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Agroforestry

Vol. 3, Issue 2, July - September 2022

INSTITUTE OF WOOD SCIENCE AND TECHNOLOGY, BENGALURU

Indian Council of Forestry Research and Education

(An Autonomous Body Under Ministry of Environment, Forest & Climate Change)


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INDIAN COUNCIL OF FORESTRY RESEARCH AND EDUCATION

(An Autonomous Council of Ministry of Environment Forest and Climate Change, Government of India)

VISION

To achieve long-term ecological stability, sustainable development and economic security through conservation and scientific management of forest ecosystems

MISSION

To generate, advance and disseminate scientific knowledge and technologies for ecological security, improved productivity, livelihoods enhancement and sustainable use of forest resources through forestry research and education

ZiBOC

- A new wood preservative which is comparable to CCA.
- Judicious use of preservative in a non-durable wood greatly enhances (6-8 folds) life of products.

Varieties/ Clones developed

- Developed improved germplasm of many forest tree species.
- Released 47 high performing and disease resistant clones of *Eucalyptus, Casuarina, Shisham, Melia* and *Sarpagandha* with a envisaged production gain of more than 20%. The developed germplasm are being made available to the State Forest Departments and farmers for use in plantations.

High performing and disease resistant clone of *Melia* sp.

CYCUS v. 1.0

- Casuarina Yield Calculator Utility Software (CYCUS v1.0) software has been developed to facilitate the farmer and other user agencies in yield estimation which requires only observations on girth of 100 sample trees per acre of plantation.

Wood Welding

Wood welding is new to our country. In this technique wood joints can be made without using nails and adhesives making them more natural and chemical free. A wood welding machine has been designed and fabricated at Forest Research Institute, Dehradun. Success has been achieved in spin welding of wood pieces of few species.

Wood Welding Machine

New Initiatives

- Transparent wood- a flexible and biodegradable transparent wood has been fabricated using poplar wood veneer and water soluble polymer- polyvinyl alcohol. The transparent wood exhibited high optical transmittance, high haze and light diffusing property.

Natural wood (Left most), Lignin modified wood (middle) and Transparent wood (right most) placed on a paper with letters "IWST"

Heat storage based modified Solar Kiln

- Solar heat storage system based solar kiln has been developed by Forest Research Institute, Dehradun for timber drying. The solar heat is trapped using suitable phase change material (PCM). The New solar kiln is able to trap 39 % more heat in winters as compared to traditional green-house based traditional FRI solar kiln developed during 1970.

Head based storage Solar Kiln

Xylarium

- Collection of authentic wood samples both from India and other countries, depicting wood biodiversity of the country like lightest, heaviest, sweet-smelling, foul smelling, smoothest, streaked, variegated wood and wood of different coloures, etc. The collection of wood cross sectional discs depicting variation in sapwood and heartwood colour is a unique feature of the xylarium.
- Wood identification services.

Xylarium- Collection of Authentic wood samples

Tree hollowness detection technique based on ultrasonic waves

- Forest Research Institute, Dehradun has developed ultrasonic techniques (Non-destructive testing) to detect the location and magnitude of the hollowness of the standing tree. This will help to remove the potential human hazards by way of falling down of such trees during a high wind regime in Urban Forestry.

Measurement of hollowness in a tree using ultrasonic detector

Agroforestry models

- Various agroforestry models (Poplar, Eucalyptus, Melia, Casuarina and Babool) have been developed to improve green cover, enhance farmers income and to mitigate climate change .

Poplar based agroforestry model with wheat

Innovative Bamboo Bottles

- Techniques for making bamboo bottles by using Bamboo Treatment Technologies of ICFRE. Most suitable bamboo species for making bottles are Shil Barak (*Bambusa salarkhanii*) & Barak (*Bambusa balcooa*). One full bamboo is sufficient for making 21 full size bottles and 12 small bottles.

Bamboo bottles

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अश्विनी कुमार चौबे
Ashwini Kumar Choubey

सत्यमेव जयते

राज्य मंत्री
पर्यावरण, वन एवं जलवायु परिवर्तन
उपभोक्ता मामले, खाद्य और सार्वजनिक वितरण
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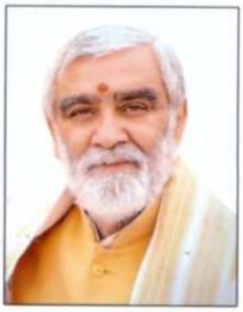

प्राक्कथन

जलवायु परिवर्तन जैसी वैश्विक चुनौती से निपटने एवं वायु प्रदूषण की रोकथाम में यह अति आवश्यक है कि वनावरण के संरक्षण एवं संर्वधन के साथ-साथ वनों के बाहर भी वृक्षारोपण को अधिक बल दिया जाए। निजी भूमि, शहरी क्षेत्रों, सड़कों, नहरों एवं रेलवे लाइनों के किनारे, सरकारी और अन्य संस्थानों की भूमि पर वृक्षारोपण के साथ साथ कृषि वानिकी पर अधिक बल दिया जाए, क्योंकि भारत की कुल भूमि का तकरीबन 60.3% भूमि कृषि भूमि है। इस अपार भूभाग में खेतों के किनारे वृक्षारोपण की असीम संभावनाऐं हैं।

कृषि वानिकी के महत्व को देखते हुए इसको बढ़ावा देने के लिए कई महत्वपूर्ण कदम उठाए जा रहे हैं। कृषि वानिकी मॉडलों को समझने और उसमें सुधार लाने हेतु वैज्ञानिक प्रयास किए जा रहे हैं।

पर्यावरण, वन और जलवायु परिवर्तन मंत्रालय द्वारा राष्ट्रीय वन नीति, राष्ट्रीय कृषि-वानिकी नीति, भारतीय वन अधिनियम और वन (संरक्षण) अधिनियम के बीच नीतिगत सामंजस्य स्थापित करने हेतु एक कार्यबल का गठन किया गया है। इसके अलावा, देश में कृषि-वानिकी तथा वनों के बाहर वृक्षों के विस्तार के लिए प्रोत्साहन प्रदान करने हेतु संभव समाधान उपलब्ध कराने के उद्देश्य से मंत्रालय द्वारा वरिष्ठ वन अधिकारियों को शामिल करके एक संयुक्त कार्यकारी समूह का भी गठन किया गया है, जिससे भारत में कृषि वानिकी को और अधिक बढ़ावा मिलेगा।

मुझे आशा है कि **"वुड इज़ गुड"** पत्रिका के इस अंक से कृषि-वानिकी अनुसंधान और विकास कार्य में लगे अनुसंधान संस्थानों, वैज्ञानिकों, शिक्षाविदों और उद्योगों को अपने लक्ष्यों को नए सिरे से उन्मुख करने तथा कृषि-वानिकी से संबंधित समस्याओं का समाधान करने में मदद मिलेगी। मैं काष्ठ विज्ञान और प्रौद्योगिकी संस्थान को इस पत्रिका को प्रकाशित करने हेतु उनके प्रयासों के लिए साधुवाद देता हूं।

(अश्विनी कुमार चौबे)

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Arun Singh Rawat, IFS

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Chancellor, FRI University

महानिदेशक
भारतीय वानिकी अनुसंधान एवं शिक्षा परिषद्
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Preface

Agroforestry is one of the most sustainable farming practices that greatly helps in making agriculture more resilient. It also helps in increasing farmer's income, reducing pressure on natural forests and boosting shared prosperity of the community in terms of environmental benefits. In India, agroforestry alone meets about 80% of the raw material consumed by various wood based industries, whereas natural forests contribute just about 3.5% of the total timber requirement of the country. With the growing demand for industrial wood, area under commercial agroforestry is expanding. As per the Forest survey of India estimate, Tree Outside Forest area produces about 74.00 million cubic meter of wood annually. It has a potential of producing 100.00 million cubic meter of timber/pulp wood, 150.00 million tonnes of firewood and sequester about 60.00 million tonnes of carbon. Hence, agroforestry has a huge potential to meet the wood requirement of the country along with coproduction of many environmental goods and services like carbon sequestration.

Realizing the potential benefits of agroforestry, in the Annual General Body meeting of ICFRE Society held on 28th April 2022 Hon'ble Union Minister, Ministry of Environment, Forest, and Climate Change emphasized that, to give boost to the agroforestry sector, ICFRE should give special focus for research on agroforestry issues. He also directed ICFRE to organize research conferences across the country to identify the problems associated with agroforestry. Pursuant to the directions of Hon'ble Union Minister, ICFRE through its institutes organized five Regional Research Conferences (RRCs) across the country. These Regional Research Conferences (RRCs) were well represented by the states, research wings of State Forest Departments (SFDs), universities, research institutions working in these thematic areas, NGOs, industrial representatives, young researchers, scientists and various other grassroot level institutions. Special sessions were held on the theme of "Promotion of agroforestry" as well as issues and challenges in promoting agroforestry.

The deliberations and key recommendations of the RRCs are published in this issue of "Wood is good" magazine along with popular articles related to agroforestry with an intention to seek the attention of stakeholders representing wood based industries, research institutions working on agroforestry, academicians, farmers, traders, and policy makers on various issues related to promotion of agroforestry in the country. It is hoped that all the stakeholders associated with the agroforestry sector come forward to work together with ICFRE institutions in addressing various issues associated with agroforestry in India to make India "Atmanirbhar Bharat" in terms of production of wood and wood products.

(Arun Singh Rawat)

पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय, भारत सरकार की एक स्वायत परिषद्
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CONTENT

POPULAR ARTICLES

IWST ACTIVITIES DURING JULY–SEPTEMBER, 2022

Webinar on Sandalwood Plantation and Management

As part of Azadi Ka Amrit Mahotsav celebration, Institute of Wood Science and Technology (IWST), Bangalore conducted a webinar on Sandalwood Plantation and Managements on 8 July 2022. Shri. V.S. Shettepanavar, Group Coordinator (Research) in his opening remarks gave a brief about Sandalwood and the steps that a grower needs to take for management of the plantation. The webinar highlighted on seed collection, processing, nursery techniques, method of quality seedling production, raising of plantation and its management, agroforestry systems, cultivation methods, spacing, manuring, irrigation, choice of hosts, pruning, etc. The topic of disease management covered the basic principles of disease, infections & major diseases/infecting in nursery & plantations and their control methods, The webinar ended with a

economics of sandalwood and evaluation of heartwood content in standing trees. Sandalwood growers, NGOs and other stakeholders benefitted from the program.

Webinar on Clonal plantation of Teak

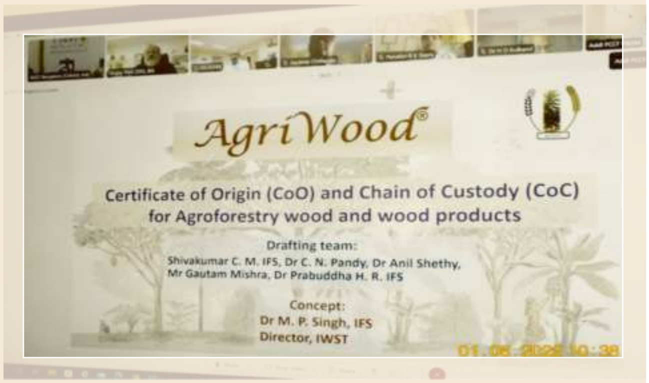
Under Azadi Ka Amrit Mahotsav celebration, IWST, Bangalore conducted a webinar on "Clonal Plantation of Teak" on 21 July 2022. The webinar was conducted in hybrid mode. Shri. V.S. Shettepanavar, Group Coordinator (Research) in his opening remarks explained about the importance of clonal propagation of Teak and Dr. M.P. Singh. IFS, Director, IWST highlighted about Teak as an important commercial species. This webinar gave an overview of teak wood in terms of clonal propagation & its importance and also silviculture & agroforestry of Teak.

Webinar on Extent and Scope for Cultivation of Melia dubia in South India

To commemorate Azadi Ka Amrit Mahotsava IWST, Bangalore conducted a webinar on "Extent and Scope for Cultivation of Melia dubia in South India" on 26th July 2022. Shri. V.S. Shettepanavar, Group Co-ordinator (Research) in his opening remarks briefed the participants about the scope of Melia dubia cultivation and Dr. M.P. Singh. IFS Director in his inaugural address, highlighted about various aspects of Melia dubia. The webinar gave a perspective on the growth of Melia dubia, cultivation status especially in Tamil Nadu, disease and pest management, wood quality, utilization and also trade issues in *Melia dubia.*

Webinar on Agriwood certification overcoming a trade barrier

IWST, Bengaluru hosted a Webinar on "Agriwood certification overcoming a trade barrier" on 1 August 2022 as part of Azadi Ka Amruth Mahotsav. Shri. A.S. Rawat, IFS, Director General, ICFRE was the Chief Guest and Shri. Bivas Ranjan, IFS, ADG (Wildlife and Forest Policy), MoEF&CC and Shri. Sanjay Pant, DDG, Bureau of Indian Standards were Guests of Honour. Also, Dr. H.D. Kulkarni, Vice President (Plantation) (Retd.), ITC, Shri. Jaydeep Chitlangia, Secretary General, FIPPI and Shri. Jikesh Thakkar, Executive Director, AIPM were some of the special Guests at the program. Other participants included representatives from wood based industries, State Forest Departments, Forest Development Corporation etc. On behalf of the Agriwood Standards Drafting Committee, Dr. H.R. Prabuddha, IFS presented on Agriwood standard for the certification of wood produced on farmlands. Shri. A.S. Rawat, Director General, ICFRE, in his inaugural address, complimented IWST for coming up with standards for promotion of agriwood in the country. Shri. Sanjay Pant, DDG, Bureau of Indian Standards (BIS) highlighted about various standards developed by BIS for different processes and products. Shri. Shiv S. Phanse, Forest Governance Expert suggested due diligence should be exercised to check mixing of certified and uncertified wood while developing a product, as it may not be acceptable in any International market. Shri. O.P. Singh, APCCF, Orissa Forest Department explained that there is a need to come up with industry friendly wood based guidelines and collectively work to meet demand and supply gap for wood and wood products in the



country. Dr. H.D. Kulkarni gave a series of inputs to make robust certifying system for agriwood on the lines of Forest Stewardship Council (FSC) and Program for the Endorsement of Forest Certification (PEFC) which are based on 3 pillars of sustainability namely, environmental, economical and social principles. In this regard, Director, IWST, Dr. M.P. Singh opined that coming up with certification standard covering sustainable standard principles, making certifying system very complex and cost prohibitive will end up in discouraging Indian farmers in adopting it. So he suggested that the proposed draft of Agriwood standards should mainly cover legality of wood and certificate of ownership which can be implemented through IT solutions.

Three days training workshop for IFS officers on Integrated pest and disease management in nurseries, plantations and forests

IWST, Bangalore organized three days training workshop on "Integrated Pest and Disease management in Nurseries, Plantations and Forests" for the serving IFS officers during 03-05 August 2022 sponsored by Ministry of Environment Forest and Climate Change, Government of India. Dr. M. P. Singh, IFS, Director inaugurated the training program. 19 IFS officers from different states participated in the training workshop. Dr. R. Sundararaj, Head, FP Division, IWST explained about insects as an integral component of ecosystem and the potential natural means of managing insect pests. Menace of wood feeders in living trees and its management with special reference to Sal heartwood borer was highlighted by Dr. Nitin Kulkarni, Director, IFP, Ranchi. Dr. Amit Pandey, Head, FP Division, FRI, Dehra Dun spoke about forest tree diseases: case studies on mortality of some important tree species. Dr. Amit Yadav, Scientist-D, NCCS, Pune spoke about weeds, pulses, coconut to Sandalwood:

Understanding devastating phytoplasma -related diseases, while Dr. V. Mohan, Scientist G (Retd), ICFRE touched upon nursery diseases of important forest trees and their management and importance of bio fertilizers in healthy forestry practices. Dr. A.N. Shylesha, Principal Scientist, NBAIR, Bangalore highlighted on bio-intensive management of important forest insect pests. Dr. K. Nagaraju, Deputy Director, RCIPMC, Bengaluru educated the participants on plant quarantine requirements for import and clearance of wood and wood products.

Onsite awareness programme for Young Foresters on Protection of Trees under Urban Development Projects

As part of Azadi Ka Amrit Mahotsav, IWST, Bengaluru conducted an onsite awareness program on Protection of Trees under Urban Development Projects at HAL, Helicopter Division, Vimanapura for Field Officers of Forest Wing, BBMP, Bengaluru on 11 August 2022. DRFOs and RFOs from BBMP Forest Wing and Field staff of proponent agency (Coast Guard Aeronautical Overseeing Team) participated in the program. Dr. A. Muthukumar, Scientist, IWST educated them on the importance of protection (retention and transplantation) of trees in urban conditions, especially during planning of developmental projects.

Independence Day

IWST, Bengaluru grandly celebrated 75th Independence Day of the country. Dr. M. P. Singh IFS, Director, IWST hoisted the National flag during the ceremony and addressed the employees and students of IWST. He called upon the employees and students to contribute for nation development by way of innovative research in their respective field of research. Flag hoisting program was followed by distribution of prizes to the winners of various competitions organized as part of Independence Day celebration and concluded with cultural programs by IWST staff and their children.

Capacity Building Workshop on Developing State REDD+ Action Plan

IWST, Bengaluru conducted two days Capacity Building Workshop at Goa on 23-24 August 2022 for state Forest Department of Goa on Developing State REDD+ Action Plan under CAMPA funded ICFRE scheme on Strengthening Forest Research for Ecological Sustainability and productivity enhancement. 35 participants from Goa Forest Department including Chief conservator of Forests, Conservator of Forests, DCFs, ACFs and RFOs participated in the workshop.

Workshop on "Integration of Wood and Wood based products in Green Building" – IWST jointly with NACIN and DGHRD, CBIC

IWST, NACIN, Bangalore and DGHRD, CBIC jointly organized a one day workshop on "Integration of Wood and Wood based products in Green Building" on 25th August 2022. Shri G. Narayanaswamy, ADG, NACIN delivered the inaugural address and Dr. M. P. Singh, Director, IWST gave the special address during the workshop. About user expectations on integration of wood and wood based products in green building was presented by Shri, Subash Agarwal, ADG (Infrastructure), NACIN. Scientists of IWST presented on wood based multistory buildings, wood based composites products for building construction and also wood from alternative timber species for building construction. This was followed by fruitful interaction and visit to Advance Woodworking Training Centre of IWST. About 50 senior officers from NACIN, CBIC and CPWD participated in the workshop.

Forestry Training and Capacity Building: Training of Other Stakeholders on Sandalwood Cultivation and its Prospects

IWST organized a three day training on "Sandalwood Cultivation and its Prospects" to sensitize and educate stakeholders like NGOs, students from educational institutions, nature clubs/eco-clubs, panchayats, elected representatives, personnel from banking institutions, social activists, press and media persons etc. during 14-16 September 2022. The training was sponsored by Ministry of Environment, Forest and Climate Change under the Umbrella Scheme: Forestry Training and Capacity Building - Training to Other Stakeholders.

Short term training on Sandalwood: Establishment and Maintenance of Healthy Nurseries and Plantations

IWST, Bangalore organized a five days training program on "Sandalwood: Establishment and Maintenance of Healthy Nurseries and Plantations" from from 19-23 September 2022. A total of 50 farmers and sandalwood growers attended the training program. The technical session covered seed and nursery technology, management of pests and diseases in sandalwood nursery and plantations with special focus on good silvicultural practices for best health, sandalwood trade, economics, protection, utilization and assessment of oil content, policy and schemes of Forest Department for encouraging raising of sandalwood plantations. A hands-on session at the IWST nursery to learn about seed and nursery technology and visit to sandalwood plantation, entomology & pathology lab was also arranged.

Training on Wood Identification, Seasoning and Preservation

Training program on "Wood identification, wood seasoning and wood preservation" was conducted for officials of Museum of Art and Photography (MAP), Bengaluru from 20 to 22 September 2022 at IWST, Bengaluru. Scientists and technical staff delivered lectures on properties and utilization of wood, general and anatomical properties of wood followed by hands on training on field identification of selected timber species, anomalies and defects in wood and wood products, basics of wood seasoning/drying and preservative treatments for protection of wood. Trainees visited Xylarium, laboratories, wood workshop and Advanced Woodworking Training Centre.

Specialized Technical Course onTimber Technology

One-week Specialized Technical Course on 'Timber Technology' for Group B Officers of Directorate General of Quality Assurance (DGQA - GS), Kanpur was conducted from 26 to 30 September 2022 at IWST, Bengaluru. Topics like basics of wood, general and anatomical properties, physical and mechanical properties of timbers, thermal modification of wood, anomalies and defects in wood and wood products, wood deteriorating agents (borers and termites) and their management, wood and bamboo based panel products, basics of wood seasoning/drying, preservative treatments for protection of wood and bamboo, chemical modification of wood, surface treatment of wood products: wood coatings, fungal degradation of wood and its protection were covered under the training by scientists of the Institute. Trainees visited laboratories and workshops for practical demonstration of seasoning and preservation methods. Practical demonstration on processing of wood composites, WPC was also conducted for trainees.

Hindi Pakhwada Celebration 2022

IWST, Bangalore celebrated Hindi Pakhwada during 14 - 28 September 2022. Dr. M.P. Singh, IFS, Director of the Institute inaugurated the hindi fortnight. The Director addressed all the scientists, officers and staffs of the institute on this occasion and made an appeal to the employees and encouraged them to use Hindi in day to day official correspondences. He also requested to promote Hindi as Rajbhasha in personal as well as organizational capacity. Several competitions were organized for the employees of the institute and a large number of employees participated with enthusiasm. The closing ceremony was conducted on 29 September 2022. Dr. S.N. Singh, Director (Rtd.), Central Translation Bureau, Department of Rajbhasha was the chief guest for the function. He explained the importance and utility of Rajbhasha and requested the employees for devotion towards the use and implementation of Hindi in official work.

Training on Bamboo Cultivation, Management, and Utilization

One day Training Program on Bamboo Cultivation, Management, and Utilization was conducted by IWST, Bengaluru on 23 September 2022 at SARA Centre, Dombekoppa, Shivamogga. The training program was inaugurated through watering of Bamboo seedlings by Mr. Ramachandra V. Bhat, an agriculturist from Khanaja Centre and officials of IWST and UAHS. Ms. P. R. Triveni, CTO and PI of the project from IWST welcomed the participants and gave a brief about the purpose of the training program. Dr. Ramakrishna Hegde, Professor, UAHS, Shivamogga, Dr. M. V. Durai, Scientist and Mr. B. S. Chandrashekhar delivered talks on Bamboo Cultivation: Species selection and management, Bamboo clump management and harvesting, preservation, utilization and value addition of bamboo respectively. Mr. Ramachandra Bhat, Mavinasara shared his experience on bamboo cultivation. The program ended with distribution of seedlings of Dendocalumus asper, Dendocalumus brandisii and Guadua angusifolia to the participants of the training program.

VVK – KVK trainings

Under the Vana Vigyan Trainings funded by CAMPA, IWST, Bengaluru in collaboration with Krishi Vigyana Kendra (KVK) conducted training programs on "Sandalwood based agroforestry models" at Kolar, Suthur, Sira and Gubbi. Farmers from around these places participated in the training programs and learned about different Agroforestry models.

Proceedings and Outcomes Regional Research Conference on Agroforestry Hosted by ICFRE institutes

In the Annual General Body Meeting of Indian Council of Forestry Research and Education (ICFRE) society held on 28th April 2022 the Hon'ble Union Minister, Ministry of Environment, Forests, and Climate Change emphasized that to give boost to the agroforestry sector, ICFRE should give special focus for the research on agroforestry issues and also directed the ICFRE to organize research conferences across the country to identify the problems associated with agroforestry. Pursuant to the directions of Hon'ble Union Minister, ICFRE institutes organized five Regional Research Conferences (RRCs) across the country. The outcomes of the RRCs are given below.

Regional Research Conference jointly hosted by AFRI and TFRI:
Status of Forestry Research with Special Reference to Agroforestry of Dry Regions
1.1 INAUGURAL SESSION

Regional Research Conference on "Status of Forestry Research with Special Reference to Agroforestry in Dry Regions" was jointly organized by Arid Forest Research Institute (AFRI), Jodhpur and Tropical Forest Research Institute (TFRI) Jabalpur. at AFRI, Jodhpur on 22 June, 2022 in hybrid mode. as per directions received from MoEF&CC and ICFRE, the focus was given on Agroforestry.

Sh. M. R. Baloch IFS, Director, AFRI welcomed the dignitaries present in the meeting, viz. Chairman, RRC, Sh. A.S. Rawat, IFS, Director General, ICFRE, Chief Guest Sh. Mayank Mohan Sharma, IFS, PCCF & HoFF, Gujarat, Guest of Honor Dr Deep Narayan Pandey, IFS, PCCF & HoFF, Rajasthan, Sh. M.L. Meena PCCF (WP&FS) Rajasthan, Sh. R.K. Dogra, IFS, DDG(Research), ICFRE, Dehradun, Dr L.N. Harsh, Former VC Agriculture University, Jodhpur, Dr Mahesh Singh, IFS, APCCF(R&T), SFD Gujarat, Dr G. Singh, Scientist G (Retd), AFRI, Jodhpur and all the participants from the six states viz. Rajasthan, Gujarat, Dadar and Nagar Haveli, Madhya Pradesh, Chhattisgarh and Maharashtra, subject matter experts, NGO'S, farmers, Forest officials, Scientist and technical officers from CAZRI and AFRI and other participants who joined this meeting from different parts of India.

Thereafter, DDG (Research), ICFRE, Sh. R. K. Dogra, welcomed officials from SFD Gujarat and SFD Rajasthan, colleagues, Directors from ICFRE, Vice Chancellor, NGO and representatives from sister organizations. He stated that ICFRE is on the forefront to provide solutions related to forestry. He enlightened the participants regarding how research and allied activities at ICFRE are undertaken by prioritizing the National Forestry Research Plans (NFRP) with the goal of achieving national and international commitments. Sh. Dogra then explained that the purpose of organizing RRC since its inception in 2018 is to provide a platform for the forest council, forest departments, and sister scientific organizations, NGOs and other stakeholders to discuss the current issues, share the updated knowledge and draw current priorities to identify justifiable research needs through deliberations. He then flagged two important matters.

