichment planting, forest protection from wildfires, invasive species removal, coppice reduction and encroacher species management, multipurpose woodlots and tree plantations in areas where acute disturbances have occurred.

With the private sector (communities, small, medium and large landowners) and the public sector interventions, there is an increasing traction in landscape-level restoration that has created teak mosaics alongside other exotic tree species in natural landscapes for enhanced conservation of biodiversity. These efforts have been supported through incentives (ranging from the provision of tree seedlings, grants, technical assistance, and strengthening forest-based value chains) and, most importantly, enforcing restoration standards.

This study examined best practices for a landscape-level restoration on teak landscapes in Uganda and highlighted key lessons for upscaling, replicating these approaches in the decade of ecosystem restoration.

**Keywords:** Teak Landscape, Forest Restoration, Landscape-Level Restoration, Forest-Based Value Chains, Standards



## **Social and environmental aspects of the Lama teak forest landscape in Benin**

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### **Abstract**

The Lama Forest in southern Benin offers a compelling example of integrated landscape management (ILM) that balances environmental conservation with local socio-economic development. In response to growing pressures from agriculture, logging, settlement expansion, and limited financial resources for forest management, a collaborative approach was established involving stakeholders at multiple levels - including local communities, government agencies, traditional authorities, and conservation organizations. This initiative integrates ecological restoration, biodiversity conservation, and sustainable livelihoods through participatory governance, land-use zoning, agroforestry, and the incorporation of traditional knowledge. Community-managed zones support both subsistence farming and forest regeneration, while co-developed management plans promote equitable resource access and long-term ecosystem health. Teak plantations serve a dual purpose: providing fuelwood for local communities and generating revenue for the forest administration to support other land uses, thereby fostering a self-sustaining management model. The Lama Forest ILM model illustrates how coordinated, multi-stakeholder efforts can balance production, conservation, and community needs, while enhancing resilience, reducing conflict, and building a shared vision for sustainable landscape stewardship in West Africa. It also underscores the critical role of self-sustaining local systems in ensuring long-term forest management success. However, to ensure the long-term sustainability of the management plan, further actions are needed-such as greater involvement of the working-class populations from surrounding communities in the management system and extending forest activity planning beyond six months per year.

**Keywords:** Integrated Landscape Management (ILM), Agroforestry



## **Carbon sequestration potential of farm-grown teak in three agroclimatic zones of Tamil Nadu**

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### **Abstract**

A study was conducted to assess the growth attributes, climatic, edaphic influence, and carbon sequestration potential of farm-grown teak in three agroclimatic zones of Tamil Nadu, i.e., High Rainfall Zone (HRZ), Southern Zone (SZ), and Cauvery Delta Zone (CDZ), under four age classes (0-5, 5-10, 10-15, and 15-20 years). The study evaluated growth parameters in 150 teak farms. Among the zones, HRZ recorded the highest growth attributes in the 15-20 years age class, with maximum diameter at breast height (0.314 m and 0.366 m), tree height (12.50 m and 13.00 m), and tree volume (0.927 m<sup>3</sup> and 1.369 m<sup>3</sup>) in both block and boundary plantations. Soil parameters were analysed in surface (0-15 cm) and subsurface (15-30 cm) layer. HRZ exhibited higher organic carbon (0.62%), available nitrogen (197 kg ha<sup>-1</sup>), phosphorus (22 kg ha<sup>-1</sup>), and potassium (340 Kg ha<sup>-1</sup>) in surface soils, while SZ had higher pH (8.30) and electrical conductivity (0.24 dS/m). Tree volume showed a positive correlation with annual rainfall, mean maximum and minimum temperatures, and relative humidity. Similarly, tree volume positively correlated with organic carbon, available nitrogen, phosphorus, and potassium but negatively correlated with pH and electrical conductivity. Regarding carbon sequestration, teak plantations in HRZ recorded the highest carbon content (0.6347 MT ha<sup>-1</sup>) and carbon dioxide equivalent (2.3293 MT ha<sup>-1</sup>) in the 15-20 year age class. A carbon yield model was developed using multiple linear regression for both boundary and block plantations across age classes and agroclimatic zones, with validation showing over 95% accuracy. The study concludes that HRZ is the most suitable zone for commercial teak cultivation due to superior growth performance and carbon sequestration potential, making it ideal for both economic and ecological benefits.