Sh. A.S. Rawat (IFS), D.G., ICFRE, Chairman of RRC welcomed the eminent delegates and resource persons from different parts of the country participating from their respective jurisdictional states/UTs. With its mission to generate, advance and disseminate scientific knowledge and technologies for ecological security, improved productivity, livelihoods enhancement and sustainable use of forest resources through forestry research and education, ICFRE intends to achieve long-term ecological stability, sustainable development and economic security through conservation and scientific management of forest ecosystems. He informed that in this direction ICFRE is presently running 31 All India

Coordinated projects under CAMPA covering a wide array of themes and topics. Chairman RRC also mentioned in his address that ICFRE has been depending on recommendations by stakeholders participating in RRC to formulate projects. He also informed that land degradation, biodiversity loss, and climate change are three different faces of the same central challenge and are interrelated, the situation being particularly grave in semi-arid regions. He notified that due to climate change, areas are becoming drier and anthropogenic pressure is building up. Shifts in bioclimatic zones from humid/ dry sub-humid to semi-arid/ arid are the indicators of degradations in habitats and the environmental conditions. Thus, land degradation and biodiversity loss are two major issues to be addressed at present. With the expansion of agriculture, deforestation has become a major challenge in forest areas. With respect to semi-arid regions, a large population is dependent on land for both survival and livelihood. With ongoing land degradation, this population will be negatively affected. Land degradation, therefore, needs to be checked which if not addressed properly now will make it impossible for feeding the large human as well as cattle population. He also informed that extensive forestry and extensive agriculture cannot go simultaneously which necessitates agroforestry. Agroforestry is envisaged to benefit by making agriculture more profitable, not only in terms of economic gains but also for eco-restoration. Industry is a major driver for agroforestry, so there has been success in adoption of agroforestry in some pockets of the country wherein industries flourish but not in others. Hence, it is the right time to venture into the possibilities of creating driving force for agroforestry in such areas by roping in industries. It is also imperative that agroforestry is made profitable for farmers to make them more willing to accept agroforestry. But it is difficult task as agroforestry models are region specific and therefore both Agriculture and Forestry Departments along with state should join hands. This may be achieved by providing QPM developed by the various ICFRE institutes in terms of improved clones and varieties to the SFDs. He also suggested to the representatives from SFDs that requirement of relaxation in the policy for felling and transit of tree species of agroforestry significance may be looked into by SFDs to popularize agroforestry among masses.

Dr. Deep Narayan Pandey, IFS, PCCF & HoFF, Rajasthan, Guest of honor of the inaugural session during his address talked about the challenges faced by farmers to earn livelihoods that are further aggravated in dry regions due to climate change. He supported agroforestry as a solution to these issues. He flagged three matters important both for scientists and practitioners. He mentioned that climate change, land degradation and livelihood challenges are three challenges of major scientific relevance. To address these challenges, the scientists are required to carry out science in order to come up with strong and dependable solutions for the respective issues and the practitioners, on the other hand, are required to take solutions so generated to land. In this step, the major setback is the existing gap between knowing and doing. Dr. Pandey emphasized that agroforestry should be promoted not only in the agriculture lands but it should be made a common practice in all land forms available while taking into account the concept of landscape continuum. Species should be restored and tress should be planted in and around homes, in societies, in parks and on roadside, and proper care should be taken while selecting species according to the land type. In this third appeal, Dr. Pandey requested scientists working under the auspices of ICFRE to hold more meetings and deliberation sessions with forest departments to bridge the gap between knowing and doing and to take research outputs from lab to land.

Sh. M. M. Sharma, IFS, PCCF & HoFF, Gujarat and Chief Guest of the inaugural session, briefed the participants on the status of agroforestry research in Gujarat. He highlighted the timeline of development of agroforestry in Gujarat, while stating that social forestry started in Gujarat 50 years back in 1970s. He mentioned that Gujarat Forest Departments are also distributing seedlings in Van Mahotsava to the farmers and other stakeholders. He accentuated the need for policy research and reformation to promote agroforestry among farmers. Farmers who adopt agroforestry should be given compensation for the economic loss that they have to bear due to reduction in crop yield that they have to encounter while going for agroforestry. Also, research needs to be undertaken in providing agroforestry models suitable for an area of interest. He mentioned that area under trees outside forest has increased in Gujarat significantly to 40 crores in 2021 and the major tree species used in these models include Eucalyptus, Neem, Acacia, Teak and Ailanthus.

He informed that we have already reached a state where forests are not giving much and this needs to be addressed. He then mentioned that towards promoting agroforestry, 88 species have been exempted from regulation within the state of Gujarat and that policy reformation is still continuously in place since last 26 years. He then mentioned that drier regions of Gujarat can be compared with the dry areas of Rajasthan and invited interventions by AFRI in these areas. He also supported research in the area of value addition which in his view will go a long way in generating income for farmers.

1.2 Technical sessions

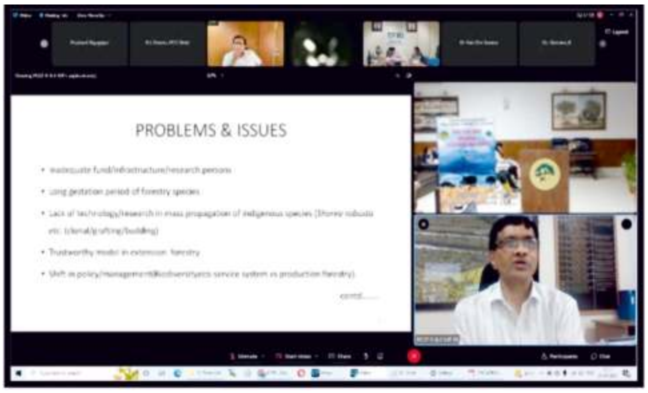
After the inaugural session, four technical sessions were held where Scientists and officers of AFRI Jodhpur, TFRI Jabalpur, Rajasthan, Gujarat, Chhattisgarh, Madya Pradesh, Maharashtra and Dadra & Nagar Haveli, and Daman & Diu (UT) deliberated various issues and research problems.

1.2.1. Status of forest Research and issues of the state forest departments

This session was chaired by Sh. R.L. Meena, Ex-PCCF, Gujarat. where in Dr. Tarun Kant, GC(R), AFRI, Jodhpur presented 'Overview of Research Works done in AFRI'. Similarly, Smt. Neelu Singh presented overview of Research Works done in TFRI, Jabalpur. In her presentation, she included the detailed information about the genetic and tree improvement work, identification of superior germplasm of *Azadirachta indica*, micro-propogation of Bamboo and other sp., selection and evaluation of natural population of *Terminalia bellirica* for active ingredient, variability for growth, wood traits and natural regeneration of Hardwickia, Introduction and evaluation of *Melia dubia*, genetic improvement and conservation of Chironji, conservation of RET sp. of Chhattisgarh Development of value chain of bamboo, selection of insect pest and disease free CPT's of *Gmelina arborea* and production of clonal planting material. She also talked about the release of 2 varieties of *Rauvolfia serpentina*, different agroforestry models, seed technology, non-destructive harvesting of important species, agro technique of medicinal plant, control of teak defoliator and skeletonizer, Sal borer, and various pest and disease management.

Presentation by Sh. Atul Jain, APCCF, Forest Department of Madhya Pradesh; He informed that it's almost 100 year of forestry research in M.P. In 1922, First Silviculture Division was initiated. He said we should go back to basics, i.e. afforestation and increasing the forest productivity, and appeal to also focus on dissemination of technology into the fields, adoption of best practices like nursery techniques, agroforestry and JFM. He also emphasized on the need for organizing trainings, and dissemination of information regarding doable practices and indigenous farm forestry models. He pointed out that there should be better coordination among forest research institutes, forest departments and other user organizations. Problem and issue raised by him were on inadequate funds/infrastructure/research person, long gestation period of forestry sp., lack of technology in mass propagation of indigenous sp. and trustworthy models in extension forestry. In his views, shift in policy/management is required and work on biodiversity and production forestry is to be focused on.

Presentation by Sh. Rajiv Chaturvedi, CCF Silva, Rajasthan Forest Department; he presented on Status of research activities and research projects of Rajasthan state forest department were discussed in detail during this presentation viz., Status, assessment and propagation technique of *Ephedra foliata*, establishment of forestry food park and world forestry arboretum Jaipur, establishment of habitat renovation Amrita Devi Park, Jaipur, establishment of herbal garden at Grass Farm Nursery, Jaipur, Development & improvement of seed orchard at Research Farm Govindpura, collection of quality seeds from seed production areas, studying effect of PUSA hydrogel on plants, documentation of flora of grass farm Jaipur, studying application of biofertilizer in plant nursery, establishment of clonal plant orchard at Grass Farm Nursery, Jaipur, establishment of climber (Lata kunj) at GFN, Jaipur, regeneration and multiplication study of Ethno medicinal plants, distribution under farm forestry scheme and awareness program for stakeholders.

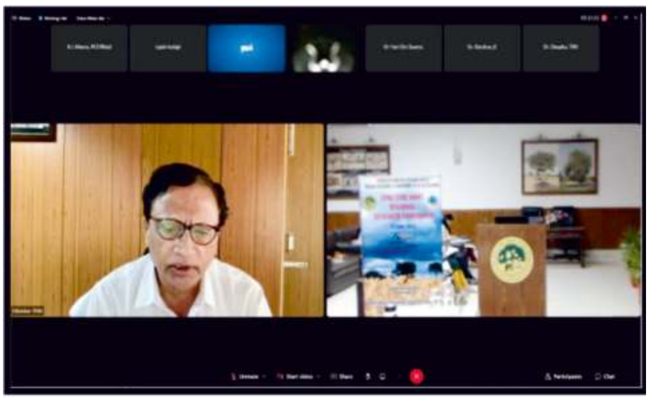


Presentation by - Shri Rajesh Kallaje, CCF (Research & Extension),Forest Department of Chhattisgarh ;

He discussed on issues related to need of development of forestry models that can be followed by others. He stated that a database on research projects should be made available to all forest departments to update them on the continuous ongoing research projects on agroforestry. Only applied forestry research with practical utility should be focused and regular sharing of data with the FD's and visits of senior scientist to field is needed.

1.2.2 Dedicated session on Agroforestry of Dry Region

This session was chaired by **Dr. L. N. Harsh, ormer VC of Agriculture University, Jodhpur.** where in Dr. G Rajeshwar Rao, Director, TFRI, Jabalpur delivered a presentation on agroforestry systems in India. He elaborated the entire agroforestry system of India by citing suitable examples viz., Ber/Anola based agroforestry, Bamboo based agroforestry, Butea monosperma – Lac based agroforestry, *Gmelina arborea* based agroforestry, betel vine-based agroforestry system. He also emphasized on role of agroforestry in climate change resilience. After the completion of his presentation, Director AFRI, inquired whether any subsidies are available on agroforestry tree species. To this Dr. G. Rajeshwar Rao answered that Telangana and some other states provide subsidy for road and avenue plantation. Dr. L. N. Harsh stated that in Sikar district of Rajasthan, farmers only go for agroforestry tree species of multipurpose uses, such as *Ailanthus excelsa, Salvadora persica,* various species of Acacia, so that they can get extra remuneration along with their agricultural yield.



Dr. D. K. Samadia, Principal Scientist, ICAR-CIAH, Bikaner presented the work undertaken at CIAH, Bikaner on various horticultural crops and Khejri wherein he explained about the climate of arid zone(s), sites and crop genotypes. He also pointed out that special attention needs to be given on planning and the production of various tree species in combination with different crop(s). He gave different examples of native crop plants for arid zone along with Agri-Horticultural

Agroforestry systems viz; Khejri+millets, Khejri+Vegetables, Khejri+unexploited fruit plants, Khejri+Legumes etc. he also explained about the germplasm conservation, propagation methods and orchard establishment through budding of thorn less Khejri (Thar Shobha and Thar Amruta). At last, he concluded by explaining the various aspects that need to be fulfilled with further research. Awareness must be encouraged among farmers/cultivators for the conservation of germplasm and the conservation and utilization for targeted regions.

Dr. Archana Verma, Scientist, CAZRI described about Agroforestry systems in Arid region and the contribution of CAZRI in this region. She emphasized on the various techniques that were developed by CAZRI, Jodhpur. She also explained about budded Khejri Agroforestry, and different successful agri-horticultural systems (Amla, Ber, Anar), horti-pastoral systems, agri-silvicultural systems. Dr. N. Singh, Sci G (GCR, TFRI) asked some questions regarding the concentration of CAZRI gum enhancer/booster.

1.2.3 States of Forestry Research and Problems an Issues of the State

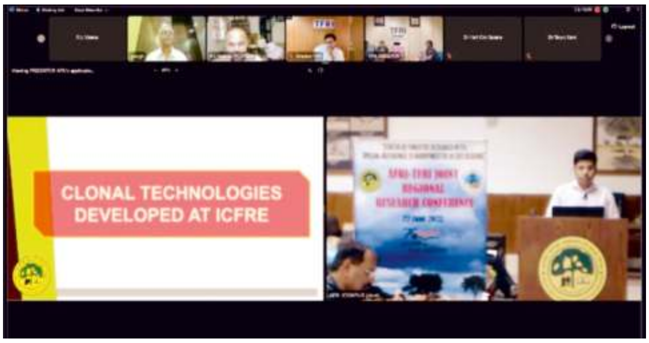
This session was chaired by Dr. G. Singh, Scientist G (Retd.), AFRI, Jodhpur. This session was divided into two portions. These covered presentations and included session for inviting inputs and views on research needs from subject experts, representatives from scientific institutes, NGOs, farmers, state forest departments, VVKs, KVKs and tribals.

Dr. R. L. Meena, IFS (Retd.), Ex-PCCF, Gujarat, delivered the lead lecture on "Expectations from Forestry Research and funding opportunities with particular emphasis on Agroforestry". He highlighted about the research problems and policy bottlenecks for the promotion of agroforestry. Further, he informed that felling and transit regulations have been relaxed for 88 agroforestry tree species in the state of Gujarat. He shed light on the concept of agroforestry being implemented in the state of Gujarat, whereby different regions are employing different tree species for agroforestry. Some of these dominant economic species in agro-forestry plantations in Gujarat include Neem (*Azadirachta indica*), Deshi babool (*Acacia nilotica*), Nilgiri (*Eucalyptus sp.*), Sharu (*Casuarina sp.*), Ardusa (*Ailanthus sp.*), Teak (*Tectona grandis*), Subabool (*Leucanea leucocephola*), Bengali babool (*Acacia auriculiformis*), Malabar neem (*Melia dubia*) and Bamboo. He also underscored importance of subsidy in agroforestry species. If subsidy and other incentives are provided to farmers, they are likely to adopt agroforestry. He underlined the expectations from forestry research for conservation and development of forest keeping the following points:

1) Raising of Quality Planting Material (QPM)
2) Plantation models in different ecological regions and land conditions
3) Tree improvement and mass multiplication for plantations
4) Silviculture and management of trees and forest plantations
5) Basic research (carbon sequestration, climate change impacts, forest ecosystems assessment, ecology of pests and diseases, wood technology etc.)

Dr. Tarun Kant, Scientist F and GC(R), AFRI, presented on clonal technologies of ICFRE. He enlisted all the 75 clones and varieties of different species so far released by ICFRE, including Eucalyptus, Teak, Casuarina, Neem, Poplar, Sarpgandha or Indian snakeroot, Calophyllum inophyllum and Sheesham. He also highlighted the macro and micro-propagation protocols that have been developed by the different institutes of ICFRE, including Neem, Teak, Guggul, Marwar Teak or Rohida, Deshi Babool, Sheesham, Eucalyptus, Sandalwood, Embelia ribes, Kusum, and a variety of orchids and bamboos.

The session was summed up by Dr. G. Singh, Chairperson while putting emphasis on proper assessment of agroforestry systems and their authentication by consolidation of data.



1.3 Final Recommendations of RRC

- Farmers that adopt agroforestry should be given compensation for the economic losses that they have to bear due to reduction in crop yield
- Agroforestry should be promoted not only in the agriculture lands but it should be made a common practice in all land forms available while taking into account the concept of landscape continuum. Species should be restored and trees should be planted in homes, and near homes in societies, in parks and on roadside, and proper care should be taken while selecting species according to the land type
- Thornless Khejri variety (Thar Shobha and Thar Amruta) should be propagated and be used in development of agroforestry models already known to be effective with normal thorned Khejri varieties.
- Research needs to be undertaken to develop agroforestry models suitable for different ecological regions and land conditions
- Plantation models in different ecological regions and land conditions should be clearly defined
- Lesser-known agroforestry species should also be evaluated by the research institutes for development of new models
- Research in the area of value addition should be undertaken that will help in augmenting income generation for farmers
- Technologies to produce Quality planting material (QPM) for agroforestry species need to be developed by the institutes and QPM so generated should be made available to the forest department for mass multiplication and further distribution to farmers and other stakeholders
- Tree improvement and mass multiplication for plantations should continue in mission mode
- Basic research (carbon sequestration, climate change impacts, forest ecosystems assessment, ecology of pests and diseases, wood technology etc.) should continue
- Focus should be given on dissemination of technology into the fields to encourage adoption of best practices, like nursery techniques, agroforestry and JFM.
- A database on research projects should be developed and made available to all forest departments to update them on the continuous ongoing research on agroforestry
- A better coordination among forest research institutes, forest departments and other user organizations should be fostered
- Demand-driven research problems should be given by SFDs to deliver solution by the research institutes
- Inadequate funds/infrastructure/research person, long gestation period of forestry sp., lack of tech./research in mass propagation of indigenous sp. and trustworthy models in extension forestry are some major problems encountered in agroforestry research, and should be addressed.

2. Regional Research Conference organized by HFRI and FRI.

Forestry Research needs and Issues in Northern Region of India

2.1 INAUGURAL SESSION

Himalayan Forest Research Institute (HFRI), Shimla in collaboration with, Dehradun organized one day "Regional Research Conference" through hybrid mode (Online/Offline) on 27th June, 2022 on the theme "Forestry Research needs and Issues in Northern Region of India". The conference comprised an inaugural session with three technical sessions, followed by brainstorming and chalking out the research agenda on the theme of the workshop.

At the outset, Dr. Sandeep Sharma, Director (In-charge) HFRI, extended a warm welcome to Sh. A.S. Rawat, IFS, Director General, ICFRE and chief guest of the occasion; Sh. Ajay Srivastav, IFS, PCCF and HoFF, Himachal Pradesh State Forest Department and Guest of Honour; Sh. Jagdish Chander, IFS, PCCF & HoFF, Haryana Forest Department and all dignitaries of Forest department of 5 states Himachal Pradesh, Punjab, Haryana, Uttarakhand and Uttar Pradesh and 4 UTs i.e Jammu and Kashmir; Ladakh Chandigarh and Delhi and other participants, who attended workshop online as well as offline.

Sh. R. K. Dogra, IFS, DDG (Research), ICFRE Dehradun outlined the theme of the conference and highlighted the importance of ICFRE institutes in fulfilling the research needs of stakeholders. He said that ICFRE being the apex forestry research organization in the country, has its research focused on biodiversity conservation, genetic resource management, climate change, land degradation, desertification, and natural forest resource management. The research at ICFRE keeps in view the objectives of the National Forest Policy, 1988.

Sh. A. S. Rawat, IFS, DG, ICFRE, Dehradun in his inaugural address as a chief guest emphasized that the Forestry Research and its Issues in context to the Northern Region of India would be deliberated in length and he was hopeful, that the outcome of the conference would be important for forestry research in the region. He said that traditional agroforestry has been practiced for long, however, there is need to have scientific inputs in agroforestry so that its productivity could be enhanced. He stated that ICFRE is working continuously to develop technologies, which will ultimately benefit the farmers. He further told that role of agroforestry in meeting the goal of 33% percent geographical area under forest is very crucial and the gaps in the field of agroforestry need to be identified and fulfilled through scientific ways. ICFRE is developing clones of important agroforestry species and these can be of great uses for farmers. Agroforestry not only help in ecology and environment improvement but also boost the income of farming communities. There is need of support from state forest departments to enhance the research work in the field of agroforestry. He hoped that different experts would give their valuable inputs and ICFRE will work on suggestions and recommendations of this conference.

Sh. Ajay Srivastava, IFS, PCCF & HoFF, Himachal Pradesh State Forest Department and Guest of Honor of the occasion said that research and monitoring are important aspects of forestry management and role of ICFRE in this area is very important. There is need to give more emphasis on research areas like restoration ecology, forest fires, etc.

Sh. Jagdish Chander, IFS, PCCF & HoFF, Haryana stressed upon scientific harvest of timber to generate revenue. Agroforestry and clonal technology can play huge role in meeting the demand of timber, fuelwood and other forestry services. He informed that India has 17% of world human population and 16% of cattle population of the world and on the other hand, the country has less than 4% of forest area of the world. Agroforestry and clonal technology can bridge this gap. He further informed that although there are more than 45000 plant species, at present agroforestry research is focused on only a chosen few. Therefore, he stressed upon research to be explored on more species. He further stressed that research needs to be focused with the sustainable development goals in mind.

2.2. TECHNICAL SESSIONS

2.2.1. Forestry research problems and issues of the Northern States and UTs Forest Departments

This session was chaired by Sh. Jagdish Chander, IFS, PCCF & HoFF, Haryana Forest Department. The session started with a presentation on overview of the research programmes in ICFRE by Dr. Vimal Kothiyal, ADG (Research & Planning), ICFRE, Dehradun.

Dr. Renu Singh, IFS, Director, FRI and Sh. N.K. Upreti, GCR, FRI presented over view of research at Forest Research Institute, Dehradun. They highlighted the different research interventions under various AICRPs, MoUs signed, DPRs on rejuvenation of Yamuna rivers & other extension & research achievements of their institute. Thereafter, representatives from northern states gave power point presentations on forestry research status and issues in their respective states.

Sh. Sanjeev Chaturvedi, IFS, CCF (Research), Uttarakhand Forest Department talked about forestry research, Clonal Technology disseminations and initiatives in Uttarakhand.

Dr. Sushil Kumar Kapta, APCCF (Management), HPSFD presented overview of forestry research activities and initiatives in Himachal Pradesh. He raised the issues pertaining to early flowering of Rhododendrons, drying of Ban Oak, development of nursery and planting technique of Betula utilis and important medicinal plants, assessment of biodiversity status in various dense/moderate/open forest of Himachal Pradesh, development of plantation techniques for moisture stress areas and degraded forest lands of H.P. and impact assessment of forest fire on flora and soil moisture of forest areas in Himachal Pradesh. Further, Sh. Satnam Singh, IFS, CF (Research) Hoshiarpur, Punjab Forest Department briefed about forestry research, Clonal Technology disseminations and initiatives in Punjab.

Sh. Jagdish Chander, IFS, PCCF &HoFF, Haryana talked about forestry research, Clonal Technology disseminations and initiatives in Haryana. He also highlighted that the problems of clonal forestry is emergence of monoculture within monoculture, that results in out break of pest & diseases.

Sh. Rakesh Abrol, DFO (Research), Jammu presented overview of forestry research needs and initiatives in Union Territory of Jammu & Kashmir. He raised the research issues pertaining to development of fast-growing clones of forestry species, development of agroforestry models for livelihood generation of common people, identification of NTFP' species for underplanting in agroforestry models and identification of best strains of Willow and development of agroforestry models on based on Falsa. Then, Sh. N.K. Janu, IFS, CCF, Meerut, Uttar Pradesh Forest Department presented forestry research, Clonal Technology disseminations and initiatives in Uttar Pradesh.

Problems of clonal forestry is emergence of monoculture within monoculture, that results in out break of pest & diseases.

2.2.2. Agroforestry and clonal technology disseminations: Problems and Issues

The session was chaired by Dr. Savita, IFS, Ex-PCCF and HoFF, HPFD. The chairperson highlighted the importance of agroforestry in food security, livelihood generation and enhancing the green cover.

Dr. Ashok Kumar, Scientist-G, FRI, Dehradun (U.K.) presented the talk on "Clonal Technology disseminations initiatives and issues". Dr. Ashok Kumar highlighted the initiatives of ICFRE in tree improvement programme and released clones of important agroforestry tree species i.e., Poplar, Eucalyptus, Teak, Shisham, Neem and Melia dubia. He informed the house that these superior clones are cultivated by the farmers and tree growers leading to higher economic returns. He further emphasized the major challenges in the clonal forestry and issue of availability of registered and certified planting stock. He appreciated the efforts of private industries like ITC and WIMCO for motivating farmers to adopt agroforestry by introducing superior clones in North India. Further, he stressed upon conducting more R&D works to develop superior clones of other suitable tree species with reduced rotation period. The clones thus developed should be popularized among the beneficiaries so that it helps in economic gains and improving their livelihood.

The second talk was delivered by Dr. R.C. Dhiman, Ex-Head WIMCO Seedling ITC Ltd. Rudrpur, U.K. India on "Agroforestry and Clonal Technology for productivity enhancement". He informed the participants about background of agroforestry plantations and clonal technology transforming in India. He also highlighted the importance of clonal forestry and its important features of agroforestry produce like uniformity, productivity and short rotation. He suggested that the clonal technology is available only for few species like poplar, eucalyptus etc. which, needs to be developed for more species. He also suggested that the micro- propagation techniques for the developed clones should be developed for mass propagation of superior genotype higher growth, productivity and return.

After the completion of the talk, Dr. Savita, chairperson of the session appreciated the contributions of industry and research organizations to lab to field transfer of clonal technology in agroforestry providing added income opportunities to the local community.

The discussion was followed by the talk on "Agroforestry research, Clonal Technology dissemination in Punjab" delivered by Dr. Sanjeev Chauhan, Head, College of Horticulture and Forestry, PAU Ludhiana. Dr. Chauhan highlighted the importance of agroforestry and emphasized that the 97% of the forests are owned by the State Forest Department while the 90% of wood supply is coming from agroforestry and tree outside forests. He expressed his views that the agroforestry is the solution for increasing industrial demand and meeting the multifarious needs of the people. He also emphasized on SWOT analysis for agroforestry systems and suggested to develop new agroforestry systems and strengthen the agroforestry research and extension activities. Dr. Chauhan further suggested that the agroforestry is a carbon neutral venture and may act as a bridge between wood demand and supply, food security, poverty alleviation and ecological security. After the talk, Dr. Savita, chairperson of the session told that extension and dissemination of Agroforestry and Clonal technology should be effectively used with positive mindset and proper knowledge of species selection to improve the Agroforestry output leading to added income. Keeping in view the limited land resources, PSIP should be exploited with technological interventions and benefits should reach the stakeholders.

Dr. R.S. Minhas, Director, HIMOARD, Rampur, Shimla, H.P. talked on "Agroforestry and organic farming initiative in Tribal Areas". Dr. Minhas highlighted his work on organic farming and agroforestry in collaboration with tribal people. He also stressed on the sustainable use of wild herbaceous plant like wild marigold and Lantana camara as a biofence, which can also be exploited to control the powdery mildew and downy mildew keeping in view the pesticidal activities of their extracts. Dr. Minhas also suggested that native tree species like Corylus jacquemonti, Juglans regia, Aesculus indica, and Pinus gerardiana species should be promoted to the hill agroforestry systems in combination with of native pulses and other traditional cash crops of the hilly region. Dr. Minhas further suggested that the cultivation techniques for the native medicinal plants like Kala Jeera and others natural resources be developed and the certification procedure for various NTFPs should be developed. Dr. Minhas informed the house that organic certification has improved the value addition of the tribal agricultural produce and has been generating higher income though monetary profits.

After the talk, Dr. Savita, IFS, Ex-PCCF and HoFF, HPFD appreciated the efforts of HIMOARD, Rampur, Shimla, H.P. for their contribution to motivate the tribal community to adopt organic farming and improving their livelihood.

Sh. Zubair Ahmad, tribal representative from Ladakh, discussed the "Agroforestry issues in Tribal Areas". Mr. Zubair highlighted that the seabuckthorn is the boon for cold desert areas but the farmers are facing problems in the region due to fluctuating market despite good production. Mr. Zubair raised the issue of unavailability of planting material of Juniper in the area which can help in improving the green cover, soil conservation and in reducing the degradation of fragile ecosystem of the valley. He also informed about the persistent insect pests outbreaks causing loss to the Salix and Poplar plantations in the region. He also emphasized that the propagation and cultivation technique needs to be developed for Rosa webbiana, an important plant used for tea and agarbatti making. He also suggested that the integrated farming system should be developed for the Ladakh region and a marketing platform should be provided to the local people to sale their organic product. He also highlighted the need to develop certification programme, insurance and buy-back mechanism for the organic produce of the region.

Sh. Shiv Paul, another tribal representative from Lahul- Spiti highlighted the problem of drying of salix, poplar and emphasized to initiate the research on factors responsible for declining populations of wild walnut, Berberis, Fraxinus and Rosa webbiana. Dr. Jagdish Chander IFS, PCCF & HoFF, Haryana Forest Department told that research should be conducted to study the wood properties of different varieties of Walnuts tree.

Sh. Mukund Mohan Shandil, Vice- President, Gram Panchayat Rajhana, Shimla, Himachal Pradesh briefed about green fodder issues in hills and raised concern regarding farm productivity enhancement. He also thanked HFRI for adopting their village as a Model Village and initiating agroforestry practices along with dissemination of various research activities of the Institute.

2.3 Recommendations of RRC

(A) For the promotion of agroforestry

1. Development of appropriate site specific and user friendly agroforestry models for productivity enhancement and sustainable income generation.
2. Identification of fast-growing species for integration in agroforestry.
3. To use geo-spatial techniques for estimation of agroforestry area and agroforestry suitability mapping.
4. To study the tree crop interaction in agroforestry systems.
5. Ecofriendly technologies need to be developed to contain the insect pests outbreaks especially in the fragile ecosystem of Cold deserts.
6. The nursery technique to propagate the Juniper species, should be disseminated to the tribal community of Ladakh.
7. Technical guidance and extension services should be developed and provided to the farmers to raise and maintain their plantations by adopting improved package of practices.
8. Marketing mechanisms to guarantee the farmers with assured support price for the agroforestry produce at the time of harvesting should be developed.
9. Research work should be conducted to provide techniques for improved nursery propagation, cultivation and harvesting emphasizing the region specific native species.
10. Awareness program to promote the native species in agroforestry systems with traditional agricultural crops and medicinal plants should be organized.
11. Population assessment of Walnut, Salix, Poplars, Fraxinus, Berberis, etc., should be conducted to assess the current status and impact of anthropogenic activities and climatic effects.
12. R&D works of the research organization should focus on developing framework for certification of various medicinal plants, NTFPs and other organic products.
13. Farmers/community-oriented research should be conducted on sustainable harvesting of forest produce to enhance the income of the tribal community.
14. Work on organic farming and value addition to the natural produce should be conducted to improve the income generation avenues.

(B) For the promotion Clonal technology

1. R&D activities should be conducted for development, testing and deployment of new superior and resistant clones of ecologically and economically important tree species like Poplar, Salix, Eucalyptus, Teak, bamboos, Shisham Melia dubia and Neem etc. and other potential native species.
2. Clonal technology for area specific species should be developed with focus on reducing the rotation period which should be cost effective.
3. Potential agroforestry species should be identified in addition to existing species and Clonal technology should be developed and transferred to the stakeholders.
4. Awareness program on mechanism of Registration and Certification of develop ed clone should be strengthened to ensure authenticity and quality of the product.

3. Regional Research Conference organized by IFP and IFB

Assessment of Phytodiversity and their Sustainable Utilization

3.1 INAUGURAL SESSION

Regional Research conference (RRC) on "Assessment of Phytodiversity and their Sustainable Utilization" was jointly organized by Institute of Forest Biodiversity (IFB), Hyderabad and Institute of Forest Productivity (IFP), Ranchi on 25th May, 2022 in virtual mode to identify research needs based on the requirements of State Forest Departments and other stakeholders for formulation of future research projects. Shri. Arun Singh Rawat, IFS, Director General (DG), Indian Council of Forestry Research and Education (ICFRE), Dehradun was the chief Patron of the conference while Dr. Jose T. Mathews, IFS, PCCF (HoFF), West Bengal was the chief guest of the conference.

The day-long conference started with the welcome address by Dr. Ratnaker Jauhari, IFS, Director, IFB, Hyderabad and Dr. Nitin Kulkarni, Director, IFP, Ranchi who welcomed the participants and briefed the objectives of the conference. The welcome address was followed by address by Shri. R.K. Dogra, IFS, Deputy Director General (DDG) Research, ICFRE, Dehradun who informed the gathering that the thrust areas of ICFRE are in alignment with national priorities and international commitments and asked the participants to share their research needs in the forum. He opined that the stakeholders and the institutes should engage in informal interactions even after completion of the conference for mutual benefit of each other. He hoped that the conference would proceed in positive direction and benefit the institutes in identifying research needs.

Biomass based alternatives to fossil fuels should be researched upon and attempts to reduce phosphorus content in designer char be researched.

Shri. Arun Singh Rawat, IFS, DG, ICFRE opined that the inputs received from RRC would be helpful in formulating research projects which would be of benefit to the state forest departments (SFDs) and other stakeholders. He highlighted the future demand for agroforestry and added that ICFRE and Indian Council of Agriculture Research (ICAR) had together started working on Tree Outside Forests (TOFs) and agroforestry aspects. He stressed upon the need to strengthen the relationship between ICFRE and SFDs which would help to extend the outputs of ICFRE research projects to farmers and industries. In this regard, he asked SFDs to suggest mechanisms for implementing the same. He emphasised on the need to research on sustainable harvesting and value addition of Non-Timber Forest Produce (NTFP) and eco-restoration. He also asked the SFDs to provide information on species for which nursery techniques and regeneration interventions are needed and added that ICFRE has the capacity to support plantation programmes of SFDs.

Shri. A.K. Rastogi, IFS, Principal Chief Conservator of Forests (PCCF) and Head of Forest Force (HoFF), Jharkhand highlighted the problems in the state like large area under mining, lesser land availability for TOF and agroforestry that make the attempts to increase forest cover and carbon stock difficult. He emphasised on the need for development of protocols for reclamation of mined lands. He also stressed on the need to develop mechanisms to meet hardwood demand of industries within the state for saving existing forest carbon stock and to meet softwood demand of industries existing outside the state for revenue generation. He added that biomass based alternatives to fossil fuels should be researched upon and attempts to reduce phosphorus content in designer char be researched.

Shri. Jose P. Mathews, IFS, PCCF and HoFF, West Bengal emphasized on the need for development of productive clones and inventorization of species composition and diversity in forests of southern parts of West Bengal. He also insisted on effective liaising between SFDs and ICFRE institutes for effective implementation of research outputs. He highlighted the problems in the state that make effective implementation of some of the programmes/activities like agroforestry difficult.

3.2 TECHNICAL SESSIONS

3.2.1. Overview of Forestry Research: Present and Future Scenario;

This session was chaired by Shri. R.M. Dobriyal, IFS, PCCF (HoFF), Telangana.

The first presentation of the session was a keynote address by **Shri. R.M. Dobriyal, IFS, PCCF (HoFF), Telangana** who briefly presented the success story of "Telangana ku Haritha Haram" an ongoing programme under Telangana Government. He opined that the programme could become a role model for all other states to be followed for increasing the forest cover percentage. He stated that the main objective of the programme was to increase the green cover from 24% to 33% in line with National Forest Policy by following the strategy of extensive plantation outside the notified forests, inside forests & rejuvenation of degraded natural forests. He added that Telangana Forest Department (TFD) had planted 230 crores of seedlings in four years by dividing district wise targets. The basic activities followed during plantation both of for inside and outside forests were discussed. He said that the programme success was a joint effort of all important state level, district level committees and people and all data pertaining to that was maintained in forest department website. He told the gathering that besides plantation, amendment to the acts also helped in achieving 85% survival of plants. In his address, he stated the importance of planting trees and suggested everyone to plant atleast two trees to increase the forest cover.

The second presentation was made by **Shri. Pravin H. Chawhan, Scientist-G and Group Coordinator Research (GCR), IFB, Hyderabad** who presented an overview about the research works at IFB, Hyderabad. He introduced to the audience about IFB and their research centre Forest Research Centre for Coastal Ecosystems (FRCCE), Visakhapatnam and a field experimental station at Mulugu. He highlighted the research achievements in biodiversity assessment in the dry red sanders (*Pterocarpus santalinus*) bearing forest areas of the Eastern Ghats, A.P., carbon sequestration and biomass estimation and in genetic resource assessment especially for *P. santalinus, Tectona grandis, Dalbergia latifolia, Melia dubia, M. azadirachta and Santalum album.* He said that several agroforestry models were tested in the semi-arid tropics of Telangana and A.P. He stated that FRCCE, earlier called as wood biodegradation and marine interpretation centre, is working on mangrove biodiversity studies and marine ecosystems. Lastly, he mentioned about the new intramural projects that were approved by ICFRE.

The third presentation was made by **Dr. Yogeshwar Mishra, Scientist-G, GCR, IFP, Ranchi** who presented an overview about the research works at IFP, Ranchi. He introduced IFP, Ranchi to the members of RRC, regarding its genesis and the states coming under its jurisdiction. Research achievements including *Populus, Salix, Ulmus* clone identification and introduction as a potent agroforestry species were mentioned. He also mentioned about the research on mapping of *Lantana camara* in Jharkhand, feasibility of edible bamboo-based agroforestry systems in Jharkhand, their submitted proposals to West Bengal SFD for developing agroforestry model with M. dubia and mahogany (*Khaya anthotheca*) and genetic improvement programme of some important plant species such as M. dubia, *Cinnamomum tamaela, Buchanania coccinenesis* etc.

On behalf of Telangana Forest Department, **Shri. Vinay Kumar, IFS, APCCF, Telangana** made a presentation regarding research needs of Telangana state forest department as well as their research activities such as multilocational trials of NTFP species, standardization of macro and micro propagation protocols for major forest tree species and so on. He expressed the need of a research base that is innovative as well as challenging, focussed on the research from traditional silviculture to commercial interest of forestry. He added that the research should be reoriented in such a way that it could fulfil the demands of social needs, the environmental services and mitigation of climate change. He emphasized on conservation and propagation of overexploited species for rescuing them from becoming extinct. He stated that ecotourism should be promoted besides protecting the TOFs.

Shri. Siddharth Tripathi, IFS, CCF, Jharkhand represented Jharkhand Forest Department and discussed about the research needs of Jharkhand. He stated that the geographical area of Jharkhand that was under forest was 30% while the cultivable land under irrigation was 11% and poorly bunded agricultural land was 35%. He said that agroforestry system was the basic research need of Jharkhand. He also emphasized on the research needs like development of agroforestry model based on timber and pulpwood, search for alternative host trees for rearing tasar and lac and development of high yielding fruit crops. Beside these, he highlighted other research needs like conversion of rooted waste of coppice sal forest into high forest, improvement of nursery techniques and reclamation of mined areas.

Smt. Pratibha Raj, IFS, APCCF, West Bengal represented West Bengal Forest Department and discussed about the research needs of forest department of West Bengal. She presented the ongoing research works of West Bengal Forest department including tree improvement programme of Teak and Acacia, mapping of soil nutrients, floristic survey of southwest and north Bengal area, survey of sacred groves, weed infested areas, etc. She highlighted the research needs like biodiversity conservation, enhancement of livelihood of people by studying of forest ecology, role of medicinal plants as livelihood of people for income generation, study of coastal mangroves and their socioeconomic impact on local population.

Shri. Akshay K. Pattnaik, IFS, CCF, Odisha represented Odisha Forest Department and made a presentation on the ongoing research activities of Odisha Forest Department like silvicultural practices, adaptive research and tree improvement programme. He also highlighted the successful trials of *Rauwolfia serpentina* and *Bauhinia vahlii* in the state. The future road map for research was shown including geotagging of all trial plots, plus trees and linking the database, establishment of conservation plots, and collection of seeds of indigenous species, extension of different NTFPs and identification and development of nursery techniques for economically important species for plantation.

Shri. Hem Kant Roy, IFS, CCF, Bihar represented Bihar Forest Department and made a presentation on the research needs of Bihar Forest Department. He stated that ecotourism, Hariyali mission and Jal jeevan hariyali mission were some initiatives/schemes to increase forest cover of the state that enhanced the forest cover upto 8% and added that their target was to increase forest cover upto 18%. For this purpose, he highlighted some of the research needs like standardization of survey techniques, development and propagation of disease resistant clones/varieties of shisham, development of ecosystem health assessment technique, immuno assay-based rapid pathogen detection techniques for production of pathogen-free propagules and use of rooting hormones to facilitate vegetative propagation of plants.

3.2.2. Conservation of Forest Genetic Resources and sustainable utilization of phytodiversity

Chairperson of the session was Dr. Manoranjan Bhanja, IFS, Retd. PCCF (Wild Life) and Chief Wild Life Warden (CWLW), Telangana.

Under this sub theme the first presentation was by Shri. Nalini Mohan, IFS, Member Secretary, Andhra Pradesh Biodiversity Board on 'Access and benefit sharing and sustainable utilization of biodiversity'. He elaborated the basic features of Indian Biodiversity Act, 2002 and amendments suggested to improve the access and benefit sharing mechanism of the act. He explained the institutional arrangements made at national and state levels for the implementation of this act. He detailed the objectives of the act and highlighted the floral and faunal communities which are protected and exempted from the act. He explained the process of Access and Benefit Sharing (ABS) mechanism from application process and various provisions being followed by Andhra Pradesh State Biodiversity Board. Explaining about the different kinds of forms available under ABS, he also mentioned the amendments in process and responsible authorities, awareness programmes being carried out by concerned departments, regime of ABS and success achieved in saving the rights of indigenous communities as per the global agreements and compliance to the Convention on Biological Diversity. He also informed about the extension activities being carried out by the State Biodiversity Board for awareness of communities on India Biodiversity Act, 2002.

Second speaker **Dr. G.C.S. Reddy, IFS, Managing Director, Telangana State Forest Development Corporation (TSFDC)** shared his trials on replacement of *Eucalyptus* monocultures with mixed planting with beneficial plantation species. He mentioned the challenges and hoped for research on the challenges faced in converting the monocultures of *Eucalyptus* and bamboo plantations in 35 ha area. He added that *Eucalyptus* and bamboo were being grown up to seen Seven rotations and was later replaced with bamboo and bamboo helped to generate good revenue for the state. He stated that Eucalyptus plantations of seed origins in industrial belts of the state were helping to protect the soil and environment. He shared Corporation's plan to develop Eucalyptus plantations in nearly 3,000 ha area around the proposed Regional Ring Road area of Hyderabad city. As Eucalyptus might not give good aesthetics and environmental benefits to the city, he shared their plan to do mixed species planting instead of monoculture within city limits and its periphery. He presented the challenges to the research team that how a multi-storey, diverse mixed species plantation could be developed instead of monoculture maintaining the ecological benefits while retaining the commercial benefits. He shared the efforts made in 500 sq km of that area by planting bamboos and mixtures of timber and fruit bearing indigenous tree species in rows with use of green manures. He also indicated need for identification of suitable bamboo species and its nursery and plantation techniques.

Dr. V.S. Raju (Retd.), former Professor of Botany from Kakatiya University, Telangana shared his experiences and said that there was need for research prioritization and institutes need to integrate experts, local people and local think-tanks in that regard. He highlighted that state separation had increased the rate of forest fragmentation. He suggested to have forest districts instead of administrative districts, intensification of survey of flora and fauna, documentation and integration of local knowledge, develop policy to ban plantation of exotic species, design education programmes on forest ecosystems, deforestation fall out and sustainable utilization benefits in various academic institutions. He quoted that management of degraded forests around villages could meet the timber and non-timber forest produce requirements.

Dr. Swapnendu Pattanaik, Scientist F, IFB, Hyderabad presented the ongoing research work on conservation and domestication of red sanders. He introduced the new research initiatives of ICFRE on that species. He presented the ongoing All India Coordinated Research Project on Red Sanders and touched upon the progress on objectives related to provenance research to document the adaptive genetic variations in red sanders and how productivity improvement would be done through natural selection. He explained the clonal propagation of superior germplasm. He explained the criteria for candidate plus tree and plus tree selection. He informed about the air-layering experiment being carried out to standardize the method for clonal propagation and mass multiplication. He also informed about other research aspects to determine the heartwood content by non-destructive harvesting, development of biofertilizers for red sanders, development of molecular resources and transcriptomes. Dr. Manoranjan Bhanja suggested using the term seed zones instead of provenances.

3.2.2.1 Sub Theme: Sustainable Utilization of Phytodiversity

Under this sub theme there was only one presentation by Smt. Anjana Suchita Tirkey, IFS, DCF, IFP, Ranchi on establishment of bamboo demonstration plantation through people's participation for livelihood generation in eastern India. She explained the aims of National Bamboo Mission and the six schemes under this programme which were running at IFP, Ranchi. She told that under urban upgradation, bamboo nurseries and demonstration plots had been developed and added that, considering high local consumption, feasibility of edible bamboos was tested in campus plots. She highlighted the successful models with medicinal plants like turmeric, ginger, Acrous, Baccopa, Eclipta, Cyprus, Withania, Aloe, agriculture crops like rice, wheat, maize, urad, arhar, horticulture crops like vegetables and fruits. She said that various models were found useful in generating additional income for the farmers. She also highlighted the challenges faced in promoting the bamboo-based agroforestry systems such as fencing, security from animals and fire, irrigation facility, quality planting materials and suitable as well as desired species, lack of labour availability at the time of harvesting, training on value addition and need to set the minimum support price which makes them otherwise sceptical about the income. Dr. Yogeshwar Mishra, Scientist-G, GCR, IFP, Ranchi informed that a few years ago 10 bamboo species were put into trials and demo plantations were made at IFP Ranchi. Based on initial observations, *Bamboosa tulda* was found to be the best performer with high yield and rhizomes. He emphasized that *B. tulda* would be focus of their research and would be recommended for Bihar and Jharkhand.

All India Coordinated Research Project on Red Sanders touched upon the progress on objectives related to provenance research to document the adaptive genetic variations in red sanders and how productivity improvement would be done through natural selection.

3.2.2.2 Sub Theme: Tree Outside Forest

First presentation under this sub theme was by Dr. Aditya Kumar, Scientist-D, IFP, Ranchi on "Initiatives of IFP Ranchi to promote agroforestry in Bihar and development of productive Poplar clones". He highlighted the initiatives taken by IFP Ranchi for development of Poplar and other tree species in agroforestry systems. He explained the major contributions of IFP in clonal development of Poplar, Melia dubia, Eucalyptus camaldulensis, Salix, Casurina equisetifolia and Casurina junghuhuiana, Ulmus villosa and Gmelina arborea. He also informed about the infrastructure developed by the institute such as Bamboo Common Facility Centre, Model Nursery, Demonstration Plots, distribution of ETPs to support farmers and capacity building/training programmes being conducted regularly for promoting agroforestry. He indicated the challenges and limitation in popularizing agroforestry in eastern India like marketing of trees planted in agroforestry, lack of minimum support price for trees, permits for felling and sale of tree species produced from agroforestry.

3.2.2.3 Sub Theme: Agroforestry Research/Alternate land use farming

First presentation under this sub theme was by **Shri. Suneel Pandey, Vice President, ITC, Bhadrachalam** on 'Agroforestry development in India'. He introduced the agroforestry plantation programmes of ITC developed as Tree Improvement Programme which was initiated with National Forest Policy, 1988. He told that research on clonal development was initiated for Subabul, Poplars, Casurina and Eucalyptus species. He informed about the plantation models which were designed based on the need and interest of farmers like social forestry, farm forestry, agroforestry and bund plantations. He informed about the 'State of the Art Clonal Production Facility', use of root trainer technology, package of practices and the success received in reducing the rotation age of plantations and income generation while meeting the demand of the industry and their commitments to conserve the environment. He also informed about the key features of the sustainable wood chain which ITC followed. He highlighted how their R&D programme had helped to transform the paper industry. He also stressed upon the fact that plantations need to be industry linked and end-use based and stated the need to involve private sector. He expressed the need of bringing in more tree species in agroforestry which was still limited to species having relaxed felling and transit permits across the state. He informed that industry needed additional wood growing areas to meet the additional wood requirements in next Seven years. Based on his previous experiences he said that farmers preferred short rotation crops to have an early income which should be kept in consideration while promoting tree species for agroforestry and other plantation programmes. He suggested to take measures to scale up and mechanize plantation programmes to improve cost competitiveness and financially support small and marginal farmers to adopt agroforestry.

Last presentation of this technical session was made by **Dr. A. Madhavi Latha, Professor and Principal, Agricultural Polytechnic, PJTSAU, Telangana** on 'Agroforestry models for southern region'. She explained about the concept and components of agroforestry elaborating about the successful agri-silvicultural model, silvipastoral model, agrisilvipastoral and hortipastoral model, agri-horticulture, alley cropping and shelterbelts in southern India. She informed about the gains under popular agricultural models with the combinations of cluster bean + tamarind + curry leaf, red gram + tamarind + custard apple, castor + pongamia, pongamia + sweet sorghum. She informed about the silvi medicinal system initiated in the university campus with the combination of insulin plant + pongamia which had good yield and carbon sequestration potential. She also informed about other combinations of medicinal herb and tree species such as Ashwagandha with Amla and Andrographis with Terminalia which had potential to generate good income for farmers.

Take measures to scale up and mechanize plantation programmes to improve cost competitiveness and financially support small and marginal farmers to adopt agroforestry.

3.3. Recommendations of the RRC

After deliberation on various research needs that were suggested in various technical sessions, the following recommendations were finalized.

- Most of the stakeholders, including State Forest Departments, emphasized on large-scale promotion of Agroforestry with high yielding clones of suitable indigenous tree species and compatible crops.
- Many successful agroforestry models are available for different agroclimatic zones. Identification, validation and extension of such Agroforestry models should be taken up to enhance sustainability of the agroecosystems.
- Research organizations and State Forest Departments need to put in more effort to improve availability of quality planting material for block plantation programmes as well as agroforestry.
- Suitable agroforestry models should be developed and validated on a regional basis. The species that are giving returns in a shorter period should be concentrated upon.
- There is a need to have more coordination with ICFRE, national level agroforestry institutions of ICAR and best practices from the world should be looked into and coordination with leading experts in the field in the globe should be pursued for better results.
- Studies on identification of available models/protocol/best practices for rehabilitation of degraded lands/mined over burden should be given priority by the research organizations in collaboration with the SFDs.
- Although some amount of data on demand and supply of softwood are available from paper and pulp industries, the same is not the case with hardwood. There is an urgent need of quantification of demand and supply of both hardwood and softwoods to identify the gap for better planning in the forest sector.
- Value addition of timber & non-timber forest produce and development of market linkages are two important aspects for which more research is needed developing workable models.
- Unlike fossil fuels, biomass is a sustainable and renewable source of energy. Research on development of wood pallets employing wood waste, barks and bamboo should be initiated.
- There is an urgent need of identification of suitable species and their improved varieties for cultivation as TOF in order to reduce dependency of forest fringe communities on natural forests.
- Intensive screening of suitable bamboo species over diverse areas along with work on breeding high yielding clones and clump management directed towards productivity improvement should be done.
- NMPB and State MPBs have been promoting cultivation of Sandalwood for the last several years. As a result of which many tree farmers has taken up its cultivation. Some policy level Intervention is needed to standardize purchase mechanism and market chain for Sandalwood and other such economically important species to boost the TOF sector.
- There is a need of threat assessment of important plant species in natural and modified forested landscapes for conservation planning and better management.
- Stakeholders from SFDs felt that besides the timber species under cultivation, there is a need to identify and domesticate secondary timber species to meet some part of the domestic wood requirement.
- Assisted Natural Regeneration/Aided Natural Regeneration is an important component of eco-rehabilitation of degraded forest lands being adopted by most SFDs of Eastern region. The stakeholders felt that some impact studies should be taken up to highlight its importance.
- Regional phenological calendar for arborescent taxa are important for conservation and sustainable utilization of Forest Genetic Resources (FGR). ICFRE institutes need to develop such calendars in collaboration with SFDs.
- Ecological Niche Modelling' studies need to be taken up for threatened taxa/RET species in order to identify suitable habitats for their introduction/reintroduction under changed climate scenario.
- There is a need to identify suitable species for stabilization of costal embankments and develop plantation models to improve coastal protection
- ICFRE need to develop/suggest plantation models for diversification of *Eucalyptus* monoculture plantations to economically viable mixed species plantations.

4. Regional Research Conference organized by Rain Forest Research Institute

Forestry Research and Issues in North-Eastern Region of India for promotion of agroforestry

4.1. INAUGURAL SESSION

The Regional Research Conference for North-Eastern Region, 2022 was organized by Rain Forest Research Institute, Jorhat, Assam on 14 June, 2022 to address the various issues related to forestry in general and on agroforestry. The conference was organized in virtual mode as well as offline mode. The prime objective of the conference is to identify and prioritize the needs of the forestry research in the North-Eastern states of India. The conference was physically attended by Shri R. Arun Kumar, IFS, ADG (M & E), ICFRE, Dr. K. K. Sarmah, Chief Agronomist, AAU, Jorhat, Dr. Ranjita Bezbarua, Scientist, Horticultural Research Station (AAU), Kahikuchi, Guwahati, Dr. Lohit Baishya, Scientist, ICAR RC for NEH, Nagaland Campus, Shri Nandhakumar DFO, Jorhat, Shri Ranjit Konwar, Working Plan Officer, Jorhat, students from Karbi Anglong and Nagaland along with Scientists, Officers and Research Fellows. Different senior forest officers from North Eastern states participated in the conference virtually and contributed to the conference.

Shri Arun Singh Rawat, IFS, DG, ICFRE, inaugurated the conference virtually. In his address, DG, ICFRE emphasized that focus should be on need-based research and involvement of all the key stakeholders is much needed. He also said that need should be defined in proposal for funding. He stressed that demand of timber is high due to increase in population, to meet demand of timber more emphasis should be given on agroforestry. He stated that agroforestry is practiced only in certain pockets of the country and needs expansion to meet the timber demands of the country. He also mentioned that the issues related to agroforestry should be discussed with all the stakeholders for proper management and policy formulation. He appealed that the Forest Department and the Department of Agriculture should together take up the challenge. He urged that we have NTFP which is very good source of livelihood of North East people.

4.2 TECHNICAL SESSIONS

4.2.1. Forestry Research issues of States:

Smt. Sonali Ghosh, IFS, CCF, Assam, as representative from Assam forest department spoke about working plan and research policies of Assam forest department. She said that 25 species documented for agroforestry in working plan under pipeline. She stressed that we should collaborate agroforestry along with NTFP and capacity building through agroforestry. We should provide roadmap for agroforestry management. She mentioned that minor forest produce should be well documented.

Raj Priya Singh, IFS, CF (RPU), Nagaland presented on priorities forestry research problems in Nagaland. Major research needs of Nagaland includes, managing shifting cultivation; biodiversity assessment and monitoring ; Participatory forest management; Protection of endangered species; HRM problems of forest department ; development of agroforestry/social forestry models ; eco-restoration of degraded forest and Planting stock improvement of important species.

Wangdup Bhutia, IFS, CF, from Tripura spoke about the agroforestry practices in Tripura state. He said that best model of agroforestry practiced in Tripura is pineapple, mango and banana. Pineapple is priority species. He focused on importance of healthy plant species in agroforestry model so that it can increase the resource of that places along with the increase of market value which will be helpful for the farmers to increase income. He stressed that more research is needed on different crops which grow in the forest and should work on disease control. Development of package and practices for agroforestry crops is required. Marketing of agroforestry products is also challenging issue in Tripura. Ecological restoration of Jhum lands in Tripura is the need of the hour. Standardization of propagation and conservation techniques of local indigenous species e.g., Ashoka also required. He also stated that Tripura forest department is promoting Agar cultivation in association with RFRI Jorhat. He said that pathogen should be cultured and given to the farmers and promotion of conservation of Agarwood by *ex-situ* and *in-situ* methods. He said that NTFPs can play major role in livelihood of rural people which provides good income to forest dwellers.