**Keywords:** Farm Grown Teak, Agroclimatic Zones, Growth Parameters, Edaphic, Carbon Sequestration



## **Wildfire impacts on teak forests in the Southern Western Ghats**

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### **Abstract**

Teak has a natural habitat in India and the first teak plantation was established in Kerala, in the South Western part of India in 1840s. At present teak is the principal forest plantation in Kerala and occupies 70 percent of the plantation forestry. According to IUCN red list status, wildfire is one of the potential threats identified for teak. Recently these plantations in Kerala have been increasingly affected by wildfires. This study mainly focuses on the impact of forest fire on teak growing soils in southern Western Ghats. Soil profiles were dug in toposequence (low, medium and high slopes) up to a 1m depth in both fire affected and unaffected teak plantations. Basic soil parameters were analysed following standard protocols. A comparison of pH in fire affected and unaffected soils showed a considerable increase of soil reaction in the fire affected soils ( $5.66 \pm 0.1$  to  $5.34 \pm 0.02$ ). Total organic carbon content was found higher in the teak forest not affected by fire ( $1.78 \pm 0.51$  to  $0.7 \pm 0.26$ ), though the values decreased down the depth in both the systems. Proportion of clay sized fraction ( $<0.002$  mm) decreased after fire with a concomitant increase in the sand sized fraction ( $> 2.00$  mm). Thus, after a fire scenario addition of basic cations (ash) would have decreased the acidic nature of soils and formed large sized aggregates having lesser porosity.

**Keywords:** Teak, Southern Western Ghats Forest Fire, Physico-Chemical Characters.



## **Growth dynamics and productivity of teak plantations in Southern Western Ghats**

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### **Abstract**

With favorable climatic conditions and rich soil types, Southern Western Ghats offers an ideal environment for Teak. Southern Western Ghats is one of the leading regions for teak plantations in India. In recent years, the Kerala Forest Department has been increasingly focused on the sustainable management of these plantations, with an emphasis on scientific forestry practices. This includes monitoring growth patterns, improving plantation techniques, and ensuring that the teak resources are used in sustainable manner. This study focuses on the growth characteristics and productivity of teak (*Tectona grandis*) plantations in Southern Western Ghats. The data was collected from 41 sample plots, representing diverse age groups ranging from 20-80 years. Tree parameters such as Girth at Breast Height (GBH) and height was collected from a 26'26m<sup>2</sup> of plot by standard protocols. The Mean Annual Increment was higher for the age group 20-35 years revealing a higher rate of increase in younger plantations. Mean stock value and stock ratio showed a similar trend with highest value (167.38 m<sup>3</sup> ha<sup>-1</sup> and 0.123) at younger age group (20-35 year) relating to higher density. Mean basal area and mean volume of the trees increased gradually and the mean Diameter at Breast Height (DBH) got stabilized after 65 years which in turn demonstrates significant growth with the age of the plantations. Thus, age and tree size were positively correlated with each other. This study throws light into the growth dynamics of teak plantations under different age groups in Southern Western Ghats.