4.2.2. Forestry Research in the North-eastern region

Dr. R.S.C. Jayaraj, Director, RFRI, gave overall research and developmental activities including transfer of technologies through/taken up by RFRI itself. He mentioned that RFRI is one of the seven Scientific Authorities in India under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). He said that RFRI is responsible for recommending the quota for international trade and for monitoring the export permits, besides advising the CITES Management Authority on Conservation of the species.

4.2.3.Discussion of 'Agroforestry issues' in Northeast India

Invited speaker Dr. K. K. Sarmah, Chief Agronomist, AAU, Jorhat emphasized on need of agroforestry in India. He said that agroforestry is integrated dynamic system which have interrelationship among agriculture, forestry and animal husbandry. Agroforestry is a very young but important science to prepare ourselves for the increasing demands. He mentioned that north-east traditionally acquainted with agroforestry, homestead agroforestry practiced since Ahom times. He gave the detailed information of different type of agroforestry systems in practices along with integrated farming system. He presented various modules of IFS of different Indian states. He said that integrated farming system is very helpful for raising farm income and it provides food and nutrient security along with employment generation. He stated that both agroforestry and integrated farming system are based on three principles productivity, profitability and sustainability.

Dr. Ranjita Bezbaruah, made detailed presentation on agroforestry system prevalent in Assam. She enlightened the benefit of agroforestry and key traits of agroforestry practices, i.e., 4I's (International, Intensive, Interactive, and Integrated). She said that to understand the structure of existing agroforestry system in actual field situation and mode of change of agroforestry system with time; and planning for intervention needed in the existing agroforestry system for maximizing the output, they did random survey of agroforestry system in farmer's field of 15 district of Assam. She presented all the agroforestry system being used in Assam.

Dr. Luhit Baishya, Principal Scientist, ICAR-Research complex for NEH region, Umiam, Meghalaya spoke on "Agroforestry intervention to improve shifting cultivation". He talked about the agroforestry use values which is very important for the increasing productivity and carbon pool as well as soil fertility amelioration and reduce vulnerability. He presented SWOC analysis of agroforestry and status of agroforestry in India. He focussed on different issues of shifting cultivation. He presented on Jhum rehabilitation through agro-forestry interventions. Various rehabilitation models were discussed by him. He gave details of cost benefit analysis of some of the IIFS models. In addition he presented constraints in promoting agroforestry in India.

Dr. Arup Das, Principal Scientist, ICAR-Research complex for NEH region, Tripura talked on agroforestry model for Tripura. He presented on various kind of land degradation and status of natural resources in Tripura. He said that majority of the land area under forest followed by agriculture. Area under rubber plantation is increasing continuously in Tripura therefore, rubber has the major impact on the economic sustainability of the state. Under horticulture land use system banana has the highest plantation area followed by pineapple and mango. He briefed about the existing agroforestry system in Tripura.

4.3. Recommendations of the RRC

- Focus should be on need-based research and involvement of all the key stakeholders. Need should be defined in proposal for funding.
- Issues for agroforestry should be discussed with all the stakeholders. All the stakeholders to discuss at one platform and carry forward research on agroforestry.
- Forest department should come forward along with private industries for promotion of agroforestry.
- Guidelines must be developed for agroforestry. Package and practices for cultivation is requirement.
- Creation of baseline database for timber species for agroforestry modules.
- Marketing infrastructure is required for agroforestry products. Establishment of marketing institutions is requirement.
- Agroforestry is contributing significantly to land use and farm income diversification so the promotion of agroforestry modules should be done among farmers.
- Integrated farming system model can be utilized for proper land utilization by small and marginal farmers.
- Promotion of tree based integrated farming system model.
- Link the existing policies to agroforestry for promotion.
- Strategic placement of agroforestry in the tree cover mapping.
- Development of an integrated agroforestry policy is requirement.
- Requirement of organized agroforestry extension service to increase the adoption rate of agroforestry among farmers by dissemination of research results.
- Lack of highyielding quality planting material is constraint for agroforestry so more research should be focus on availability of quality planting materials.
- Encourage different agroforestry modules to uplift the socio-economic status of farmers.
- Insufficient research on agroforestry models suitable for the diverse agro-climatic regions Heance more research should focus on this aspect.
- Massive awareness capacity building programme for promotion of agroforestry.
- Agroforestry based system based on rubber should be studied.
- Cost benefit analysis of various systems need to be studied.
- Demand and supply studies of broom grass and large cardamom.
- Impact of rubber wood on the utilization of teak in Tripura may be studied.
- Impact of rubber cultivation on livelihood of people of Tripura.
- Impact of rubber cultivation on soil may be studied, if possible, in collaboration with RFRI.

Regional Research Conference jointly hosted by IWST and IFGTB

Regional Research Conference 2022 was organised by the Institute of Wood Science and Technology (IWST), Bengaluru on the topic "Forestry Research in Southern States of India with a special focus on Agroforestry issues" on June 10, 2022. It was co-organised by the Institute of Forest Genetics and Tree Breeding (IFGTB), Coimbatore, by virtual participation. The inaugural session was presided over by the Chief Patron, Shri. A. S. Rawat, IFS, Director General, ICFRE, Dehradun, along with Shri. R. K. Dogra, IFS, DDG-Research of ICFRE and PCCFs from the states of Karnataka, Tamil Nadu, Kerala, Andhra Pradesh, Goa, and Andaman & Nicobar, who expressed their views as guests of honour. Senior IFS officers representing the forest departments of various southern states, researchers and academicians from institutes and forestry colleges; and representatives from various wood-based industries participated in the conference. The proceeding of the said conference has been already published in the previous issue of Wood is Good magazine.

Key recommendations

Major outcomes of the RRCs conducted by all the Institutes of ICFRE are summarized below.

- A comprehensive documentation of the various existing region-wise Agroforestry models for different promising tree species (timber, fruit, fodder medicinal and green manure) under irrigated and rainfed conditions for wetland, garden land and drylands systems and record on economic returns should be developed with the primary aim upon productivity enhancement and sustainable income generation.
- Quantification of the demand and supply of both hardwood and softwood species used in agroforestry systems should be made and will be highly useful in identifying the gaps for better planning in the forestry sector.
- Research work should be focussed to provide techniques for improved nursery propagation, cultivation, harvesting and sustainable harvesting of forest produce emphasizing the region-specific native species and lesser known Agroforestry species to enhance the income of the farming and tribal community.
- Lack of high-yielding quality planting material is a major constraint for agroforestry systems so more research should be focused on the availability of quality planting material and production of new clones on the economically important species tree species like Poplar, Salix, Eucalyptus, Teak, Bamboos, shisham, Melia dubia and neem etc. and other potential native species.
- There is an urgent need of identification of suitable species and their improved varieties for cultivation in TOF to reduce the dependency of forest fringe communities on natural forests for the fuel, fodder and food.
- Development of soil health card for different forest types/ ecosystems for the benefit of the farmers and tribals to use them in their private/allotted lands under FRA while practicing agroforestry.
- Developing farm forestry with special focus on fast growing tree species as well as developing the multi-tier fruit forests for small and medium farmers.
- Many promising tree crops like rubber and bamboos in the North East are popular among the tribals and other indigenous people of Tripura, ssam etc., suitable agroforestry models using them may be studied and the best combinations should be disseminated to the field.
- Shifting cultivation or the Jhum cultivation is one of the harmful traditional practices followed by the indigenous people of the North East. After the implementation of FRA, 2006 act, several scheduled tribes and other forest dwellers were allotted forest lands (based on the preoccupation as per the cutoff date). These lands are being underutilized or used for mono crop which does not prove economical and ecologically sound on long run. Hence research should be focussed on sustainable integrated farming systems with indigenous tree species.
- Shifting (jhum) cultivation is practiced prevalently in North-East. Once the land is left fallow it significantly affects the forest floor, flora and biodiversity of the area. Significant agroforestry models may be tested and proposed for recovery of the land with financial outturn using the primary vegetation forest trees.
- Thornless Khejri variety (Thar Shobha and Thar Amruta) is one of the most promising tree species in arid lands which should be propagated and be used in development of agroforestry models already known to be effective with normal thorned Khejri varieties.
- Integrated Farming Systems (IFS) have confirmed the short-term, midterm and long- term returns to farmers and prevent the farmers from complete economic loss. Research on Integrated Farming Systems temporally and vertically should be carried out in different climatic zones and the best practices should be documented and disseminated to the farmers.
- Research on agroforestry using organic farming practices and ecofriendly techniques should be attempted for the fragile ecosystems like cold deserts.
- Collaborative research among research organizations like ICFRE, ICAR, SFD's, MOTA, SAU's etc., should be institutionalized along with sharing the information and best practices to give speedy recommendations against the constraints of agroforestry to the various stakeholders. National-level agroforestry institutions of ICAR and best and

sustainable practices from the world should be looked into and coordination with leading experts in the field in the globe should be pursued for better results.

- A database and map on research outputs with geospatial tools should be developed and made available to all forest departments to update them on the continuous ongoing research and outputs on agroforestry. Documentation of technology in the form of success stories, case studies etc. should be made available for the knowledge of the stake holders.
- A shift in policy/management is required to promote agroforestry; therefore, revisiting various existing forestry policies and legislations in the context of promoting tree cultivation in farmlands and easing of production and marketing of wood from farmlands.
- Industry establishment is needed to meet the economic expectation of farmers and growers under agroforestry systems, therefore small and medium scale industries should be promoted.
- Developing consortium of industrial agroforestry that paves way for active participation of farmers as growers and industries as utilizers and research organizations in providing advanced technical interventions for both.
- Species like red sanders (*Pterocarpus marsupium*) and sandal (*Santalum album*) are well promoted in the states of Andhra Pradesh, Tamil Nadu, Telangana, Karnataka and Kerala. The marketing and purchasing mechanisms of this royal timbers needs policy level intervention to utilize them to the full extent in Agroforestry.
- Extending Finance Credit facilities for agroforestry wood products including the crop insurance schemes for trees in farmlands, as existing for agricultural and horticultural crops should be made available.
- Due to the non-availability of proper marketing infrastructure and mechanism, the marketing of agroforestry products suffers and sometimes due to the involvement of middlemen. Hence establishment of clean chain of marketing institutions for agroforestry products is much needed for the complete economical outturn to the farmers.
- Massive awareness, as well as capacity-building programs on adoption, value addition, marketing, fair pricing and extension for the promotion of agroforestry should be attempted.
- Extending knowledge updates on agroforestry research and development through e- portals and social media platforms and upscaling and expanding of digital platform tools.

Institute of Wood Science and Technology, Bangalore
Publications for Sale

IWST PUBLICATIONS FOR SALE

BOOKS

Sl. No.	Name of the Books	Language	Rate
1.	Gem of Peninsular India Sandalwood	English	1,500
2.	Endemic Possession of Eastern Ghats: Red sanders	English	150
3.	Biodeterioration of Timber and its Prevention in Indian Coastal Waters - 3rd Progress Report (1982-2005)	English	250
4.	Anatomy and Properties of Lesser Known Timbers of North-East with particular reference to Nagaland	English	175

PROCEEDINGS / ABSTRACTS

Sl. No.	Name of the Books	Language	Rate
1.	Forestry, Forest Products and Coastal Population	English	200
2.	Wood Preservation in India: Challenges, Opportunities and strategies	English	250
3.	Conservation, Restoration and Sustainable Management of Mangrove Forests in India	English	250
4.	Intellectual Property in Forestry issues	English	250
5.	Bamboo Reserve Management & Advances in Utilization Options	English	200
6.	Indian Sandal wood. Compendium Abstracts of Research carried out English	400	
7.	Abstracts of the Published Research Papers (1998-2007)	English	Free

TECHNICAL BULLETINS /BROCHURES

Sl. No.	Name of the Technical Bulletin	Language	Rate
1.	Sandalwood	English/Kannada	100
2.	Sandalwood Tree (Pests, Diseases and their Management)	English	80
3.	A Guide to some important timbers in South Indian markets	English	150
4.	Arbuscular Mycorrhizal (AM) fungi as biofertilizer in forestry	English	30
5.	Teak Heartwood Borer. AlcterogystiaCadambae (moore) and its management	English	50
6.	Whitefly pests in Forestry and their management	English	30
7.	Wood Polymer Composite: New age Material	English	50
8.	Protection of Wood from Weathering	English	80
9.	Flower Gall Inducer of PongamiaPinnata and its management	English	60
10.	Cultivation prospects of edible bamboo shoots in South India	English	100
11.	Ficus Tree in Semi-arid. Agro Ecosystem of Karnataka	English	150
12.	Bamboos of India	English	200
13.	GuaduaanguistifoliaKunth: A Vegetable Steel Bamboo Species	English	150
14.	Dendorocalamusstocksii (Munro): A Potential Multipurpose Species for Peninsular India	English	150
15.	DendorocalamusBrandisii (Munro): An ideal Bamboo Species for Domestication in Humid Tropics	English	150
16.	Micro propagation of Bamboo Species	English	150
17	Disease Alert on Eruption of Sandal Spike Disease in Conservation and Cultivation of Indian Sandalwood	English	100
18	Important Insect Pests in Mangroves of Maharashtra and their Management	English	100
19	Genuine Mahagony – Cultivation, Management and Uses	English	100
20	Meliadubia Malabar Neem	English	100
21	Phytoplasma: Thrust for developing effective management strategies	English	100
22	Sandal oil: Adulteration and detection techniques	English	100
23	Bamboo Lumber: A sustainable alternative to solid wood	English	100
24	Utilization Potential of Palmyra Palm Wood (Borassusflabellifer L.)	English	100

Proposed AgriWood® Standards for Certificate of Origin and Chain of Custody for Agriwood and Wood Products

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Institute of Wood Sciences and Technology (IWST), Bengaluru has proposed draft guidelines on AgriWood® standards on certificate of origin (CoO) and chain of custody (CoC) for agriwood and wood products with an objective of providing certified wood material to the wood-based industries in order to boost the export of wooden products to the Western markets. The proposed guidelines consists of four chapters and appendices. These guidelines have been developed by IWST based on the existing standards adopted by Australia and Western countries. In the process of developing these guidelines, series of consultations were made with various stakeholders from wood-based industries, academicians, practitioners of wood certification, government, etc. These guidelines have been submitted to the Bureau of Indian Standards and Ministry of Environment Forest and Climate Change for necessary consideration and adoption as national standards for CoO and CoC for agriwood and wood products.

Chapter 1

1.1 Background

Globally, the forestry sector is facing several common problems, including deforestation and illegal logging. Deforestation is a major contributor to the loss of animal habitats, including many endangered species. It is perhaps not surprising that many industrial customers and end-consumers of wood products have become increasingly interested in knowing whether their timber or wood products are sourced and manufactured in an eco-friendly and sustainable manner. This, in turn, has highlighted the increased need for supply chain traceability and transaction transparency during the entire life cycle, from planting to cutting until distributing to the end customers.

The advent of the latest National Forest Policy of India (1988) necessitated the paradigm shift in the then 'forest-based' industries to 'farm wood based' industries. However, the supply of raw material was limited as it was either from agroforestry ('AgriWood') or by imports. Dwindling imports due to the price escalations of wood raw materials in the international markets and related import tax issues presented challenges to the sustainability of wood-based industries. Organizing internal supply of wood raw materials was another challenge, as promotion of AgriWood production by farmers was necessary, but suffered from the absence of adequate legislation for exclusion of the same from restrictive legal provisions applicable on harvest and transport of trees planted on farmlands.

Tree outside the forest are also being recognized by the policy makers and planners as essential components of sustainable development and critical to food security besides reducing the burden on foreign exchequer. In 2014, the Govt. of India has brought a special policy on agroforestry for the promotion of agroforestry in India. Government initiation of agroforestry programme to enhance farmers' income by inter-cropping commercially important fast growing tree species has led to the availability of agro-wood which has now become the major source of industrial roundwood. This has helped the farmers in improving their income, besides believed to have a higher potential to sequester carbon and achieve the national goal of bringing one third of total geographical area (TGA) under green cover. Tree growers under agroforestry are generally small land holders in India; however they meet 92% of total wood demand in the country. To sustain the farm wood production drive in India, the wood-based industries have already created enough processing facilities for veneering, sawmilling, plywood, MDF and particle board besides furniture and handicrafts so that the increased supply of such short duration timber is sustained, integrated to industries and enable farmers to get the remunerative prices for their produce.

Although there are a number of certification systems prevailing across the globe, most of these certifications are directed towards supply of timber from forests and none of them suit the certification of agriwood produced from the agroforestry systems, as most of the farmers in India are small and marginal. Moreover, the prevailing international certifications systems are very cumbersome and expensive for Indian farmers. It is therefore necessary to develop an Agri-wood certification system which will be very simple, acceptable, and easy to adopt. Apart from this, the system will also ensure reliable and auditable proof of traceability, when certified materials are physically indistinguishable from non-certified materials and are often commingled

With the development of information technology (IT), it is now possible to use IT based solutions to develop a certification system to ascertain the legality and origin of wood from agroforestry. Digital tagging can be introduced at the farm level and the same can be used across supply chains to verify the chain-of-custody. Since certification is a market driven process, this will help wood-based industries to have greater access to global markets.

The proposed IT based certification system will address the following points:

1. Proof of ownership and proof of origin.
2. Enable and facilitate end-to-end transparency across multiple supply chain partners which is immutable and tamper-proof.
3. Reduce the bureaucracy and cost overheads associated with manual inspection, audits and certification.

Certification of origin (CoO) and chain of custody (CoC) can also be integrated into the existing systems in the company, already implementing ISO 9001 or ISO 14012 standards. Once the management system is in place and the additional requirements implemented, the company needs to be audited by an independent body.

1.2 Scope

This document will serve as the broad framework for the development of a certification system for farm wood in India. It elaborates on how to establish the CoO and CoC and traceability across the supply chain (TSC). It describes the related processes and standards as described in the ISO 38200 standard on CoC of wood and wood-based products. Finally, the document helps to provide an understanding of the information technology concepts and products that can be leveraged to provide automation of the process rather than just creating a bureaucratic and manual process to make the compliance and certification process of the farm wood industry efficient, effective and competitive in the national and international market. AgriWood® standard is applicable only to the legally harvested material from agroforestry and legally procured material that enters the chain of custody.

1.3 Application

This standard is intended to apply to the processes that various certified wood and wood products are undergoing. It is applicable to wood and wood products available from farm lands. Examples of wood and wood products include, but are not limited to, the following:

- wood products, such as unprocessed logs, poles, piles, woodchips;
- wood products that arise directly from Manufacturing such as sawn timber, veneer, pulp;
- wood products that arise from reconstruction processes, such as composite board (plywood, particle board, MDF, LVL etc), paper, paper board, composite board, furniture, doors, window frames; and
- by-products that arise indirectly from manufacturing or re-manufacturing, such as wood chips, flakes, shavings and sawdust;
- The CoC criteria and requirements are applicable to all organizations in the certification chain which:
- have control over wood and wood products including their flow; and can define their input and output stages of the wood and wood product flow.
- Guidance for the implementation of the CoC requirements in an organization with a network of sites (multi-sites) is provided in Appendix A.

1.4 Recognition/endorsement

Other CoC systems or schemes may be recognized as being compatible or substantially equivalent with the requirements of this standard, especially those with third-party auditing requirements developed according to or consistent with, the requirements of national and international standards and conformity assessment forums such as ISO (ISO-38200). It is expected that assessment of conformity of such national or international standards will have a basis in the ISO/IEC guides.

1.5 Definitions

The definitions of terms used in this document are as follows:

(I) Accreditation body: The governing authorities, either government owned or under agreement with the government that establish the suitability of any participating certification body to carry out audits for AgriWood®.

(ii) 'Farm wood' means wood and wood products sourced from trees exempted from the requirement of felling permissions and/or transit permits under state specific rules and/or located on all lands excluded from the definition of forests as per prevalent laws and their interpretation, subject to the limitation of their applicability to private property. They include:

a) trees on farmlands and built-up areas, both in rural and urban areas;

b) trees planted, domesticated or grown on private lands;

c) trees growing in meadows, pastoral areas and on farms, or in towns, gardens and parks; and

d) trees growing on lands using alley cropping and permanent tree cover crops (e.g. coffee, cocoa), windbreaks, hedgerows, home gardens and fruittree plantations;

(iii) 'AgriWood® ' means the standard developed for legality assessment, verification of legality and CoC of farm wood.

(iv) Certification body: It is the organization committed to assuring the continued integrity and validity of the standard.

(v) Certified: It refers to materials having undergone the verification process under AgriWood® standards.

vi) CoC: The process of tracking wood and wood products originating in farm lands through all phases of ownership, transportation, and manufacturing from the defined farmland to the final product and delivery to the end consumer.

(vii) Due diligence: Refers to ensure that only legally harvested wood and legally procured wood and wood products can enter the CoC.

(viii) 'Imported wood' means all wood and wood products imported from other countries.

(ix) Organization: A company, corporation, firm, enterprise, authority, institution, or part or combination thereof, whether incorporated or not, public or private, that has its own functions and administration, and that, for the purposes of this standard, applies for qualification of its CoC.

(x) Third-party: An independent organization, accredited by a reputable accreditatio organization and in possession of sectoral expertise that provides certification services.

(xi) "Tree growers" mean individuals or organizations engaged in the production of farm wood by themselves or by hired labour or otherwise, and includes farmers, Farmer Producer Organizations, Forest Protection Committees, wood-based industries, companies, partnership firms, limited liability partnerships, co-operative societies, societies, and any associations or body of persons duly incorporated or recognized as a group under any ongoing programmes, schemes or resolutions of the central government or the state government.

(xii) 'Trader or agent' means a person who buys farm wood or imported wood by way of interstate or intrastate trade or a combination thereof, either for self or on behalf of one or more persons for the purpose of wholesale trade, retail, end-use, value addition, processing, manufacturing, export, consumption or for such other purpose.

(xiii) 'Interstate trade' means the act of buying or selling of farm wood, wherein a trader or agent of one state buys farm wood from tree growers or a trader of another state and such farm wood is transported to a state other than the state in which the trader purchased such farm wood or where such farm wood originated.

(xiv) 'Intrastate trade' means the act of buying or selling of farm wood, wherein a trader of one state buys the farm wood from a tree grower or a trader of the same state in which the trader purchased such farm wood or where such farm wood originated.

(xv) 'Electronic trading and transaction platform' means a platform set up to facilitate direct and online buying and selling for conduct of trade and commerce of farm wood through a network of electronic devices and internet applications, where each such transaction results in physical delivery of farm wood.

(xvi) 'State' means state or union territory (UT).

(xvii)' State Agriculture Produce Market Committee Act' or 'State APMC Act' means any state legislation in force in India, by whatever name it is called, which regulates markets for agricultural produce in that state.

(xviii) 'Farm in agreement' means a written agreement between the tree grower and sponsor, such as:

a) 'trade and commerce agreement', where the ownership of farm wood remains with the tree grower during production and he gets the price of produce on its delivery as per the agreed terms with the sponsor;

b) 'production agreement', where the sponsor agrees to provide farm services, either fully or partially, and to bear the risk of output; and

c) any other such agreements or a combination of the agreements specified above.

(xix) 'Sponsor' means a person, trader or agent who has entered into a farming agreement with the tree grower for growing trees.

(xx) 'Local bodies' means panchayats and municipalities, by whatever name it is called, within the meaning of Article 243B (1) and Article 243Q (1) of the Constitution of India, and, in the absence of any panchayat or municipality, institutions of self-government constituted under any other provision of the Constitution of India or any Central or State act, and in their absence, any officer or group of officers authorized by the state government.

(xxi) 'Wood-based industry' means any industry which processes wood as its raw material and includes saw mills, veneer, housing, construction, packaging, furniture, handicrafts, sports, railways, ship building, mining, bioenergy, pulp and paper, plywood, panel (MDF, particleboard, OSB, etc.) industries, sandalwood, katha wood, agarwood and such other industries.

Chapter 2

Certificate of origin and ownership

2.1 Overview:

Certificate of origin and ownership is the prerequisite for determining the legality of AgriWood. The organization that initially receives wood or wood products directly from the farm land shall implement a recognition system for verification of the origin of the wood or wood products used in subsequent processes and also for procured wood or wood products. The legality of the origin of wood is ensured through the issue of a certificate of ownership to the land owner following a due diligence process. The following information and documents are needed to fulfill the requirement of the due diligence system:

a) description: including trade name and type of relevant commodities and products as well as the common name of the species and its full scientific name where applicable;

b) quantity: of the relevant product (number/mass/volume);

c) identification of the area (village, taluk, district and state) of production;

d) geo-coordinates of all the plots of land where the relevant products were produced with the date; and

e) name and address of the business/persons from whom they have been supplied relevant products and to whom the products have been supplied.

NOTE 1: The organization's recognition system needs to provide adequate detail of the origin of the product to ensure no ambiguity in legality, locality, place or area exists. For example, it may include location details such as district/taluka/village/khata number/killa number/khasra number/GPS location.

NOTE 2: The verification of the origin through a recognition system is only directly relevant to the initial receiving organization, i.e. for products direct from a farm land or other legal source. These details cannot necessarily be maintained past the initial point of merchandising or processing and it is not intended that they should have access to:

- details of wood or wood product status (from certified source or not) or percentage of certified content in the products; and
- Documentation supporting this information, e.g., certificates, delivery notes, invoices, etc. for organizations beyond the initial receiving organization.

2.2 Procedural requirements:

The process of certification of origin and ownership involves the following steps.

a) Validation of land records from local self-government/panchayat office or e-records.

b) Aadhar-based authentication of the owner and ownership of land/processing unit verification.

c) Developing GIS based farm survey application and geo-tagging of trees within farmland.

d) Placing IT based solution for QR code-based tracing and tracking that feeds to COC certification.

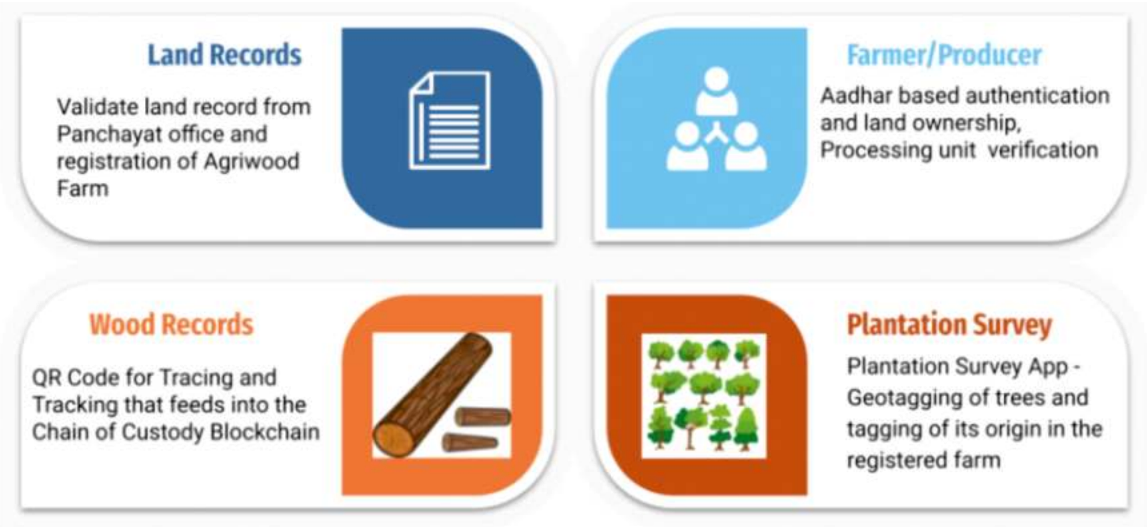


Figure 1. Primary elements for generating the CoO

A user-friendly mobile app with native language support shall be developed to enable the farmers to enter the relevant data and information for verification. It shall be the responsibility of the certifying agency to verify the uploaded information by the farmers. The local bodies or any other designated field officer shall be the verifier in case of state governments or state-owned agencies functioning as a certifying body. Similarly, a trader or an agent shall be designated as the verifier in case of other private organizations or companies accredited to act as a certifying body.