**Keywords:** Teak, Southern Western Ghats, Growth dynamics, Sustainable Management



## **Role of ODEF increasing development teak plantation in Togo**

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### **Abstract**

Teak is one of the most important hardwood species planted extensively in several countries in the African region. It is one of the most valuable multi-purpose timbers in the world. The teak plantation in Togo currently covers almost 25,000 ha. This species has been planted in the country for more than 50 years and is of considerable socio-economic importance as it offers employment opportunities and provides foreign currency. The first 4000 ha were planted in 1905, now spread to over 55000 ha in several plots established according to an age-related mosaic design. The purpose of this study was to determine the optimum thinning regime and sound silviculture practices through planting trials. The overall Mean Annual Increment (MAI) is currently estimated at 2 m<sup>3</sup>/ha/year to >15 m<sup>3</sup>/ha/year at the half rotation age of 30-40 years. This paper reports in detail on the main characteristics and accomplishments of the ODEF project to date, and provides an orientation for the future.

**Keywords:** Teak Plantation, Silviculture, ODEF, Management, Togo



## **Assessment of carbon sequestration in teak plantations at PDKV, Akola**

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### **Abstract**

This study, conducted during 2022-23 at Panjabrao Deshmukh Krishi Vidyapeeth, Akola, aimed to assess tree productivity and soil physico-chemical properties under teak (*Tectona grandis*) plantations across four locations (P1, P2, P3, and P4). Tree growth parameters, including height, Girth at Breast Height (GBH), basal area, volume, biomass, and total carbon sequestration, were evaluated. Soil samples were collected at depths of 0-15 cm, 15-30 cm, and 30-45 cm from both teak plantations and adjacent barren land and analyzed for pH, electrical conductivity (EC), organic carbon (OC), and available nitrogen (N), phosphorus (P), and potassium (K). P2 recorded the highest tree density (3333 trees ha<sup>-1</sup>), while P1 had the tallest trees (14.90 m) and largest GBH (0.90 m), along with the highest basal area (0.65 m<sup>2</sup> tree<sup>-1</sup>) and volume (0.44 m<sup>3</sup> tree<sup>-1</sup>). However, due to its greater tree density, P2 exhibited the highest total biomass (191.05 t ha<sup>-1</sup>) and carbon sequestration (95.52 t ha<sup>-1</sup>), followed by P1 (96.80 t ha<sup>-1</sup>), P4 (12.33 t ha<sup>-1</sup>), and P3 (9.14 t ha<sup>-1</sup>). Soil analysis revealed lower pH, EC, and OC values under teak plantations compared to adjacent barren sites, whereas available N, P, and K were consistently higher. Among all sites, P2 showed superior soil fertility with maximum OC (0.90%), N (240.33 kg ha<sup>-1</sup>), P (22.14 kg ha<sup>-1</sup>), and K (278.22 kg ha<sup>-1</sup>), while the adjacent barren site had lower values. These findings underscore the role of teak plantations in enhancing soil health and carbon sequestration, emphasizing their significance in ecosystem sustainability. By improving soil fertility and acting as a carbon sink, teak plantations contribute to long-term ecological resilience and environmental well-being.

**Keywords:** Carbon Sequestration, Teak Plantation, Biomass Estimation, Soil Fertility, Ecosystem Sustainability

## *ITTO-BMLEH teak session*



**Session Chairs:** Tetra Yanuariadi, Projects Manager, International Tropical Timber Organization (ITTO), Japan



Paula Sarigumba, Communications and Outreach Officer, International Tropical Timber Organization (ITTO), Japan

The ITTO-BMLEH Teak Session focused on advancing quality timber production and strengthening sustainable supply chains through smallholder and community-based teak plantations across tropical regions. The session highlighted the achievements of the ITTO-BMLEH Teak Project and outlining its future directions. The presentations collectively emphasized the growing importance of smallholder plantations in meeting global teak demand while promoting inclusive economic development and responsible forest management. Country experiences from Indonesia, Cambodia, India, Vietnam, Thailand, and Togo provided diverse perspectives on plantation development, productivity monitoring, pest management, and financial mechanisms supporting smallholders.