The mobile application may be developed with the following features.

a) Recording the owner's details:

The owner of the land should provide the details such as name, cell phone number, aadhar number for registration.

b) OTP based authentication:

The details provided by the land owner will be verified through aadhar and one time password (OTP) based authentication.

c) Recording the farm details

The land owner should provide the farm details which are vital information for ascertaining ownership. The farm details include survey number, total area of the farm, village, taluk, district, and state in which the farm is located.

d) Uploading land records:

The owner of the land will have the option to upload land records as the proof of ownership. These records would be verified by the certifying agency.

e) Recording of geo-coordinates of the tree plantation:

The land owner should provide the geo-coordinates (minimum of four corners) of the tree plantation patch within the farm with high GPS accuracy with error margin not more than 5 m. More than one tree plantation patch can be uploaded.

f) Recording the geo-coordinates of individual trees

The land owner should provide the geo-coordinates of individual trees with details such as common name of the species, age of the tree, girth of the tree, etc.

g) Photography of the plantation and individual trees

The land owner should upload a minimum of four photographs from four corners of the plantation patch within his farmland. One photograph of each tree has to be uploaded.

h) Recording a short video of the plantation

A short video of the tree plantation should be uploaded by the owner of the land.

i) Generating QR code for individual log

The land owner should generate a printable QR code which contains all the information entered by the owner. The printed QR code slips should be affixed on each log.

j) Generating a map with all the recorded details

The land owner should generate a geo referenced map depicting all the recorded details.

Figure 2. Google-based mapping of individual trees, corners of tree plantation and the farmland

Existing crop survey and tree census apps can be enhanced to capture these details and the application should be developed using the blockchain architecture, so as to make the records immutable, the ability for a blockchain ledger to remain a permanent, indelible, and unalterable history of transactions. The blockchain architecture will also provide provenance, maintaining the complete documentary evidence of an entity that can be used to prove its legitimacy later if required.

Chapter 3

CoC Requirement

3.1 Overview:

In order to provide a credible, third-party independent and operational CoC system for wood or wood products, a number of guiding principles provide the necessary support to the criteria and requirements of such a system. These principles are.

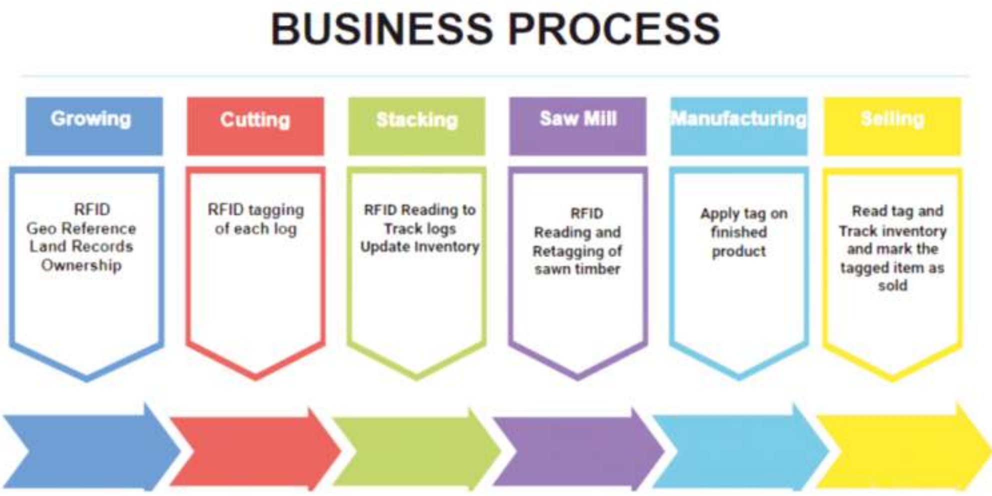
1. CoC certification is a voluntary activity and it seeks to assure buyers and consumers that the certified wood or wood products they purchase are the products sourced from farm land/participating processing/manufacturing companies.
2. The CoC system is used to track wood and wood products to meet the certification needs of all organizations along the certification chain such as farm owners, sawmills, wood-based panel industries, pulp and paper mills, wholesalers, retailers, customers, and the community at large.
3. Accredited, independent, third-party certification bodies will be responsible for the verification and auditing of the performance requirements of the CoC system and as such play an important role in safeguarding its credibility.
4. Organizations in the certification chain are responsible for ensuring the credibility of the CoC system as their day to day business activities will affect the outcomes of the CoC system.
5. Continual improvement in the AgriWood® standard is necessary so as to ensure that the criteria and requirements are regularly reviewed and revised to incorporate changes that will improve their effectiveness.

3.2 CoC requirements

This section sets out the essential criteria and the performance requirements for an organization participating in a CoC system and that is seeking certification of that system. The proposed strategy for certification of origin of farm wood and CoC is as follows:

Block chain method:

Block chain technology helps to electronically trace wood from the tree to the final user. The architecture offers the possibility of global, geo-referenced, real-time monitoring, conducted by forestry administrators, on the status of operations. It could also help to precisely define areas of interest and desired quantities, sizes, and species of wood for the market, or identify—even down to a single tree—the presence of particularly valuable materials. The very nature of block chain enables 'backward inferences' to be made through the processing phase, to identify processes or inputs at individual steps of the chain, both backward and forward in time.



3.2.1 Management commitment to CoC:

The organization shall define a management policy that includes a commitment to:

- supporting any claims related to the source of wood and wood products with CoC certification;
- providing assurance of the continuity, integrity and validity of the CoC system and the wood and wood products certified by it;
- ensuring compliance with applicable laws and/or regulations covering environmental impacts of the manufacturing facility;
- recognizing the right for personnel to collectively bargain consistent with the international labour organization conventions; and
- Continuous improvement of the CoC system.

The organization shall ensure that procedures, controls and guidelines are in place and roles and responsibilities are defined to implement the CoC system. The organization shall ensure that staff and contractors have appropriate skills, competencies and available resources that are essential for the implementation and control of the CoC system.

The organization shall identify a management representative with the responsibility and authority to implement and maintain the CoC system. Senior management of the organization shall annually review the effectiveness of the CoC system. The organization shall ensure that its manufacturing facility meets or exceeds all applicable laws and/or regulations covering health and safety of personnel.

3.2.2 Document control system

The organization shall establish, document and update a control system that addresses the CoC system for its certified wood or wood products and which:

- specifies the personnel responsible for control of the CoC system and their specific responsibilities in relation to the system;
- identifies the infrastructure and technical facilities required for the implementation and maintenance of the organization's CoC system;
- describes the raw material flow within the production process;
- specifies components of an information system or parts thereof that relate to the CoC system including the necessary forms, records or documentation as well as activities or actions; and

  details specific and correct requirements for completing the components of the information system or parts thereof including the necessary forms, records or documents.

NOTE 1: The control system may be in a hard copy or an electronic format but must be suitable for audit inspection for a period of at least five years after the product has passed to the next link in the certification chain.

NOTE 2: The responsibilities of the personnel in control of the CoC system could include:

- wood or wood product purchasing, product processing and sales;
- product labelling, when applicable;
- record keeping; and
- internal audits and non-conformity control.

NOTE 3: The personnel may need to include transport or haulage organizations that are contracted by the organization as part of their CoC system.

3.2.3 Personnel training and development

The organization shall provide or have a system in place that provides for the:

- training and orientation of the personnel involved in handling and presentation of certified wood or wood products and non-certified products:
- training of personnel sufficient for them to understand their specific responsibilities in the implementation and control of the CoC system;
- written instructions/guidelines or an accessible electronic system covering instructions/guidelines on the CoC system handling and presentation procedures and policies for certified wood or forest products and non-certified products; and
- local and regional workforce to be given employment opportunities at the manufacturing facility.

3.2.4. Approaches to CoC verification

To verify the origin of wood or wood products, the organization shall select either an inventory control and accounting of raw material flow option (see Appendix B) or a physical separation and/or marking of raw material option (see Appendix C) as its preferred CoC system.

NOTE 1: The inventory control and accounting of raw material flow option incorporates two approaches for calculating the percentage of certified material within the output batch, namely a percentage input/output system (%in / %out) or a rolling average percentage method. Both approaches are described in further detail in Appendix B.

NOTE 2: An organization seeking CoC certification may choose the most appropriate option of the two available, noting that one option has two distinct approaches, for different facilities if it requires such flexibility due to the mix of inputs. If the organization carries CoC certification, it can change its current option or approach to an alternative option or approach provided it complies with the criteria and requirements of this standard and seeks the prior approval of the certification body. This may or may not, at the discretion of the certification body, be contingent on an audit of the organization.

NOTE 3: An organization applying the rolling average percentage method must transfer the certification percentage to the product(s) included in the output batch using the average percentage method or volume credit method. Both of these methods are described in further detail in Appendix B.

3.2.5 Illegal operations or sources

The organization shall ensure that no wood or wood products known to be from illegal operations or sources, under relevant domestic and/or international law, enters any stages within the organization's link along the certification chain.

Species exempted under felling and transit regulation, as notified by Ministry of Agriculture, Cooperation and Farmers Welfare Department of Agriculture, Cooperation and Farmers Welfare. Govt. of India also needs to be covered under this standard. State-wise list of trees species free from felling and transit regulations growing on non-forest area /private land in various states and UTs are given in Appendix D.

3.2.6 Final inspection

The organization shall carry out a final inspection of certified wood or wood products at the end of their link in the certification chain, and prior to distributing to the next link, to ensure that:

- identification and traceability has been established and maintained throughout the certification chain;
- necessary tracking and recording has been completed in the document system; and
- relevant data, documentation and records are complete, duly authorized and retained for audit purposes for a period of five years.

The organization, where appropriate circumstances permit practical application, shall store certified wood or wood products separate from non-certified wood or wood products.

3.2.7 Record keeping

The organization shall maintain appropriate records of all wood or wood products procured, processed or sold. The records shall relate to purchase, delivery, shipment, receipt, forwarding and invoicing of certified wood or wood products and include information on their category status.

The records shall be sufficient to allow both an organization and/or a certification body or an independent assessor to undertake traceability to and from certified input and certified output and to determine the conversion rates for manufacture of certified output from given certified input.

The organization shall conduct internal audits of the CoC system and shall maintain records of such audits of the CoC system and any non-conformity that occurred, and corrective or remedial action that has been taken. In the event of non-conformity, a corrective or remedial action report shall include the changes necessary to the CoC system that could be expected to prevent a reoccurrence of the non-conformity. At no time shall the internal audits be less frequent than third-party audits.

NOTE: It would be expected that a certification body would examine all non-conformances contained in a non-conformance register at the routine external audits.

The organization shall seek the prior approval of the certification body for any change to its selected option or approach to CoC system verification under requirement of clause 2.2.4.2.

The records, including management reviews and audit and corrective or remedial action reports, shall be stored and maintained in such a manner to ensure ease of retrieval and protection against damage, deterioration, tampering or loss.

All records shall be kept for a minimum period of five years.

3.2.8 Use of certificates

The organization shall have controls to ensure that its CoC certificate is not misused.

The organization shall acknowledge that the certification body is responsible for verifying the CoC system and the certification body controls and supervises the use of the CoC certificate.

The organization shall acknowledge that the certification body uses a two-tier system for breaches of the CoC system prior to undertaking punitive action. The breaches in order of severity are minor non-conformance and major non-conformance. NOTE: Prior to issuing breach notices, the certification body may issue an observation to the organization as an indication that corrective and remedial action may be warranted to avoid notifiable breaches of the CoC system.The organization shall acknowledge that the certification body may cancel the CoC certificate where it has transparent and sufficient reasons to conclude that exploitation has occurred.

3.2.9 Continuous improvement

The organization shall demonstrate throughout its CoC system that it has relevant and appropriate mechanisms in place to facilitate the continuous improvement of its CoC system. The organization shall:

- maintain a record of all complaints or comments made known to the organization relating to its CoC system;
- take appropriate corrective and preventative action to deal with deficiencies in its CoC system;
- provide a documented record of corrective and preventative actions undertaken in its CoC system;
- establish and implement a programme of periodic internal checking, auditing, corrective action and review of its CoC system; and
- ensure that internal audits are at a relevant frequency and take into account the outcomes of previous internal audits.

APPENDIX - A

Implementation of the CoC system in multi-site organizations

The aim of this appendix is to establish the guidance for the implementation of CoC requirements in an organization with a network of sites, thus ensuring on the one hand, that the certification/registration of the CoC is practical and feasible in economic and operative terms and on the other, that the assessment provides adequate confidence in the conformity of the CoC system. A multi-site approach also allows implementation and certification of the CoC in a group of typically small independent companies.

This appendix includes only requirements applicable for the multi-site organization to implement the CoC requirements of this standard. Requirements and guidance for the certification registration bodies for the assessment and certification of a multi-site organization are described in the IAF guidance on the application of ISO/IEC guide 62:19967 general requirements for bodies operating assessment and certification/ registration of quality systems and IAF guidance on the application of ISO/IEC guide 66:19968 general requirements for bodies operating assessment and certification/registration of environmental management systems, EMS.

Definitions

A multi-site organization is defined as an organization having an identified central function (hereafter referred to as a 'central office') at which certain activities are planned, controlled and managed, and a network of local offices or branches (sites) at which such activities are fully or partially carried out.

The organization need not to be a unique entity, but all sites shall have a legal or contractual link with the central office of the organization and be subject to a common CoC which is subject to continuous surveillance by the central office. This means that the central office has the right to implement corrective actions when needed at any site. Wherever applicable this should be laid down in the contract between the central office and the sites.

Examples of possible multi-site organizations are:

a) organizations operating with franchises;

b) companies with multiple branches; or

c) a group of legally independent companies.

NOTE: Group of legally independent companies means a network of typically small independent enterprises associated together for the purpose of obtaining and maintaining CoC certification for the whole group. The central office may be an appropriate trade association, or any other properly experienced legal entity that is either nominated for the purpose by a group of intending members or offers a group service managed for the purposes of and consistently with this standard. The central office can also be administered by one member of the group.

Eligibility criteria for the multi-site organization

The organization's CoC shall be centrally administered and be subject to central review. All the relevant sites (including the central administration function) shall be subject to the organizations' internal audit programme and shall be audited in accordance with that programme prior to the certification / registration body starting its assessment.

It shall be demonstrated that the central office of the organization has established a CoC in accordance with this standard and that the whole organization (including all the sites) meets the requirements of the standard.

The organization shall be able to demonstrate its ability to collect and analyse data from all sites including the central office authority and ability to initiate change in the CoC operating in the sites if required.

Function and responsibilities of the central office

The central office of the multi-site organization shall:

(a) provide a commitment on behalf of the whole multi-site organization to establish and maintain a CoC in accordance with the requirements of this standard;

(b) provide all the sites with information and guidance needed for effective implementation and maintenance of the CoC in accordance with this standard;

c) provide organizational or contractual connection with all sites covered by the multi-site organization including commitments by the sites to implement and maintain the CoC in accordance with this standard. The contract shall also include the right of the central office to exclude any site from participation in the CoC of the multi-site organization in case of serious non-conformities with this standard;

(d) keep a register of all the sites of the multi-site organization;

(e) operate an internal audit programme, and audit all the relevant sites (including its own central administration function) in accordance with that programme, prior to the independent certification/registration body starting its assessment; and

(f) operate a review of the conformity of sites based on results of internal audits; establish corrective and preventive measures if required and evaluate effectiveness of corrective actions taken.

Function and responsibilities of sites

Sites connected to a multi-site organization shall be responsible for:

- implementation and maintenance of the CoC requirements in accordance with this standard;
- Responding effectively to all requests from the central office or certification/registration body for relevant data, documentation or other information whether in connection with formal audits or reviews or otherwise;
- Providing full co-operation and assistance in respect of the satisfactory completion of internal audits, reviews, relevant routine enquiries or corrective actions; and
- implementation of relevant corrective and preventive actions established by the central office.

APPENDIX - B

Inventory control and accounting of raw material flow

General

1. The organization shall ensure that it is able to verify the origin of or accept clearly marked wood or wood products before and after transport, handling and processing on the basis of relevant documentation.
2. The organization shall be able to verify the quantity of wood or wood products coming from different suppliers on the basis of documentation covering deliveries received at its site or facility.
3. The organization shall maintain reliable and current data by volume and/or weight on any wood or wood products which are mixed such that an independent certification body would be able to verify, as easily identifiable, the appropriate share of any mix during selected production periods.
4. The organization shall maintain a record system in which information on the suppliers of wood or wood products can be attached to wood or wood products or associated documentation.
5. The organization shall ensure that the percentage by weight or volume of all wood or wood products deliveries are documented up to the point of feeding into the processing stream to allow for detailed accounting of material flows. The monitoring of material flows shall provide clear and transparent information about the share of certified wood used in various products.

Percentage input/output system

6. An organization shall be deemed to be utilizing the percentage input/output system when it operates at a site, facility or production line with a known percentage of certified material (i.e., an input batch) entering the processing stream and the same percentage of production from that stream (i.e., output batch) being considered to be certified products.

When an organization is not able to define:

I) a single measurement unit for all output products of the output batch; or

ii) input batch products with different ratios between input wood raw material volume and output product volume, the organization shall transfer the certification percentage separately for the products with different measurement units or the input/output ratio.

An example would be for input wood raw material into a sawmill of 1000 cubic metres, which contains 80% certified content, provides a certification percentage on the output batch, which can have products in cubic metres (sawn timber) or tonnes (woodchips, sawdust) of 80% on each of the products.

7. The assessment of the percentage of inputs and outputs is, on an average basis, over a period of up to three months that is equivalent to the period of the output batch.

NOTE: This system is particularly appropriate where there is a discrete batch of certified wood or wood product being processed, and the batch does not account for all of the production being processed and/or sold.

Rolling average percentage system

8. The organization applying rolling average percentage system shall calculate the certification percentage for the specific batch using the quantity of raw material procured in the specified previous time period. The total maximum time for the rolling average calculation shall not exceed twelve (12) months.

The calculation shall be based on the volume or weight of all the wood or wood products, including solid wood, assembled goods, pulp and paper, wood chips and fibre using the following equation:

Certified percentage = (quantity of certified raw material/quantity of total raw material) x 100

The documentation accompanying certified material shall specify the basis of its certification.

NOTE 1: This system can be applied where certified wood accounts for a proportion of the wood input, but where it is difficult and/or costly to segregate certified wood inputs from non certified wood inputs through the processing stream.

NOTE 2: The unit of certified wood can be specified by either weight or volume. In the case of weight, the moisture content and basis of determination (e.g., at 0% or 12% and whether wet/dry) must be specified. In the case of volume, it must be specified whether gross or net. These units are used to determine the percentage of certified wood in wood products and must be applied consistently. The applicable unit will be decided by the organization and verified by the certification body.

Transfer of the calculated percentage to the outputs can be achieved using the following approaches:

1. The average percentage method: The certified wood percentage is transferred to all the outputs of the batch through an average percentage claim. The batch products will be certified as containing percentage of certified wood.

NOTE: Under the average percentage method, the minimum average percentage for certification claims via labelling shall be not be less than 70% by volume or by weight for all wood or wood products, including solid wood, assembled goods, pulp and paper, woodchips and fibre.

2. The volume credit method: The certified wood percentage is transferred to only a part of the outputs of the batch. The volume credits are transferred in such a way that the products receiving these credits are certified as containing 100% of certified material.

Under the volume credit method, an organization shall transfer the certification percentage into volume credit separately for products included in the output batch that have different measurement units or input/output ratios.

The organization can accumulate the volume credits by creating a credit account, which can be used for subsequent batches. The total quantity of credits accumulated at the credit account cannot exceed the sum of credits entered into the credit account during the last 12 months.

9. An organization utilizing either method shall monitor raw material flows (input batches) in accordance with:

(a) a maximum monitoring period of up to 12 months;

(b) the actual period to be calculated as a rolling average of the output;

c) the organization determining the period; and

(d) any calculations for the period based on verifiable documentation.

10. The system shall have the capacity to ensure that any product sold by the organization as certified is accompanied by documentation issued by the organization to a purchaser being the next link in the certification chain.

The documentation shall include:

(a) a description of the product;

(b) the volume/quantity of the product;

c) category of the input material's origin (including percentage of certified raw material if a percentage-based method was used by the organization or the supplier(s) of the certified raw material);

(d) date of delivery or period of delivery or accounting period; and

(e) the organization's CoC certificate registration code and expiry date.

The information provided on the sales invoice from one organization (output from a link) shall be regarded as input information for the receiving organization (input for a link) at the commencement of its processes.

NOTE: The intent of this system is that the rolling average percentage be applied using the same moisture content basis for more than one source of input. In practice, this is difficult unless there is allowance for the use of verifiable conversion factors and sampling methods to apply these. For example, certified chip comes into a particle board plant at a nominal 130% moisture content (MC) from one source and non certified chip comes in from source B at 90% MC. Sampling techniques are used on each batch from each source to predict the MC of the chip from each source. From this, the bone-dry weight (i.e., at 0% MC) can be calculated for each, and then the blending ratio can be used to determine whether the 70% minimum on the basis of weight is achieved.

APPENDIX - C

Physical separation and/or marking of raw materials

1. The organization participating in this option shall ensure that only certified wood or wood products, which have been verified by the physical separation approach in all previous stages, are utilized at its site, facility or production line for processing to a certified product.
2. The organization should store certified inputs and products in separate designated areas to augment the physical separation option.
3. The organization shall ensure that when wood or wood products are received at a site, facility or production line that they are clearly marked or have distinguishing marks to indicate their origin and are otherwise readily identifiable as certified inputs or products. NOTE: Clearly marked or distinguishing marks may take the form of colour coding, branding, bar coding, stencil brand or other form of CoC coding (to be determined). All such coding will assist the organization and the certification body in the identification of certified inputs and products. A mechanism should be available to enable the certification body to readily decode the distinguishing mark(s) and trace the product in the organization's CoC system.4. Certified inputs or products shall remain readily identifiable as certified throughout the certification chain.

The organization shall achieve this by:

(a) directing wood or wood products to separate mills, sites, facilities or production lines;

(b) using products at different times or runs if the organization has certified products and non certified products at the same mill, site, facility; or

c) marking the certified products prior to, and at all stages in any process to ensure that intermediate, semi-processed and end products can be identified as certified.

NOTE: The option of marking certified inputs or products may not be relevant for chips, flakes, shavings, sawdust or particles due to inherent logistical constraints of such products. Also for some products e.g., veneers, marking may have a detrimental effect on the appearance of the end product.

5. The organization shall demonstrate that it has a verifiable method to distinguish certified from non certified products where such products are unable to be readily marked due to logistical, appearance or other reasons.
6. The organization shall ensure that wood or wood products are clearly marked or labelled or otherwise readily identifiable in a way that the marking or labelling does not become detached, ambiguous or otherwise indistinguishable during storage, handling, packaging, transportation or delivery.
7. The system shall have the capacity to ensure that any product sold by the organization as certified is accompanied by documentation issued by the organization to a purchaser.

The documentation shall include:

(a) a description of the product;

(b) the volume/quantity of the product;

© category of the input material's origin (including percentage of certified raw material if a percentage based method was used by the organization or the supplier(s) of the certified raw material);

(d) date or period of delivery or the accounting period; and

(e) the organization's CoC certificate registration code and expiry date.

Organization shall demonstrate that it has a verifiable method to distinguish certified from non certified products

APPENDIX - D

State wise list of trees species free from felling and transit regulations growing on non-forest area / private land in following states and UTs as received from MoEF and CC.