## **Improving high-value teak timber for sustainable supply chains under the ITTO–BMLEH teak project**

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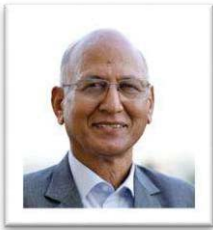
### **Abstract**

Teak (*Tectona grandis*) is a high-value tropical hardwood known for its durability, dimensional stability, and superior wood aesthetics, making it suitable for premium applications such as shipbuilding, high-grade furniture, and interior decoration. Historically, teak was produced from natural forests in India, Myanmar, Thailand, and Laos. However, conservation policies and logging restrictions have led to declining availability of large-diameter logs from these natural forests and a shift towards plantation-based production systems. Globally, teak plantations now cover approximately 4.85 million hectares across 80 tropical countries, with smallholder and community-managed systems accounting for nearly one-quarter of the planted area. Despite their importance in global teak supply chains, smallholder plantations often show low productivity and inferior timber quality due to the use of poor-quality planting material, inadequate silvicultural management, pest and disease pressures, long rotation periods, and limited access to finance, markets, and technical support.

To address these constraints, the International Tropical Timber Organization (ITTO), with financial support from the Federal Ministry of Agriculture, Food and Regional Identity (BMLEH), initiated the multi-country project Promoting Quality Timber Production in Smallholder and Community-based Teak and Other Valuable Species Plantations in the Tropics. The project is implemented across six countries—Cambodia, India, Indonesia, Thailand, Vietnam, and Togo. The study highlights the critical role of genetic improvement strategies, including clonal testing, provenance evaluation, and tissue culture-based propagation, in ensuring the availability of superior planting material. Adoption of improved silvicultural practices—such as optimized spacing regimes, systematic pruning and thinning, and integrated pest management—was found to substantially enhance stand growth, stem form, and timber quality across the study regions. Case studies from participating countries demonstrate that integrating improved genetic material with intensive silvicultural management can reduce rotation periods from conventional cycles of 40–60 years to approximately 15–20 years while maintaining desirable wood characteristics. In addition, the project evaluates innovative financial mechanisms, including microfinance schemes, contract farming arrangements, and tree-collateral lending models, to alleviate liquidity constraints faced by smallholders. Overall, the findings underscore the importance of integrated interventions combining genetic improvement, silvicultural intensification, pest management, financial innovation, and supportive policy frameworks to transform smallholder teak plantations into reliable sources of high-value timber, thereby strengthening sustainable supply chains, enhancing rural livelihoods, and contributing to climate-resilient forestry development.

**Keywords:** Teak, smallholder plantations, clonal forestry, silviculture, value chains, finance, ITTO, sustainable timber

## *Forest Stewardship Council (FSC) session on responsible sourcing of teak: EUDR and beyond*



**Moderator:** Suresh Gairola, FSC India Country Director

This session focused on strengthening responsible sourcing practices within the global teak sector amid evolving regulatory and market expectations. The session opened with a welcome speech by Aakriti Tomar, Communications Manager, FSC India, followed by a keynote address from Cindy Cheng, Regional Director, FSC Asia Pacific, who outlined FSC's global strategies for responsible sourcing and highlighted initiatives supporting sustainable forest management.



## **FSC solutions to promote forest sustainability**

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### **Abstract**

Ever-increasing international and domestic trade in Teak raises concerns not only about the quality but also about sustainable management and responsible sourcing. Credible forest certification systems like Forest Stewardship Council (FSC) forest management certification, chain of custody certification, verified impacts of ecosystems services and other sustainability instruments ensure adherence to the three pillars of sustainability- environmental, social and economic aspects – and responsible sourcing following international norms of legality, traceability, management practices, conservation measures, rights and privileges and relationship with the local communities, environmental values and impacts, monitoring and assessment, and safeguarding of high conservation values.

This paper presents FSC instruments for ensuring responsible management and sourcing of Teak from natural forests and plantations globally. Special sustainability solutions developed by FSC for small holders and assurance system are also highlighted.

**Keywords:** Sustainable Management, Responsible Sourcing, Certification, Local Communities, Legality



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