	Name of state/UT	Status
1.	Andaman and Nicobar	Transit permit is required for transit of forest produce in A & N Islands and no exemption for any sp. has been provided in the regulation.
2.	Assam	No felling permission (FP) is required for home grown bamboo. No transit pass (TP) is required. Certificate from Gram Panchayat is required.
3.	Andhra Pradesh	NO FP. All spp. exempted. NO TP, All spp. exempted.
4.	Arunachal Pradesh	No FP is for bonafide use except commercial use. No TP is required except commercial and other use.
5.	Bihar	Tree spp. currently exempted from transit regulations (as on 27 February 2009). Poplar, Eucalyptus, Kadamb, Gamhar, Mango, Litchi, Toddy palm, Khajur, Bamboo spp. (except Dandrocalamus strictus), Semul. Some more spp. are in process to be exempted.
6.	Chandigarh	No interstate transit permit is being issued by forest department as no forest check posts have been established.The permission for felling of trees on private/non forest land is given only in two cases, i.e., either for any development work or trees are dangerous to human life or property. As such no tree spp. Is exempted under this.
7.	Chhattisgarh	Timber Spp. that have been exempted from transit regulations are Poplar, Casuarina, Su-babul, Israili babul, Vilayati babul, Manzium , Nilgiri.
8.	Delhi	Since land is premium commodity in Delhi, farmers generally do not practice agroforestry here. Spp. like Poplar, Kikar and Eucalyptus have been proposed for exemption. So FP is required. There is no transit rules in Delhi for transportation of timber.
9.	Goa	No FP. Omitted bamboo from the definition of tree. No TP. All types of bamboo grown in private areas (non-forest areas) will not fall under the purview of forest produce and hence transit permit for bamboo felled from private areas are exempted
10.	Gujarat	Nilgiri, Subabul, Saru, Champa, Laxmanfal , Ramfal, Sitafal, Asopalav, Pendula Nagkesar,Nagchampha, Falsa, Ingorio/Angarea, Kamrakh, Kadhipatta, Limbu, Chikotru, Bijoru/Turanj, Narangi, Mausambi, Maharuk, Rukhdo, Motoarduso, Limdo,Neem, Bakan, Bakan, nim, Irani nim, Nimbara, Limbara, Mahanim, Mahogony, Bordi, Bor, Khati bor, Ghulbor, Liehi, Lilchi, Aritha, Aritha, Amba, Kadvo Saragavo, Saragavo , Agathin, Segto, Agastin, Desi Baval, Goras amlili, Gando baval, Ganda baval, Botlle Brush, Jamphal, Dadam, Chikoo, Boralli/Mursal/ Vakal/ Varasd/ Bakul,Saptaparni, Champo, Safed champo, Liar/ Nani/ Gundi/ Nagod, Nirgund/ Nargundi, Lingur Nirgudi, Ambla, Fanas, Pipli/papri, Shetur, Haredo, Harero, Poplar, Golden cane palm, Oilplam
11.	Himachal Pradesh	KalA Siris/Ohi/Sriris, Kachnar/ Karial, Safeda, Kimu/ Chirmu, /Shahtoot/Tut/Mulberry, Poplar, Indian Willow/Biuns,Kuth, Kala Zira, Japanese Shehoot/paper mulberry, Paik,

		/Koi,/Kosh/Kunis/Kunish/Nyun, Khirk/ Khadki, Darark/Bakin, Fagoora/ Phagoora/Tiamble/timla/ tirmal/anjiri/cluster fig/goolar, Toon, Jamun, Teak/Sagun/Sagwan, Arjun, Semal, Shalmaltas, Bihul/ Beul/ Bhimal/ Bhiunal/Dhaman, Paza/ Padam, Kamala/ Raini/Rohan/Rohini/ Sinduri, Aam (Mango wild variety), Rishtak/Ritha/Dode.
12.	Haryana	Some spp. are exempted from regulations under Punjab Land Preservation Act 1900. These are Eucalyptas, Poplar, Ailanthas and Acacia tortilis. There is no transit rules applied for timber spp.
13.	Jharkhand	Eucalyptus (Safeda), Poplar, Casuarina, Maha Neem, Baken Kadmb, Subabool, Silver Oak, Israeli Babool Vilayati Babool, Babool, Plam, Ber, Munga, Mulberry Guava, Nimboo, Santra, Mussambi, Ashok.
14.	Jammu &	Kikar, Bel, Siris, Champ, Neem, Malugarh, Kakrad, Palas, Amaltus/Karangal, KashmirSisoo/Tali, Dhamman, Nili Gulmohar, Akhrot(khod), Kehbal jhingar, Baronkal, Bilati Kikar, Safeda, Poplar, Robin, Chitta banddha, Rondu banddha, Sagwan, Arjun, Beheda, Tun/Toon, Bana, Dhoi.
5.	Karnataka	Acacia hybrid, Acacia mangium, Tree of Heaven, Rain tree, All Cassias except Golden Rain tree, Cashew, Christmas tree, Arecanut, Casuarina, India Beef wood, Lemon, Ornage, Coconut, Coffee, Mayflower, Indian coral tree, Eucalyptus, Glyceridia / Quick stick, Silver Oak, Rubber, Jacaranda, Sausage tree, Subabul, Umbrella tree, Sapota/Chikoo fruit, Melia, Indian Cork tree, Drumstick, Mulberry, Curry leaf tree, Peltoform, Purple bauhinia, Pagoda tree, False Ashoka, Guava, Sesbania, Hummingbrid tree, Paradise tree, African tulip, Tabebula, Trumpet tree.
16.	Kerala	Species for Ply wood: Vellappine, Kurangandi/ Narivenga/ Mundani, Karakily/Kalpine, Kulamavu/ Kulirmavu/Ooravu, Pali/Palendinjan, Thellipine/Undapine, Kulavu, Red Cedar, Poon/Punna/Punnappa, Vediplavu/Mullampali, Charu, Pothundi/Perunthondi, Cheeni, Nedunar, Vallabham/Varangu, Chorapine, Chemmaram, Champakam, Cherukonna, Mulliam, Neeramruthu, Peenary, Kumbil, Veembu, Gnavel, Kattunelli, Vakka, Thavala. Species for matchwood: Aspin/Kanala/Nasakam, Elavu/Poola, Pala/Mukkampala. Species for bobbin wood: Vellakil, Manjakdambu. Species for pencil wood: Venkotta, Perumtholi/Poochakadmbu, Attuthekku/Cadambu. Species for packing wood: Kara/ Bhadraksham, Amazham, Aval, Arayanjili, Kalaveppu/Malaveppu, Vatta/Uppathi, Fire wood: Palvu (Jack), Parankimavu (cashew), Kattadi (Casuarina) Poovarasu (Poovarasu), Mavu (Mango tree), Puli(Tamarind tree), Nattupunna (Nattupunna), Aanjili(Aanjili), Vaka (Vaha- species), Poovam (Poovam), Konna), Thanni (Thanni), Uthi (Uthi), Aal Jatikal (Ficus species), Matti (Matti), Murukku (Murukku), Elappu (IIoia) and Kodamuli (Koadampuli).
17	Lakshadweep	No FP. IFA or any Forest Act is not enforced in Lakshadweep. Also, bamboo is not grown anywhere in Lakshadweep. Therefore amendment in IFA or any Forest Act does not arise in this state. No TP.
18.	Madhya Pradesh	Neelgiri, Casuarina , Poplar, Subabul, Israili Babul, Vilayati, Babul, Australian Babul, Babul, Khamer, Maharukh, Kadamb, Cassia Siamea, Gulmohar, Jacaranda, Silver oak, Plam, Ber, Mulberry , Katahal, Amrood, Nimbu, Santra, Mussambi, Munga, Molshri, Ashok, Putranjiva, Imli, Jamun, Mango, Saptparni, Kaitha, Jungle Jalebi,

		Petltaphorum, Neem, Bakain, Sissoo, Karanj, Palash, Safed Sirus, Pipal, Bargad, Gular, Rubber, Semal, Kapok, Chirol, Gliricidea, Rimjha, Meithi Neem, Gurhal, , Jasoun, Conifers, and imported timber species.
19.	Maharashtra	Nilgiri trees,Babhul, Subabhul, Prosopis, Ashok, Drumstick, Sindi, Orange, Chiku, Bhendi, Acacia, Poplar, Lac, Casuarina equisetifolia , Rubberwood.
20.	Meghalaya	Meghalaya being a hilly state, there is no agroforestry at all, since percentage of states land is covered by agriculture is very less. If any blank interstate movement of timber is permitted, state will lose meagre resource of forests under control of the State government.
21.	Mizoram	Kothal, Tung, Eucalyptus spp., Mulberry, Neem, Rubber tree, Imli, Silver Oak, Subabul, Mango, Guava, Coconut, Citrus, Areca nut.
22.	Manipur	No FP is required. No TP is required for home grown within state. TP is required outside state.
23.	Nagaland	Aam, Korei, Walnut, Neem, Alder, Manipur Sim, Kadam, Hollock , Khokan, Teak, Gamari
24.	Odisha	Bada chakunda, Sana Chakunda, Jhaun, Sliver Oak, Patas/ Nilgiri, Sunajhari/Acacia, Subabul, Kaitha, Ambada, Batapi, Oau, Sajana, Karamanga, Sahada, Plam tree, Debadaru, Bhersunga, Gohira, Giliricidia, Paladhua, Coconut.
25.	Punjab	'Forest produce' shall specifically mean timber (converted or otherwise), firewood, charcoal, katha and resin, but shall not include non-timber forest produces (NTFPs) like bamboos and agro-forestry species such as Populus spp., Eucalyptus spp., Melia azedarach (Drek), Morus alba (Mulberry), Leucaena leucocephala (Subabul), Casuarina spp., Grevillea robusta (Silver Oak), Acacia mangium, Melia dubia (Malabar Neem), Prosopis cineraria (Khejri), Salix alba (Indian willow), Gmelina arborea (Gamari) or any other species declared by the state/authorized agency as agro-forestry species from time to time.
26.	Rajasthan	Casuarina, Australian babul, Khamer, Caaia Siamea, Gulmohar, Jaccaranda, Silver oak, Plam, Ber, Mulberry, Katahal, Amrood, Sehjana, Molshri, Ashok, Putranjiva, Imli, Jamun, Saptarni, Kaitha, Jungle Jalebi , Petaphorum, Bakain, Karanj, Safed Sirus, Semal, Kapok, Churel, Mithi neem.
27.	Sikkim	No permission for felling of trees on any private or forest land has been granted. If anyone wishes, he has to apply to Block Officer.
28.	Tamil Nadu	Mesquite, Casuarina, Subabul, Palmyrah, Dadops, Umbrella thom, White Back Acacia/Panicled Acacia, Maharuch, Maharukh/East India Walnut/Siris, Cashew, Kadam, Jack, Neem/Margosa, Red silk cotton/ Kapok, Sappan, Cassia, white silk cotton tree/kapok, Sissoo, Coral tree, Eucalyptus, Gamari, Rubber, Sea Hibiscus, Mohua, Mango, Persian Lilac, Malabar Neem, Morinda /Suranji, Manila/ Tamarind, Pongam/ Indian Beach, Rain tree, Mahogeny, Jamun/Indian cherry, Tamarind, Esperanaza, Indian Portia tree/Indian Tulip, Red Cedar/Toon, Silver Oak.
29.	Telagana	(i) Eucalyptus, Neelagiri, Jama oil (ii) Casurina, Sarugudu, Sarvi, Saru (iii) Poplar (iv) Subabul (v) Israeli Babool (vi) Seema,Thumma(vii) Australian babul(viii) Gummaadi teak (ix) Pddamanu (x) Kadamb, (xi) Seema/Tangedu (xii) Jacaranda (xiii) Silver oak (xiv) Regu, Ber (xv) Mulberry (xvi) Jama, Guava (xvii) Orange and related species, (xviii) Munga (xix) Ashok/Naramamidi (xx) Mahaputrajivi/Putrajeevi (xxi) Edakulapala (xxii) Turakavepa (xxiii) Kanuga (xxiv) Rubber / Seemamarri (xxv)

		Tella Tumma(xxvi) Gliricidea/Seema/Kanuga (xxvii) Tella Tumma (xxviii) Kaivepaku (xxix) Mandara (xxx) Conifers (chir, Kail, Deodar, Pine species) (xxxi) Tati, Tadi, Palmyrah (xxxii) Sapota (xxxiii) Coconut, Kobbari, Tenkai, (xxxiv) Cashew, Jeedimamidi (xxxv) Semma, Chinta, (xxxvi) Raint ree, Nidragannreru, (xxxviii) Mango, Mamidi (xxix) Panasa, Jackfruit.
30.	Tripura	Tree species like Mango, Litchi, Drumstick, Guava, Rubber and bamboo are exempted from extraction from private land. Bamboo spp. have been exempted from transit permits both from private and forest land. Transport of timber is also permitted.
31.	Uttar Prades	Aru, Casuarina, Jangal Jalebi, Poplar, Babool, Vilayati Babool, Rabania, Siris, Su babool, Kathber, Jamun, Eucalyptus, Dhak Palas, Paper Mulberry, Ber, Sainjana, Shah toot, Mango (Desi, Tukhmi or Kalmi).
32.	Uttarakhand	Twenty-seven tree species have been exempted from the provision of Tree protection Act 1976. This includes fodder and small timber species that are being used in small scale industries, animal husbandry, agricultural implements and allied activity. Other 7 tree species like Walnut, Neem, Oak, Ficus (Peepal and Banyan) and Deodar have been placed in the restricted category and felling permission can be granted only in case of dead or dangerous trees.

Short term Courses offered by
The Advanced Woodworking Training Centre (AWTC)

The Advanced Woodworking Training Centre (AWTC) is a premier training centre located in the heart of Bengaluru city. It was established by Institute of Wood Science and Technology (IWST) as the first training centre in India with an aim to enhance skillset of manpower working in wood based industries. So far AWTC has trained more than 2500 professionals. The courses are designed to give first hand experience in handling advanced machines and tools to wrok on various wood and wood products that meet the global standards.

Conventional Woodworking and Finishing (4 Weeks)

Admission Eligibility	:	10th Class Pass.
Course Fee	:	Rs.15,000/- for entire course
Extra	:	Rs.1,650/- towards Accommodation Charges, Food Charges (as per actual)
Security Deposit	:	Rs.5,000/- (Refundable) :Maximum 5 Candidates per Batch
Intake	:	Maximum 20 Candidates per Batch

Product Designing and Development on CNC Router (4 Weeks)

Eligibility	:	Completion of Conventional Woodworking and Finishing course at AWTC
Course Fee	:	Rs.20,000/- for entire course
Extra	:	Rs.1,650/- towards Accommodation Charges Food charges (as per actual)
Security Deposit	:	Rs.5,000/- (Refundable)
Intake	:	Maximum 5 Candidates per Batch

Product Designing and Development on PYTHA 3D (2 Weeks)

Eligibility	:	Completion of Product Designing and Development on CNC Router at AWTC.
Course Fee	:	Rs.10, 000/- for entire course
Extra	:	Rs.1, 650/- towards Accommodation Charges,
Food Charges	:	Extra (as per actual)
Intake	:	Maximum 5 Candidates per Batch.

IWST

Advanced Woodworking Training Centre
INSTITUTE OF WOOD SCIENCE AND TECHNOLOGY
(Indian Council of Forestry Research and Education)
An Autonomous Body of Ministry of Environment, Forest and Climate Change, Govt. of India
P.O. Malleswaram, Bengaluru – 560 003, India
Website : http: //iwst.icfre.gov.in/awwtc/awwtc.htm
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Proposed draft on Wood Based Industries (Establishment & Regulation) Guidelines

DRAFT RESOLUTION

S.O.________________________the Ministry of Environment, Forest and Climate Change, Government of India vide Resolution dated__ ________October, 2022 proposes to issue following resolution in order to facilitate and promote agro-forestry and farm forestry. The Ministry of Environment, Forest and Climate Change, Government of India vide Resolution dated 11th November, 2016 had issued the Wood Based Industries (Establishment and Regulation) Guidelines, 2016, which were amended vide Resolution dated 11th September, 2017. However, the Ministry has been receiving several representations and comments / observations from various stakeholders, including states, to further amend these Guidelines in order to promote sustainable development of wood-based industries in the country to its potential.

The Government of India also recognizes that agroforestry and farm forestry is being widely practiced in the country on lands outside forests, yet their achievement is far below the potential whereas the area of lands that are subject to desertification process continue to be very large and there is an urgent need to reverse this process on such affected lands. Promotion of agroforestry and farm forestry is the key to achieve the National Forest Policy 1988 target of having one-third land area of the country under Forest or Tree cover. Besides, it will make the country self-sufficient in wood and wood products by reversing the current increasing trend of massive imports thereby also saving precious foreign exchange, help achieve the Nationally Determined Contribution target for Carbon sequestration, create green employment, a host of other green secondary and tertiary services, expand skill-base of people, and enhance income of the farmers especially in the hinterland where poverty removal is a major challenge. Promotion of wood-based industries like veneering, pulping, plywood, MDF and particle boards to support the agroforestry and farm-forests by way of creating sustainable demand and remunerative price for tree growers is essential so that farmers are encouraged to grow more and more trees on their lands. This helps in augmenting ecological services flow and enhancement of total Carbon stock, including Carbon locked in wood products, in the country. This entails further rationalization of the existing Guidelines 2016 and 2017 so that on the one hand such wood-based industries do not face unnecessary delay or debilitating control in their lawful operation and on the other hand there is an overall sustainable conservation and development of forests in the country. Therefore, the Ministry of Environment, Forest and Climate Change, Government of India is pleased to make the following revised Guidelines to rationalize the establishment of such wood based industries as under:-

1. Short Title and commencement

I. These guidelines shall be called the Wood-Based Industries (Establishment, Facilitation and Regulation) Guidelines (Revised), 2022.

ii. These shall extend to the whole of India.

iii. These shall come into force from the date of their publication in the official gazette.

2. Definitions

I. In these guidelines, unless the context otherwise requires: -

a. Industrial Estate' means area notified or earmarked by the state government or Union Territory for establishment of industries including wood-based industries. It shall also include all industrial townships, district industrial areas and such other areas established for the aforesaid purpose.

b. Municipal area' means any area notified by the state government or Union Territories. It also includes district, tehsil, Circle or Block headquarters notified by state governments or UTs, the industrial townships and cantonment boards.

c. License' means a license granted under the rules notified by a state government or UT in pursuance of these guidelines.

d. Principal Chief Conservator of Forests' means a Forest Officer of the rank of Principal Chief Conservator of Forests in a state government or UT and it also includes an officer designated as Head of Forest department in a state government or UT where no post in the rank of Principal Chief Conservator of Forest exists.

e. Saw Mill' means plants and machinery in a fixed structure or enclosure, for conversion of round logs of wood into sawn timber.

f. Sawn timber' means beams, scantlings, planks, battens and such other products obtained from sawing of a round log of wood.

g. Wood Based Industry' means any industry which processes wood as its primary raw material, and includes other form such as Katha (catechu) wood, Sandalwood, Charcoal etc.

h. State Level Committee' means a committee constituted by the state Government under Para 3 of these guidelines.

I. Wood Council' means the Wood Council ('WC' in short) constituted by the Central Government or the State/UT governments under Para 4 of these guidelines.

j. Trees Outside Forests' ('ToF' in short) means trees located on all lands outside notified forests, recorded forest and such other forest which have been identified by the Expert Committee constituted by the state government as forest and to which Forest (Conservation) Act 1980 applies.

k. Farm wood' (or 'ToF Timber' or 'Vanetar Kahtha' or any other vernacular name having same meaning) includes all wood, whether cut up or fashioned or hollowed out for any purpose or not, obtained from ToF.

l. Imported wood' means all wood and wood products imported from other countries.

m. Charcoal' means a form of carbon derived from incomplete combustion of wood from a tree.

n. Tree growers' mean individuals or organizations engaged in the growing of ToF and / or production of farm wood by themselves or by hired labour or otherwise, and includes farmers, Farmer Producer Organizations, Forest Protection Committees, companies, partnership firms including limited liability partnerships firms, co-operative societies, societies, and any associations or body of persons duly incorporated or recognized as a group under any ongoing programmes, schemes or resolutions of the Central Government or the state Government.

o. Trader or agent' means a person who buys farm wood or imported wood by way of inter-state or intra-state or intra-country trade or a combination thereof, either for self or on behalf of one or more persons for the purpose of wholesale trade, retail, end-use, value addition, processing, manufacturing, export, consumption or for other such purpose.

p. Inter-state trade' for the purpose of these guidelines means the act of buying or selling of farm wood, wherein a trader or agent of one state buys farm wood from tree growers or a trader of another state and such farm wood is transported to a state other than the state in which the trader purchased such farm wood or where such farm wood originated.

q. Intra-state trade' for the purpose of these guidelines means the act of buying or selling of farm wood, wherein a trader of one state buys the farm wood from a tree grower or a trader of the same state in which the trader purchased such farm wood or where such farm wood originated.

r. Electronic trading and transaction platform' for the purpose of these guidelines m eans a platform set up to facilitate direct and online buying and selling for conduct of trade and commerce of farm wood through a network of electronic devices and internet applications, where each such transaction results in physical delivery of farm wood, and will include commodity exchanges and Futures market.

s. Trade area' for the purpose of these guidelines means an area designated for supply of farm wood, high potential of ToFs, preferred establishment of specific wood based industries etc.

t. Sponsor' means a person, trader or agent who has entered into a farming agreement with the tree grower for growing trees.

u. Farming agreement' means a written agreement between the tree grower and sponsor, such as:

I. Trade and commerce agreement', where the ownership of farm wood remains with the tree grower during production and he gets the price of produce on its delivery as per the agreed terms with the sponsor;

ii. Production agreement', where the sponsor agrees to provide farm services, either fully or partially, and to bear the risk of output; and

iii. Any other such agreements or a combination of the agreements specified above.

v. Local bodies' means Panchayats and Municipalities, by whatever name called, within the meaning of Article 243B (1) and Article 243Q (1) of the Constitution of India, any institution of self government constituted under any other provision of the Constitution of India or any Central or state Act, Biodiversity Management Committee under Biodiversity Diversity Act, 2002 (Act 18 of 2003), or Joint Forest Management Committee constituted under the order/ Resolution of the respective State.

w. Year' means a financial year from 1st day of April to 31st day of March of the following year.

x. Words and expressions used but not defined under these guidelines and defined in the Indian Forest Act, 1927 (Act 16 of 1927) or the relevant local Forest Act as applicable in a state, and rules framed there under shall have the meaning assigned to them in such Act or Rules.

y. In case of any dispute regarding interpretation of any word or expression, the decision of the Ministry of Environment, Forest and Climate Change shall be final.

1.	Principal Chief Conservator of Forests	Chairperson
2.	A nominee of Ministry of Environment, Forest and Climate Change, Government of India	Member
3.	A representative of State Forest Department not below the rank of a Conservator of Forests dealing with preparation of Working Plans/Working Schemes*	Member
4.	Director of Department of Industries, and the Director of Department of Agriculture	Members
5.	Representative of each Autonomous District Council constituted in accordance with the provisions of the Sixth Schedule to the Constitution, in case such Council exists in the state	Member
6.	Representative of the Forest Development Corporation, in case any such Corporation exists in the state	Member
7.	An office not below the rank of Conservator of Forests working in the Forest Headquarters or in-charge of forest resource management/ utilization*	Member
8.	The State Level Committee may co-opt an officer from the Territorial wing of the Forest Department not below the rank of CF and officers from Department of Agriculture and Department of Revenue of the concerned State government or UT.	

*Asst. or Dy. Conservator of Forests where post of Conservator of Forests not available.

3. Constitution of the State Level Committee

I. Each state shall constitute a State Level Committee ("SLC") to exercise the powers and perform the functions stipulated in these guidelines.

ii. The State Level Committee shall consist of the following:

iii. Such a state where the composition of State Level Committee already constituted is different from as stipulated in these guidelines, shall within one year from the date of publication of these guidelines, re constitute the State Level Committee. The reconstitution of the State Level Committee will be without any prejudice to the recommendations made or the decisions taken by the existing StateLevel Committee till its re-constitution.

iv. The State Level Committee shall meet at least once in three (3) months.

v. The quorum of the State Level Committee meeting shall be at least fifty (50) percent of the permanent members.

vi. The State Level Committee will invite at least two (2) representatives of the wood-based industry nominated by the association of wood-based industries in the state as a special invitee to each and every meeting of the State Level Committee.

4. Wood Councils

I. Wood Councils will provide a platform for deliberation and collaboration amongst tree growers, sponsors and the wood-based industries, government representatives, forestry institutions and other stakeholders for the establishment of interface between the wood industries and tree growers at various levels i.e. national, state, regional or district.

ii. The Central Government may constitute a Wood Council at national level to recommend to the Central Government or through the Central Government to the concerned State Governments or any other institutions the measures with respect to

a) intra and inter-state trade, electronic trading and transaction platform, legality and certificate of origin, certification and chain of custody, trade area and farming agreement, priority finance and risk mitigating instruments, skill and tool/technique up -gradation for on-site harvesting, conversion, peeling, veneering, impregnation, modification, seasoning, storage and such other value addition activities etc. that need to be adopted for promotion of wood-based industries.

b) Accreditation of nurseries, certification of seeds of forestry species, availability of quality planting stock, release of new clones or cultivars, wood productivity and pricing mechanism for the benefits of tree growers.

iii. Wood Councils shall be constituted at the State level as well as the regional or district level by resolutions of the State/UTs government. The Chairmanship of such council shall be an eminent personality from wood sector nominated by the Chief Minister of the respective State/UT. The secretariat support may be provided by State level committee or any other structure decided by the state government. The functions and powers of State level Wood Council shall be as below:

a) The regional or district-level Wood Councils shall function under the overall guidance of their respective State-level Wood Councils, and the decisions of their respective State-level Wood Council shall be binding on them. State-level Wood councils shall facilitate vertical integration of the above-mentioned linkages between all stakeholders.

b) The State-level Wood Council shall recommend on the establishment of farm wood-based industries to maintain sustainable demand of such wood in the State.

c) The State-level Wood Council should ensure less transportation cost and may fix minimum and maximum price of local farm wood in trade areas based on market chain analysis.

d) The State-level Wood Council should strive to remove the widespread mismatch between demand and supply of farm wood at the State and the regional level;

e) The State-level Wood Council may recommend on demarcation and designation of trade area for trader, agent and sponsor so as to encourage tree growers (farmers) to grow trees on their lands.

f) The State-level Wood Councils may provide for their own electronic trading and transaction platform for intra-state trade and commerce in a trade area following the chain of custody regime electronically.

g) The State-level Wood Council should provide for upgradation and deployment of tools and techniques for on-site harvesting, conversion, peeling, veneering, impregnation, modification, seasoning, storage and other such value additions to farm wood.

h) The State-level Wood Council should decide on the electronic framework for registration of all wood based industries exempted from license and procurement of wood from legitimate sources.

I) The State-level Wood Council should support running campaigns such as 'Grow More Trees Outside Forests' and 'Wood is Good' to spur a mutually healthy balance between demand and supply.

j) The State-level Wood Council may carry out studies on Institutional (legal, procedural and policy) reforms that are needed to promote concomitant growth of tree growing and wood based industries, including tree species wise or geographical area wise rationalization of State specific rules/ regulations that impede the availability of sustainably produced wood to the WBIs, and setting-up of support structures/ organizations to oversee that these reforms.

k) The State-level Wood Council may prescribe other green norms such as reduced proportion of wastage, use of multiple wood species and wood types as raw material, recycling of waste, use of non-polluting binders, geographical location in a preferred area to support farm wood, etc. for the wood-based industries and providing a market-based incentive mechanism to promote achievement beyond the prescribed Green norms. Such Green norms may also be taken into consideration by the SLC or the authorized officer while granting or renewing a license to a WBI

l) Any other matter related to promotion of sustainable wood based industries.

5. Powers and Functions of the State Level Committee

The State Level Committee (SLC) shall:-

I. Assess the availability of wood in the state by way of appropriate study on demand and supply as and when it decides. SLC shall devise suitable mechanism for sustainable use of wood in a way that does not affect the forests of the area adversely while ensuring sustainable demand for farm wood and remunerative price for tree growers.

ii. Approve the name of wood-based industries which may be considered for grant of fresh license or enhancement of the existing licenses capacity in case it is satisfied that wood is available legally.

iii. Ensure that the amount lying with the respective State Forest Departments (recovered from Wood Based Industries) or any amount including fee, fine, penalty or compensation collected from the Wood Based Industries is utilized for the purpose of afforestation only.

iv. Take follow-up action on the recommendations of the State-level Wood Council and Wood Advisory

Council at the national level as conveyed by the Ministry of Environment, Forest and Climate Change, Government of India.

6. Restriction on location of wood-based industries

I. In the North Eastern States of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura and Sikkim, wood-based industries shall be established within the industrial estates notified by the state governments for such industries.

ii. In the states and UTs (other than North Eastern States), in respect of distance from the boundary of nearest notified forests or protected areas, wood based industries shall be allowed to operate as per state-specific order/approval of the Hon'ble Supreme Court/ Hon'ble High Court/ Central Empowered Committee.

OR

Beyond an aerial distance from the boundary of the nearest notified forest or Protected Area, excluding road/rail/canal-side or institutional plantations, notified by the respective state government.

PROVIDED THAT, a wood-based industry may be established in an Industrial Estate or a Municipal area, irrespective of the aerial distance from the boundary of nearest notified forest or Protected Area.

7. Grant of a license to a wood-based industry:

I. No license to a new wood-based industry shall be granted without obtaining prior approval of SLC. However, power of renewal or transfer, including upon sale, succession, change of partnership of the proprietor or like circumstances, of license to a wood-based industry may be delegated by the SLC to the concerned Divisional Forest Officer.

PROVIDED THAT, the SLC of the concerned state may allow installation of additional saws or any specialized equipment in any licensed wood-based industry for conversion of wooden logs into other forms subject to availability of legally procured wood by that industry.

ii. Following Industries/processing units shall not require license prescribed in clause (I) above:

(a) Veneers, plywood, Medium Density Fibre (MDF) Boards, Particle Boards, pulp and paper and such other industries which use farm wood or imported wood as raw material and procured from legitimate sources, or (b) Which use sawn timber, plywood, veneers, Block board, MDF or similar wood-based products, procured from legitimate sources.

iii. Such wood-based industries as enumerated in clause (ii) above shall be registered (online) with the State/ UT Forest Department; these industries shall be required to submit self-attested returns of wood procured and used by them at such intervals and in such online electronic format that the State/ UT Forest Department will prescribe.

8. Appeal against the decision of the State Level Committee:

Any wood-based industry against which a decision is taken by the State Level Committee may file a representation before the concerned Regional Empowered Committee (REC) of the Ministry of Environment, Forest & Climate Change within a period of thirty (30) days. The decision of the REC shall be conveyed to the aggrieved within three (3) months of filing the representation. Revision against such decision shall lie before the designated Additional Director General, Ministry of Environment, Forests & Climate Change within a period of thirty (30) days, and the same shall be disposed of within a period of three (3) months. The decision in the Revision shall be final.

9. Power of State Government to frame rules or resolutions:

The respective State Government and UT Administration are empowered to frame rules or resolutions to give effect to the provisions of these guidelines.

10. All wood based industries will follow all environmental and other regulations prescribed by the State pollution Control Boards, Central pollution Control Board and Ministry of Environment, Forest and Climate Change as applicable to these industries under the Environment (protection) Act, 1986 and other central and state acts.

Comparison of Wood Based Industries (WBI) Guidelines of 2016 and proposed WBI guidelines

Existing WBI Guidelines of 2016	Proposed Guidelines
The feature of the guidelines	
Only Regulation	Regulation and Facilitation
Definitions added / enlarged	
Added Added Definitions in guidelines 2022: Municipal area, Wood council, Tree outside Forests, Farm wood, Imported wood, Charcoal, Tree growers, Trader or agent, Inter-state trade, Intra-state trade, Electronic trading and transaction platform, Trade area, Sponsor, Farming agreement, Local bodies	
• Industrial Estate means areas notified by the state government or Union Territory Administration of establishment of wood based industries • No specific definition of Municipal area	• Definition enlarged: It shall also include all industrial townships, district industrial areas and such other areas established for the aforesaid purpose. • Municipal area' means any area notified by the state government or UT. It also includes **district, tehsil, Circle or Block headquarters** notified by state governments or UTs, and **cantonment boards.**
Forum for wood based industries and other related stakeholders	
• No forum for wood based industries and other related stakeholders	• Wood advisory council at national level, State and District/ regional level wood councils proposed
Separate of farm-grown wood from that of forests	
• All wood whether from forests or agricultural fieldsunder one category	• Farm wood made a separate category for Trees outside Forests (ToF)
Grant of license to WBI	
• WBI using raw materials from ToF • Compulsory assessment of wood availability for such industries	• Industries based on raw materials only from ToF or imported wood to be free from the liability of licensing and these inLicensing for WBI is compulsory even for dustries will require only online registration • Assessment of wood availability for such industries is not required provided they demonstrate electronically about wood procurement from legal sources
State Level committee (Powers & functions)	
• No Explicit provision regarding **Licensing** regulation for industries using only Farm Wood **(Plywood/MDF/Particle Board)**	• No requirement of licensing for veneers, plywood, Medium Density Fibre (MDF) Boards, Particl Boards, pulp and paper, and such other industries that primarily use 'farm wood' or 'imported wood' as raw material. • Such wood-based industries shall be registeredwith th State/ UT Forest Department; and shall be required to submit self-attested returns of wood procured and used by them at such intervals in such online electronic format that the State/ UT Fores Department will prescribe. • In the states and UTs (other than North Eastern States), in respect of distance from the boundary of nearest notified forests or protected areas, wood-based industries shall be allowed to operate as per state-specific order/approval of the Hon'ble Supreme Court/ Hon'ble High Court/ Central Empowered Committee.

State Level committee (Composition)	
• Ambiguity in composition with respect to PCCF (HoFF) being the Chairman • Representation of Regional office of MoEFCC in the committee. • Representation of the industry restricted to one • No representation from Agriculture sector	• Any officer of the rank of PCCF may be notified as Chairman • Broadening the scope of representation of MoEF&CC: Any nominee from MoEF&CC • Broadened to at least two representatives from WBI • Director of Dept. of Agriculture is a member
State Level committee (Appeal)	
• **Aggrieved by any decision taken by the State Level** Committee may file an appeal before the concerned Regional office of the Central Government in the MoEFCC seeking appropriate relief within 60 days' time. • Conflict of interests and subordination of SLC • No review provision	• Appeal before the concerned Regional Empowered Committee (REC) of the MoEFCC within a period of thirty (30) days. • The decision of the REC shall be conveyed to the aggrieved within three (3) months of the filing Revision against such decision shall lie before the Additional Director General (Forest Conservation), MoEFCC.

Common Facility Centre at IWST

Common Facility Centre (CFC) has been established inside IWST campus during the year 2016. The CFC houses many modern wood working and bamboo processing machines. CFC extends wood and bamboo processing facilities to various stake holders, self-help groups, NGOs, wood based small scale/cottage industries and local artisans. All the machines can be used on payment basis during all working days (Monday to Friday) from 9:00 AM to 5:30 PM. The details of available wood working and bamboo machines and their description are given below.

A. List of Wood and Bamboo Working Machines

No.	Name of Machinery	Description
1	Surface Planer	Suitable for removing rough surface of the wood by planing.
2	Thickness Planer	Suitable for sizing the piece of wood in two dimensions
3	Sliding Table Panel Saw	Suitable to cut a wood lumber/panel board to the required sizes in different cutting like rip cut, & scoring for pre lamboard.
4	Small Table Circular Saw	Suitable for rip cutting, cross cutting, and chamfering of wood.
5	Multi Spindle boring	Suitable for multi boring on wood/panel boards like vertical, horizontal and angular bores.
6	Spindle Molder	Suitable for edge profiling and contouring.
7	Belt Sander	Suitable for sanding the surface
8	Finger Jointing Machine	Suitable for joining small solid wood pieces
9	Seasoning Kiln	Suitable for seasoning the wood(Capacity: 200 cft)
10	Bamboo Cross Cutting	Suitable for cross cutting of Bamboo culms.
11	Bamboo Semi Half Splitting	Suitable for splitting the bamboo culms to rectangular strips.
12	Bamboo Variable Size splitting	Suitable for splitting the bamboo culms to number of strips.
13	Bamboo External Knot Removing	Suitable for removing external knots of bamboo culms.
14	Bamboo Thickness Planning	Suitable for thickness planning of bamboo strips to variable size.
15	Bamboo Slat Gluing	Suitable for gluing the bamboo strips for making panel of different sizes.
16	Bamboo Panel Drier	Suitable for drying glues bamboo panels.

To use the facility and for further details, please contact:
Officer incharge of Common Facility Centre, **Institute of Wood Science and Technology**
18th Cross, Malleshwaram, Bangalore Ph:080 22190178, E Mail: cfc_iwst@icfre.org

One year Diploma in Advanced Woodworking

Course Description:

The Diploma Course was launched in the year 2018-19 jointly with M/s. Biesse Manufacturing Company Private Limited. This program offers an excellent opportunity for trainees to acquire required skill set to work on wood and wood products. This course structured to provide first hand experience in handling state of the art machineries to make them employable in wood based industries. This course has eight major modules namely, Fundamentals of wood materials, Fundamentals of Engineering, Wood processing using advanced machines & allied processes, Loading & unloading systems, machinery safety, maintenance of machines, Assembly & Joinery, Advanced application of software (CNC, CAD/CAM & 3D-Pytha) and project work. Upon successful completion of training, the trainees will be able to handle most of the advanced woodworking machines that are used in the wood based industries.

Eligibility	:	Pass in Pre-University Course/Senior Secondary/ XII/ Equivalent from recognized Board. (Graduates in Science / Forestry / Engineering are encouraged to apply).
Course Fee	:	Rs. 50,000/- for the entire course
Extra	:	Rs.1,650/- per month towards Accommodation Charges Food Charges (as per actual)
Security Deposit	:	Rs. 5,000/- (Refundable)
Intake	:	Maximum 30 Candidates

INSTITUTE OF WOOD SCIENCE AND TECHNOLOGY
(Indian Council of Forestry Research and Education)
An Autonomous Body of Ministry of Environment, Forest and Climate Change, Govt. of India
P.O. Malleswaram, Bengaluru – 560 003, India Website: http://iwst.icfre.gov.in/awwtc/awwtc.htm
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Agroforestry for Green Economic Transition and Mission Life

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CONTEXT

Conventional production systems and unconscious consumerism contribute to half of the crisis of climate change and environmental degradation, which directly or indirectly impact the health of lives and landscapes. The current trajectory of unsustainable agricultural production requires a paradigm shift towards an agroecological transition with tree-based systems that combine production, consumption, conservation, and restoration with significant co-benefits to people, culture, and nature. The majority of the world's agriculture, on the other hand, is suffering from severe tree shortages, with a few trees remaining in the highly intensive mainstream farming. This results in a significant loss of life support system: green cover, diversity, soil organic matter and overall soil health, ecosystem services and overall source of resilience. Treeless or tree deficit landscapes cannot regulate temperature, soil biota, nutrients and water cycle. Agroforestry and tree-based production systems are the solutions to the climate crisis when they integrate crops-trees-livestock in the right combination with proper conservation practices. However, it requires systematic, well-organized collective actions with a well-developed pay-back mechanism for a gradual transition to scaling without penalties. The approach focusses on the principle of landscape ecology and the production follows functions that enrich soil organic matter, restore soil health, fix the broken food system and simultaneously establish a practical incentive mechanism for payment for ecosystem services through carbon sequestration and biodiversity conservation. It articulates the urgent need for boosting nature-based solutions with feedback loops and incentive mechanisms that are undeniably profitable to smallholder farmers, with a return of 8–13 times more profits than conventional agriculture. The leveraging of technological innovations will certainly provide necessary aid for scaling with the right incentives for the restoration of ecosystem services and result-based management for the impactful transformation of livelihoods and landscapes.

Green Economic Transition

The dynamics of agricultural production and associated economic returns are driven by various factors, especially environmental elements such as drastic fluctuations in temperature, erratic precipitation trends, and water supply is often the most limiting factor in making agriculture profitable and sustainable. They are characterized by persistent water scarcity, extreme climatic variability, high susceptibility to land degradation, desertification, and loss of natural resources, including biodiversity, at elevated rates.

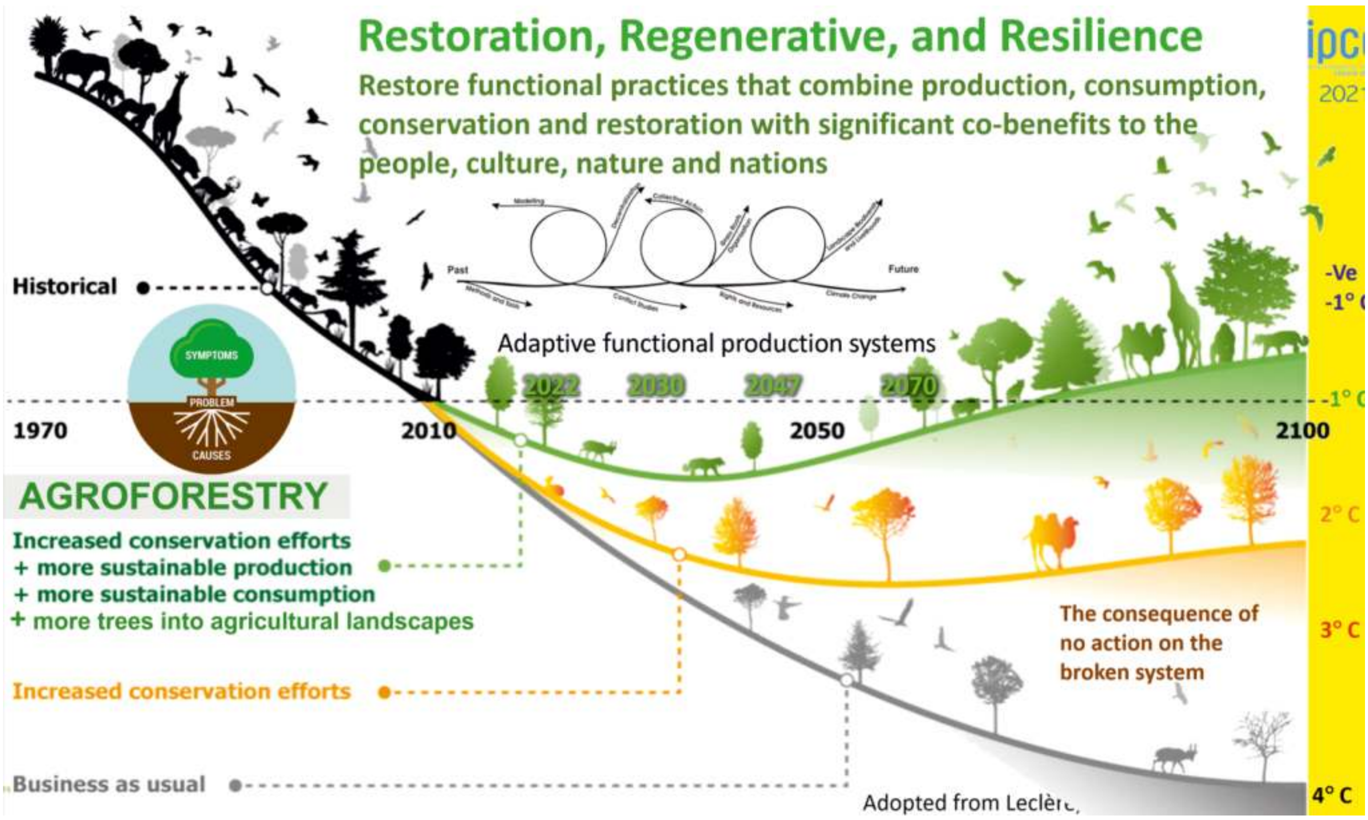
An example of a gradual transition from degraded landscapes to diversified multifunctional agroforestry systems. Aerial and inlet photos: C. Biradar

However, we often fail to understand and hardly emphasize underlying factors and drivers responsible for building the resilience of agroecosystems where the trees in production landscapes and soil organic matter are the primary shock observers to withstand the changes. Refining conventional yield-centric production into climate-resilient agroforestry requires systematic combinations of crops, trees, animal species, and conservation practices in specific agroecological zones. Pursuing sustainable livelihood goals with a green economic transition should be based on several factors, including the right combination of trees-crops-animals, climate, soils, markets, capital, trade, and traditional knowledge. To improve landscapes and livelihoods, an integrated approach with an ecologically sound functional production system is required. As a result, international and national initiatives emphasise a gradual transition to diversified tree-based agroecology to achieve at least 30% of the target through strategic investment, innovative research, outreach, and enabling policies and the environment to achieve sustainable development goals.

The core value of an innovation for a green economic transition lies in the synergies of site-option-context-specific adoption of the species, models, technologies, and package of practices through the collective action of significant interaction between researchers, policymakers and farming system stakeholders where the farmers are stewards of the reforms. While it also needs to emphasise reducing the risks and vulnerabilities of smallholders by investing in mechanisms for incentives for payment for ecosystem services such as carbon sequestration and biodiversity. The context-specific interventions of agroforestry and tree-based agroecology present emerging trends that allow researchers and decision-makers to diagnose vulnerabilities by considering the dynamics of land use, land tenure, patterns, supply chains, demographics and climate change.

Trees For The Transformation

Most urban areas and cities have lost or keep losing their tree cover and green space in the name of development. The consequences of no green cover are numerous, including lack of direct contact between citizens and nature, loss of biodiversity, ecosystem system services, people's health, urban heat island effect, increased energy costs, exponential increase in pollution load of all kinds at high levels, and the list goes on. Urban population experience varied climate change impacts and extreme weather events such as heat waves



Agroforestry and tree-based production systems for system-level transformation from green to economic transition for supporting mission LiFE.

in summer, cold waves in winter, and flash floods in the rainy season and associated costs for cooling, heating and disaster management are often never linked to loss of green cover. However, we all know that trees and green cover have solutions to the consequences of the unprecedented growth of concrete jungles without room for nature.

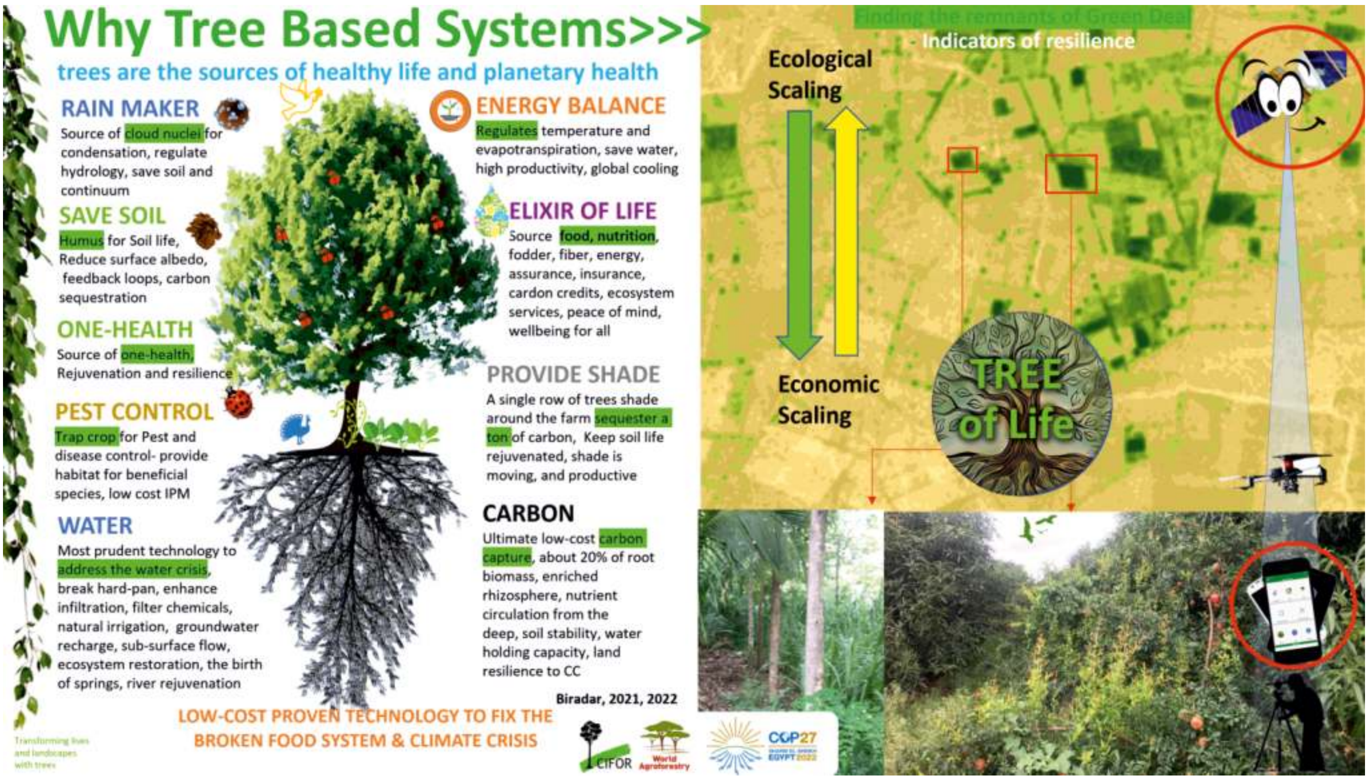
Role of the tree-based system in addressing climate change

Trees are vital in creating a sustainably livable ecosystem in urban areas. A mere 4% of green cover reduces the temperature by 1 C. Due to the interconnectedness of trees, 8% green cover can reduce not 2 C but 3 C degrees, creating a microclimatic impact on interconnected life support systems. Trees, urban agroforestry, and rooftop gardens, in particular, are simple solutions to many urban problems. They provide shade, shelter, food, and act as city lungs by filtering air; what we breathe, they breathe, and vice versa, and trees are the most effective shock absorbers for all types of pollution (air, water, noise, and smoke). There are many options to increase green cover in urban areas, such as planting trees and food gardens in public parks, schools, roadsides, road dividers, rooftop gardens, community gardens, empty sites, abandoned places, even converting garbage dumpsites into beautiful gardens. In Cairo, there is a lovely green park called Al-Azar Park in the city, which was a garbage dumpsite converted into beautiful gardens.

Agroforestry for mission life

Lifestyle for environment (Mission LiFE) movement was launched by the honourable Prime Minister of India, Shri Narendra Modi in order to protect the environment for all. It is an India-led global mass movement that will nudge individual and collective actions toward the protection and preservation of the environment, making environmental protection and conservation a participatory process.

Agroforestry plays a vital role in supporting the mission of LiFE by providing environmentally friendly inputs to lifestyle changes that contribute to climate-resilient landscapes. Also, as part of building a circular economy and multiple returns on investments. It also helps transition to renewable energy through bio-ethanol and biofuel generation and thus contributing to meeting the country's NDC targets. Among the key focus areas of the new agroforestry scheme will be sustaining and promoting LIFE. Agroforestry and trees



Agroforestry and tree-based production systems for system-level transformation from green to economic transition for supporting mission LiFE.

outside the forests (TOF) are the solutions for addressing the food, health and climate crises. The system-level transformation, achieving mission LiFE and UN SDGs may not be possible without bringing lost trees into mainstream agriculture and manmade landscapes. It is very clear that the next decade is the 'Decade of agroforestry'.

Mission LiFE begins at home, by planting more trees around our homes, living spaces, school parks and building patches of private forests. As often as not, some rich people buy expensive cars, branded watches, and gold, stocks as investment opportunities. Why not invest a certain portion of their income and dead assets into creating a patch of their private forest for weekend relaxation, build their retirement resort in their own patch of private forest, simultaneously serve mother nature and people by creating lung spaces in the cities to provide fresh air and habitat and contributes to NDC and mission LiFE.

An approach aimed at integrating an array of species diversity in reviving lost agrobiodiversity, integrated cultivation practices, and diverse dietary habits as building blocks of sustainable, resilient, and resource-efficient food systems. It puts forth the need for a crucial paradigm shift from mono-cropping to integrated resource-efficient agri-food systems and from more calories per acre to more nutrients (health) per acre. It is only possible to build resilience and incorporate sustainability by restoring healthy food systems and rebuilding the living soil via atree based diversified agroecology.

The mission LiFE begins at home by adapting eco-friendly lifestyle of growing more trees, gardens and food forests around our living space.

References: Contact author at c.biradar@cgiar.org

Framework for Wood Production through Agroforestry in India

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The agroforestry systems with technological interventions are contributing significantly to the land use and farm income diversification, natural resource management, and meeting the demands of fuel, fodder, and timber, thus helping the economic transformation of farmers. It is plays a greatest role in maintaining the resource base and increasing the overall productivity, particularly in rain-fed areas in arid and semi-arid regions. Agroforestry has an important role in reducing vulnerability, increasing the resilience of farming systems and buffering households against climate-related risks in addition to providing livelihood security. With the promotion of agroforestry in rural areas, smallholders have emerged as the major timber suppliers of the 21st century, meeting almost half of the total demand for fuelwood in the country. Besides, the increasing demand from household and wood-based industries and changing priorities in avenues like biofuels, bioenergy, value addition, employment generation, watershed protection, carbon sequestration and mitigating climate change effects, call for a new thrust on agroforestry development. The success of any programme or project mainly depends on the availability of independent guidelines, rules or policy matters, to provide supportive infrastructure for implementing that programme and achieving the defined targets.

Recent estimates have shown that more than one billion hectares of agricultural land have greater than 10% tree cover (Arunachalam et al. 2007). Of this, 160 million hectares have more than 50% tree cover. In the scenario of degrading trends in forest cover, agroforestry is the most potential way of increasing forest cover. Currently, the country fulfils about 70% of its timber needs through agroforestry which is valued at about Rs. 14,000 crores annually, and major raw materials are provided to about 26,500 wood-based industries. Agroforestry meets nearly half of the country's fuelwood needs, roughly two-thirds of its small timber needs, 70 to 80% of the wood for plywood, 60% of the raw material for paper pulp, and 9 to 11% of its green fodder needs. The tree-based systems produce lac, gum, resins, and products of medicinal value for various industries. More recently, reliance on trees (agroforestry) for traditional tree-based needs like firewood has declined due to changes in the social and economic structure of society and trees attaining the status of cash crops for sale. Agricultural ecosystems can be further improved through agroforestry to ensure environmental and biodiversity restoration, greater and sustainable farm productivity, and realization of ecological services including climate change mitigation and adaptation for improved livelihoods. There are several studies from different parts of the country suggesting that the agroforestry is more profitable to farmers than agriculture or forestry for a particular area of land. Poplar-based agroforestry has been very successful in the northern states of India. Similarly, Eucalyptus-based and Casuarina-based systems have been adopted on a large scale by the farmers in the southern tropical region. The success of these systems is due to the credit support provided by banking institutions and the buyback support provided by the industry. Hence, there is tremendous scope for promoting viable agroforestry models for different agroecological regions of the country through a quadripartite arrangement among industries, banks, research institutes, and farmers. Research institutes have developed several agroforestry models, but these are mostly restricted to research farms. These models need to be taken to the cultivator's field for the improvement of the farmer's livelihood. The ICAR-CAFRI developed successful agroforestry models for the country's various agro-climatic regions, and National Bank of Agriculture and Rural Development (NABARD) has included a few bankable models such as poplar, Eucalyptus, subabul, bamboo and Casuarina. The successful models developed by ICAR-Central Agroforestry Research Institute (CAFRI) and the All India Coordinated Research Project on Agroforestry (AICRP on agroforestry) have been compiled in the form of a technical bulletin, 'Agroforestry for income enhancement, climate resilience and ecosystem services' and it is reported that a 5-year-old Poplar-based system can have net returns up to Rs. 195,000 ha^{-1} per year.

The selection of a suitable agroforestry model is highly influenced by land holding patterns, soil productivity and marketability of the final product. Despite the countless benefits of agroforestry, the farmers are concerned about taking up the agroforestry models as they are unable to get a reasonable price for their final products because of the absence of a suitable market outlet in their locality. To overcome these hurdles and promote agroforestry, India became the first country in the world to have an exclusive National Agroforestry Policy adopted in 2014. The main objective of the policy is to promote trees outside forest (TOF) and enhance the raw material availability for wood-based industries. The policy has already been effective in bringing agroforestry into the Corporate Social Responsibility Act, establishing the National Sub-Mission on Agroforestry under the National Mission on Sustainable Agriculture to promote adoption and free farm-grown tree species from counterproductive felling and transit regulations in 25 states. The emergence of a more complete, equitable and self-sustaining value chain is unfolding with the relaxation of the timber industry. More entrepreneurship is needed, along with adequate handholding and appropriate government support, to strengthen the value chains and address issues on both the demand and supply sides. ICAR-CAFRI through its AICRP on agroforestry has identified promising agroforestry tree species and developed scalable agroforestry models suited to different agroecological regions of the country. Thus, prescribing suitable agroforestry tree species or systems need to be commensurate with the climate analogue maps.

As timber production in India is not distributed equally among the ecological regions, we need to augment wood production geographically. The geographic disparity also affects local demand and supply gaps, resulting in different market pricing. To have a comprehensive utilization of wood, we must consider the following factors:

1. Create inter-state clusters to facilitate easy transportation of timber and wood.
2. Institutionalize timber trade and transportation with adequate data banking and transparency.
3. Encourage timber-based industries to enter into buy-back agreements with farmers for timber trees due to their long gestation periods.
4. Need to have a gradual increase in import duty as a measure to discourage timber imports, thus aligning the industries to support local tree growers and in the process.
5. Extensive dissemination of information to popularize timber-based agroforestry models for adoption by the stakeholders through bankable projects.

In accordance with the National Agroforestry Policy, the country calls for the best agroforestry systems and trees at the district level for different degraded ecologies by exploiting potential multipurpose tree species as a base for provisioning goods as well as ecosystem services, thus ensuring both livelihood and environmental securities. Meanwhile, we need to emphatically identify the appropriate agroforestry trees or systems based on the market prospects, by enabling storage, certification and inter-state movement of the agroforestry product. These will ensure the overall quality and pricing. In this regard, CAFRI's experience with the Consortium of Industrial Agroforestry (CIAF) developed by the Tamil Nadu Agricultural University, Coimbatore through ICAR's National Agricultural Innovation Project has proven to be successful in bringing farmers, tree growers, industries, financial institutions, and research institutions together as a value-chain model in agroforestry. So far, assured buy-back or provision by the dependent wood industries has given popularity to upscaling agroforestry in a region. This mechanism has led to the development of production clusters at the village level.

To promote the well-being of society, the management of multifunctional agroforestry needs to be strengthened by innovations in the domestication of useful species and crafting market regimes for the products derived from agroforestry and ethno-forestry systems. Future research is needed to eliminate many of the remaining uncertainties and carefully test the main functions attributed to agroforestry against alternative land-use options to determine unequivocally how well agroforestry served these purposes. There is a need to bring indigenous multi-purpose tree species into the agroforestry system, as several underutilized and neglected tree species are slowly vanishing from their natural populations. These species are an important source of nutritionally rich fruits, and vegetables, and provide products of therapeutic and medicinal importance. These indigenous genetic resources of multi-purpose tree species require urgent attention for in situ on-farm conservation. Growing these species in farmers' fields and backyard gardens would serve the dual purpose of conserving genetic diversity and providing additional livelihood support to small and marginal farmers, while also meeting the country's timber and wood requirements and reducing pressure on forests in general.

References : Contact Author at arun.handa@icar.gov.in

Challenges and Issues in Agroforestry

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Agroforestry was an age-old practice in India. It has been officially promoted since the early 1980s. The produce from agroforestry was expected to supplement wood from the natural forests and government plantations. During the initial years, the focus was on the promotion of easy-to-grow species like Eucalyptus, Acacia, subabul, silver oak, poplar, etc. These are softwood species that grow faster, have shorter rotation periods, and most of them are good coppicers too. All these species yield good pulp. When bamboo flowered gregariously in the late eighties, the pulpwood industries quickly shifted to these species for raw materials. This transition was complete, and today no pulpwood industry is looking beyond these species. In the mid-nineties, the farming of teak gained popularity. Millions of teak trees were grown by farmers. During the first decade of this century, Melia dubia from seed origin and clonal plantations of the softwood species gained popularity. When the wood supplies from natural forests almost dried up around the year 2000, the plywood and particle board industries were looking for alternatives. As an alternative they found M. dubia, poplar and Eucalyptus. They hitched on to these species for about two decades now. As the demand grew, agroforestry, particularly the fast-growing species, expanded rapidly across the country. As of today, there is a considerable acreage of trees outside the forests as reflected in the biannual State of Forest Reports of the Forest Survey of India.

Since the late eighties, many governments across the country imposed restrictions on the felling of green trees in natural forests. Coupled with restrictions imposed by the Honourable Supreme Court on certain regions of the country and the insistence of the Government of India on approving working plans for timber extraction from the public forests, extractions from the government forests dwindled dramatically. But the population growth, economic development, urbanization, and the associated demand for wood and its products continued. For some time, the government of India promoted wood substitutes. But after realizing that the public choice was for wood, they permitted the import of wood on a large scale along with free movement across the country without transit permits. Today, hardly 5% of the timber comes from government forests and about 65% comes from agroforestry. About 50% of pulpwood and more than 80% of plywood come from farmlands. The rest comes from government-owned forest lands, particularly the plantations. This is a big shift compared to the 1980s.

The second and most significant development in the last two decades is the revolution in wood technology. An immense variety of machinery has been developed that helps produce durable engineered wood products from many different types of raw materials, including wood waste. There is a good value addition to these low-quality raw materials. Engineered wood matches natural wood in strength and appearance. It can meet almost every human need at a much lower cost. Working with it is also easier. Therefore, engineered wood has gained popularity. It substituted natural wood in a big way. It now meets more than 80% of the market demand for wood. Wood seasoning, treatment and finger jointing have emerged as landmarks, particularly in Acacia auriculiformis and rubber wood. These timbers are widely used in the furniture industry now. The strength and aesthetic appearance of finger-jointed wood products are much durable than natural wood. Finger jointing helps in producing solid wood of any size and shape. Therefore, big trees or logs are not required to get big cut sizes, but they can be manufactured. Blockboards and flush doors are manufactured from semi-hardwood timber after good treatment and seasoning. Plywood is manufactured almost entirely from softwood trees grown on farmlands. Particle boards and medium-density fibre boards are being manufactured from firewood, wood chips, sawdust, agricultural waste and so on. Pre-laminated particle boards and medium-density fibre boards are produced on a large scale by big industries. Thermal wood, bamboo lumber, chipboards, wood composites, etc. are on the horizon. These products will rule the future market.

As a consequence of the growth of agroforestry and the revolution in wood technologies, the pressure on the natural forest has come down substantially. Agroforestry is poised to meet nearly the entire market demand for wood. However, there are some constraints to this. The first is the archaic forest laws, which prescribe very complex procedures and processes for cutting trees on private lands and for the transportation of timber. There is an urgent need to simplify these laws. Otherwise, the middleman and corruption levels in the bureaucracy will hit the farmers hard. It is bound to discourage them from growing trees in a big way. The second constraint is the uneven distribution of wood-based industries. Some states have large quantities of farm-grown wood, but there are not enough wood-based industries to utilize the entire quantity, resulting in a price crash. Also, surplus wood from such states has to be transported to other states across long distances. The wood so transported will fetch the same price as that of the local wood. Since the transportation costs are high, the farmers have to ultimately sell the produce at very nominal and uneconomical prices. On the other hand, some states have so many wood-based industries that the agroforestry trees have to be harvested prematurely and supplied. Farmers do not get the best price for juvenile wood. Thus, the uneven distribution of wood-based industries has become a big barrier to transcend. To correct this imbalance, the industrial licensing regime, which at present is more complex than the tree-cutting and transportation laws, has to be liberalized substantially. In states where there are fewer industries, incentives have to be offered to establish more wood-based industries.

Wood Tech Parks are most welcome. This has to be promoted by the government. Until and unless there are enough industries to consume the entire supply of farm-grown timber, the farmers will continue to suffer. Contrarily, where the industrial density is very high and there is a shortage of wood, the industry should proactively support the agroforestry farmers by supplying high-quality planting materials, providing technical advice, arranging bank loans and entering into buyback arrangements. They should set up wood consortiums with the help of leading research and academic institutions, banks, etc. The pulpwood industry has successfully done this. The plywood and blockboard industries should follow suit. Ideally, large wood-based industries should ensure that the wood required for them is available within their hinterland. If they do not do this, some industries will be forced to shut down. The resulting capital loss will be a national loss. Overall, it is necessary to establish a balance between the demand and supply of wood at the local level for a long time to come. Unfortunately, there is no thought process about this at any level. No one is thinking of establishing sufficient growing stock and harvesting on a sustainable basis. This has to kick in sooner or later, earlier is better.

To give it a boost, agroforestry should be treated on par with agriculture or horticulture crops because the revenue to the farmer is equally good or sometimes better. Otherwise, it will not get the attention of farmers. There are incentives galore in the agriculture and horticulture sectors. Farmers get subsidies for almost anything and everything, such as rainwater harvesting, purchase of seeds, fertilizers, irrigation equipment, harvesting machinery, MSP (Minimum Support Price), cold storage, commodity boards, food parks and many others. Bank loans and insurance facilities are also available. For selling the produce APMC yards are available. If the crops fail due to drought or floods, then there is crop insurance. There are carbon sequestration benefits for growing seasonal crops like groundnut. Other sectors, like energy, seek to get climate funding to reduce their future emissions. This sector should get this before anyone else because in reality, they are the ones who do carbon sequestration! But the others are not bothered to recognize the role played and the importance of agroforestry in carbon sequestration. If offered, this will be a big boost. None of the above subsidies are available for agroforestry farmers. The only subsidy they get is for buying seedlings of unknown quality from the forest nurseries. Some states give incentives for planting and maintenance during the first three years. But fund shortages are common issue, and not all people get incentives. Paradoxically, if we include the time, efforts and shadow costs, farmers often end up spending more money than they get in the form of subsidies for agroforestry. In spite of this the farmers still go for it because they see a few indirect beneficial impacts from the trees standing on their farmlands and also expect an elusive bounty at the time of harvesting. They are ready to take the risks. Cultivation of red sanders, sandalwood, high-value medicinal plants, etc. are classical examples of their risk-taking behaviour. Government should recognize the efforts and aspirations of these people. There is a strong and urgent need to extend the financial incentives and facilities to agroforestry on par with the agriculture and horticulture sectors. It will then flourish and supply most of the materials that the country needs. That will save our natural forests and make them safe. Otherwise, we may see accelerated erosion in the stock of natural forests and their biodiversity. This will affect our ecosystem services, including drinking water supplies and therefore should not be allowed at any cost.

The extensive and unrestricted import of timber that has been taking place in the nation since the 1990s is another problem that severely affects agroforestry. The nation as a whole spends up to ₹ 50,000 crores on imports each year (rupees fifty thousand crores). It is simple for large wood consumers to purchase imported wood from seaports and maintain an adequate supply for the entire year. They find it appealing for a variety of reasons.

1. Wood availability is guaranteed. Prices are also reasonable because of bulk buying. Industries need not look around for retail purchases from farmers and opportunistic middlemen.Dependency on them gets eliminated. Industries can buy the raw materials as they wish.
2. The hassle of securing transport permits is not there for the imported wood. Any quantity can be transported based on the invoice. They do not have to report the quantities purchased, the out-turn obtained after sawing, inventory held in stock, etc. to the local forest authorities which is a big relief from the harassment of the uniformed forest force.
3. Imported wood gets naturally seasoned because of the lead time available from harvesting until utilization. Seasoned cut sizes look very good and attractive. Relative to this, the farm timber is fresh and therefore subject to warping, bending, etc. Neither the colour nor the strength is appealing. Imported timber is certainly more attractive to buyers.
4. Millers take the names of timbers that local people have never heard of or have any knowledge of and assure them of a good finish and durability, leaving the consumers confused. Millers also keep selling cut sizes of non-available timbers like Burma teak. Burma teak was exhausted a long time ago. It is no longer available for import. But millers keep selling and God knows whether it is indeed Burma teak and, if so, from where they are getting it. Overall, they can make good cash from imported timber but face no hassles.

Due to these multiple advantages, millers who use imported timber are hardly inclined to buy local farm timber which is not good for the country. Imports should stop when we have enough materials available domestically. Some timber exporting countries are running out of their stock. Others are unwilling to export round wood. They are slowly shifting to the export of scantling, planks, cut sizes and so on because they want to ensure that their local employment remains unhurt. They also want to capture a part of the value chain. Some countries do not want to export raw wood in any form. They want to export finished products only. That ensures better returns and the expansion of employment back home. More and more countries are likely to take this route in the future. If our dependency continues on imports, we as a nation will have to pay even higher price for importing such products. It is time for us to wake up and make a decisive shift away from importing wood in any form. We have sufficient raw wood to meet our domestic requirements, and we can even start exporting soon. Apart from pinching our foreign exchange reserve, wood imports add to the carbon footprint. Thus, we should shift. The earlier it is, the better. Since the inducement is heavy, the shift away from imports has to be enforced using all available means. For this, the central government should impose additional import tariffs and also create a few non-tariff barriers. Discussion on this is beyond the scope of this paper, but a call has to be made by the central government as soon as possible.

Given the high disequilibrium surrounding agroforestry, a group of retired forest officers has taken up marketing agroforestry timber through their company named Treelands Products and Services Pvt. Ltd., operates in Bengaluru. The softwood timber which is required by industries in green conditions, is harvested and supplied to industries at pre-agreed prices. In the last two years, despite Covid-19, the company has procured about 2500 metric tons of round timber from the farmers and supplied it to the industry. The company pays 30–40% higher prices to the farmers compared to the local prices. It intends to act as the main connecting link between agroforestry farmers and industries. For this purpose, ground staff are being appointed at the taluk and district levels. A mobile application is being set up to discover the agroforestry farmers who have saleable trees. Private timber depots are being set up along the lines of APMC. An e-auction platform is under construction for selling the standing trees and the round wood in the timber depots. The company will refund the revenue obtained through competitive bidding after recovering its administrative costs and a small profit. Further, the company will certify the ownership and the place of origin of the wood. The data will be made available on the cloud. The industries interested in exporting finished wood products can employ blockchain technology and certify the wood products being exported. Advanced countries insist on certified and sustainable sources of timber supply for the import of wood products. The company is getting ready to create the necessary facilities and database for this purpose. In due course, it would also be undertaking the marketing of other forest products like medicinal plants, sandalwood, bamboo, etc. The company wishes to collaborate with interested parties and extend its services to other states too. Apart from this, the company is working closely with the local Forest Department and the state government to bring in certain policy reforms. As a consequence, the government has agreed to liberalize the tree felling regulations as well as the licensing system for some of the wood-based industries. The work is in progress. Substantial relief will be available if these commodity come through.

Marketing is the weakest link in forestry. Everyone including the Forest Department is happy to be farmers and cultivators of trees. But none wants to do the marketing of farm timber. Treelands company wants to be a pioneer in marketing because efficient marketing and remunerative prices will help in the sustained growth of agroforestry. The wood-based industry will expand. Massive employment opportunities will be created on and off the farm. The tree cover outside the forests will expand rapidly and help us in reaching the national goal of bringing 33% of the geographical area under green cover. Agroforestry has more benefits than what meets the eye. The sector is ready to fly and the government should give it the wings.

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Tree Improvement for Wood Sufficiency: Role of Agroforestry

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1. Introduciton

Wood and timber deficiency in the country is mainly due to two reasons (1) rapid increase in the need as a result of increased population, higher economic growth and (2) restricted harvests from natural forests and low productivity of plantations. Indian forests and plantations are among the slowest growing in the world (Shrivastava and Saxena, 2017). At the same time the current forest policy mandates the industries to meet their wood requirement from outside the forests. Expectedly the gap between demand and production has been mainly met through imports. India is among the leading importer of wood and wood products particularly round wood (ITTO 2017). One strategy to meet the rising need for wood is agroforestry/farm forestry. Many small, medium, and large-scale planters prefer agroforestry because it offers greater economic returns and requires less labour, meeting both food and wood goals. Adoption of tree improvement practices in tree species suitable for agroforestry is essential to promote the use of genetically improved planting stock and yield enhancement.

2. Tree Improvement Research

Tree improvement research is long-term, cost-intensive and demands continuous involvement of personnel with the required expertise. Although India started tree improvement programmes almost along with the developed countries, they did not impact the productivity significantly since the one or all of the above mentioned requirements were not met. To match these aspects, careful selection of tree species for improvement is important as the extent of investment depends on their contribution to people's livelihood and industrial need. India has the largest plantations of eucalypts, teak and casuarina in the world as their wood is in great demand for paper, plywood, construction and furniture industries. Naturally these species are given the top priority and higher allocation of resources made available for their genetic & silvicultural improvement. Long-term breeding programmes are being implemented for these species for nearly three decades in collaboration with national and international organizations. Written tree improvement programmes are available for these species which are systematically implemented and periodically reviewed. The second group of species includes those emerging as promising to supplement or in some situations substitute the species mentioned above. Acacia, Gmelina and Melia have the potential to meet all three principal industrial uses, paper, plywood and solid timber and relatively fast growing with wide adaptability. The third group has species like Bamboo, Red Sanders, Terminalia, Cadamba and Calophyllum which meet various livelihood, medicinal, crafts and low-cost construction. Table 1 provides the details of different species, their principal uses and the status of their tree improvement in IFGTB.

Acacia, Gmelina and Melia have the potential to meet all three principal industrial uses, paper, plywood and solid timber and relatively fast growing with wide adaptability.

3. Output from Tree Improvement Programmes

The immediate outcome of implementing tree improvement programmes for different species is assembling a broad genetic base for each of them which serves and the base material for both breeding and conservation purposes. In the case of exotics like casuarina and eucalyptus, germplasm representing all natural and cultivated populations are involved in the ongoing breeding programmes. With regard to the indigenous species populations and sub-populations adapted to specific edaphic and climatic conditions have been represented in the germplasm banks. Utilizing this 'genetic raw material' various kinds of research assets like seed orchards (clonal- and seedling-based; one to three generations), progeny tests, clonal tests, hybridization gardens, mapping populations and

Table 1. Species under tree improvement in IFGTB and the current status of research.

Utility/ Industry	Species	Rotation (years)	Tree improvement status
Pulpwood and plywood	Casuarina, Eucalyptus	3-7A	dvanced. Hybrid clones and seeds
Timber	Teak	15-25 (farmland)	Shortlisted clones
Plywood and secondary timber	Acacia, Gmelina, Melia, Thespesia	5-10	Shortlisted clones/ Seed from orchards
Pencil, matchwood, craft & construction	Ailanthus, Cadamba, Bamboo	5-10	Shortlisted clones
Fruit bearing – edible and oil	Calophyllum, Tamarind Pongamia	5-10	Released / shortlisted clones
Medicinal	Terminalia, Red Sanders, Sandal, Neem, Haldina	10-20	Initiated

provenance resource stands have been established. These dynamic research plots are capable of providing planting material suited for different end uses and planting environment. Genetically improved seeds collected from seed orchards of many species have been supplied to tree growers since 2004 and have generally increased the plantation productivity. Specific varieties as clones possessing desirable forestry characters and adaptability have been released through an elaborate testing, evaluation and approval system of ICFRE. Since 2010, 38 clones of different species have been released for large scale cultivation, the details of which are provided in Table 2. Some of these clones particularly that of pulpwood species have been widely cultivated in agroforestry and farm forestry plantations throughout the country. The significant research activities taken up and the output from them with regard to the major tree species are briefly discussed below.

Table 2. Details of clones released by IFGTB during 2010-21.

S. No.	Species	No. of clones released	Year of release	Characteristic features
1	*Casuarina equisetifolia*	4 3	2010 2014	Fast growth. Straight stems Adaptability to sodic soils
2	*Casuarina junghuhniana*	2	2014	Fast growth, straight stem, drought tolerance
		5	2014	Suitability to windbreak groforestry
3	Casuarina hybrid	5	2017	Fast growth, straight stem,
	©. equisetifolia x C. junghuhniana)			drought tolerance
4	Eucalyptus camaldulensis	4 7	2010 2014	Fast growth Fast growth, tolerance to gall infestation
5	Calophyllum inophyllum	6	2021	High fruit yield; high oil content
6	Eucalyptus hybrid (E. camaldulensis x E. tereticornis)	2	2021	Fast growth
	Total (2010-21)	38		

3.1 Teak

Teak is a premier timber species that is widely cultivated in India, with plantations covering over 2.5 million hectares. It was traditionally grown for solid wood with rotation periods spanning up to 120 years. Teak genetic improvement initiatives and clonal forestry approaches, on the other hand, help to reduce plantation age to about 20 years in order to generate rapid returns. The genetic improvement activities of teak in India were initiated in 1960s and included research on provenance variation, identification of plus trees and development of clonal seed orchards and seed production areas. However, availability of genetically improved seeds of teak is still limited due to various biological and ecological constraints in sexual reproduction. As a result, the extent of plantations raised with seeds from orchards has been miniscule and seed production areas predominantly met the need for improved seed in teak.

Plantation productivity of teak can be maximised with the use of clones and suitable silvicultural practices. Clonal propagation has the potential to achieve higher genetic gain and uniformity which is not possible through seed route. Significant increases in productivity have been documented from tissue culture raised clonal plantations in various non-native teak regions such as Latin America and Malaysia. Clonal forestry is relatively uncommon in India. Teak clonal ramets can be produced successfully through rooting of stem cuttings and tissue culture from the coppice shoots. Unlike shoots obtained from selected mature trees, coppice shoots are typically juvenile and can be used for production of quality planting stock. IFGTB has selected about 40 outstanding teak trees from approximately 50 years old plantations in different parts of Kerala with a selection intensity of 0.3 to 0.5 per cent, of which 50% of trees showed substantially superior height of 30–35m and girth at breast-height (GBH) of 151–220 cm indicating the superiority of the selected trees and the possibility of increasing the productivity through clonal plantation (Palanisamy et al. 2009).

In vitro cultures were established from the apical buds of coppice shoots from selected trees and micro shoots multiplied using the standard protocol. Well grown shoots were rooted ex vitro cost-effectively in hycotrays of 300cc capacity to facilitate better root system development. Presently plants are supplied to farmers for block and bund plantations. Initial results are very encouraging as the plants exhibit fast growth in well-maintained farm fields (Table 3; Figure 1). Farmers provide the necessary fertigation and drip irrigation based on the management regimes provided by the Institute. The current growth of these plantations has a harvest potential in 15-20 years.

3.2 Eucalyptus

Eucalyptus is the most widely used pulpwood and plywood species grown by farmers and forest corporations throughout the country. It is suitable for cultivation in dry areas under rain fed environment. Eucalypt plantations are primarily raised using clones, and most paper industries mass produce superior clones and supply them to farmers at a discounted price. Private nurseries are also in the market for clone production. Though seedling planting is still widespread, the genetic quality of the seedlings is unknown and frequently proves to be poor.

IFGTB has been implementing the eucalypt improvement program since 1990s and genetically improved seeds have been produced from seed orchards since 2002 for supplying to farmers and other planting agencies. The forest corporations plant clones and seedlings at a ratio of 75:25 to maintain the diversity in their plantations. The paper industries also develop clones for cultivation. On an average, the eucalypt clonal and seedling raised plantations produce about 60 and 25 tons per ha respectively in a rotation of six years in the estates of Tamil Nadu Forest Development Corporation (TAFCORN).

Table 3. Average growth of two-year-old tissue culture teak plantation from three locations.

Clone Number	Average height (m)	Average girth (cm)
IFGTB-TG-1	6.25	20.16
IFGTB-TG-2	6.15	23.52
IFGTB-TG-3	5.95	24.25
IFGTB-TG-4	6.85	28.34
IFGTB-TG-5	6.83	28.36

Under the eucalypt improvement program, first generation provenance trials were established in different locations and about 100 clones were selected. The clones were selected based on the superiority for height, diameter at breast height and straightness of stem through index selection method. The clonal trials were established in three contrasting locations and 33 clones were found promising across all the three locations and they were compared with other clones and seed sources for calculation of clonal superiority. About 10 commercial clones and seed origin plants of Eucalyptus camaldulensis were also included in the experiment as reference. The four top-ranking clones (EC1 to EC4; Table 4) which showed consistent better performance in all the three trials than the commercial clones were selected and released in 2010 for commercial cultivation.

During 2008 to 2011, the eucalypt species faced a serious threat from a gall wasp, Leptocybeinvasa. Many young plantations were totally wiped out due to this infestation and chemical control was ineffective. Hence efforts were made to develop clones which possess genetic tolerance to L. invasa. Fresh selections were carried out and about 30 clones were mass multiplied for performance evaluation for growth as well as gall tolerance and field trials established during 2009-10. The study resulted in the release of seven superior clones with three levels of gall tolerance in 2014 (EC5-EC11; Table 4). The first set of clones was IFGTB-EC-11, IFGTB-EC-5, IFGTB-EC-9 and IFGTB-EC-7 which are tolerant to gall infestation. The second set of clones was IFGTB-EC-8 and IFGTB-EC-10 which showed low susceptibility to gall infestation. The third set of clone IFGTB-EC-6 which showed moderate level of susceptibility to gall infestation. IFGTB took efforts to popularize these clones by way of establishing clonal demo plantations and supply planting stock to forest departments, forest corporations, paper mills and other private nurseries. Recently, a few of the best performing and multi-site adapted clones were licensed to paper industries. The recent release (2021) of Eucalyptus clones includes two interspecific hybrids (E. camaldulensis x E. tereticornis) possessing fast growth (Table 4).

3.3 Casuarina

Casuarina is a nitrogen-fixing and multipurpose tree grown in about half a million hectares mostly in south

Table 4. List of Eucalyptus clones of released by IFGTB and their characters.

Clone no.	Height (m)	DBH (cm)	Single tree volume (m^3)	Superiority (%) for volume above commercial clones	Traits improved
IFGTB-EC-1	15.17	13.53	0.120	33.3	Growth traits
IFGTB-EC-2	15.68	12.92	0.113	25.6	Growth traits
IFGTB-EC-3	13.48	11.68	0.097	7.8	Growth traits
IFGTB-EC-4	15.24	11.7	80.091	1.1	Growth traits
IFGTB-EC-5	10.7	8.21	0.037	95.9	Growth traits and gall tolerance
IFGTB-EC-6	9.23	7.64	0.033	73.0	Growth traits and gall tolerance
IFGTB-EC-7	8.77	6.54	0.024	26.1	Growth traits and gall toleranceI
FGTB-EC-8	8.89	6.61	0.024	25.5	Growth traits and gall tolerance
IFGTB-EC-9	9.28	6.61	0.023	23.6	Growth traits and gall toleranceI
FGTB-EC-10	8.83	6.60	0.023	20.1	Growth traits and gall tolerance
IFGTB-EC-11	8.66	6.58	0.022	17.8	Growth traits and gall toleranceI
FGTB-EH1	10.22	4.69	0.027	28.6	E. camaldulensis x E. tereticornis; Growth traits
IFGTB-EH2	9.28	23.7	30.02	39.5	E. camaldulensis x E. tereticornis; Growth traits

India. It is an important source of pulpwood raw material for papermaking with an annual consumption of around 1.65 million tonnes which is 15-20% of total pulpwood used by the paper industry. The other major market for casuarina is poles for construction, scaffolding and agricultural use. Since the pole market is unorganized, precise data on the amount of wood used is not available. But it is generally estimated that casuarina wood used for these purposes is twice that of pulpwood.

IFGTB has been implementinga systematic breeding programme for Casuarina equisetifolia (CE) in collaboration with Australian Tree Seed Centre for the long term genetic improvement of the species (Pinyopusarerk, 1996; Pinyopusarerk et al., 2019). The breeding objective was to maximize the growth and improve stem form so that more wood produced for papermaking and use as poles. The base population for establishing the breeding populations were drawn from a broad genetic base of around 40 natural provenances and land races collected in Asia, Africa and Australia. The breeding populations were converted into seedling seed orchards by thinning out inferior seed lots altogether and individual trees of other accessions. Outstanding female and male trees from the breeding orchards were selected, vegetatively propagated and deployed in multilocation clonal testing. After final evaluation, the inferior clones were removed for converting clonal trials into clonal seed orchards. Seeds from the two types of orchards (SSO and CSO) have been supplied for establishing plantations since 2004. Four clones selected for fast growth and straight stems were released during 2010. The breeding cycle was repeated with selections from the first generation breeding populations to establish second and third generation breeding populations and clonal tests during 2008-2021.

IFGTB systematically introduced a new species of casuarina viz. C. junghuhniana (CJ) in the year 1996. The seed lots of CJ were provided under the Species Improvement Network Programme (SPIN) of the UNDP/FAO Regional Project FORTIP with collaboration from the Australian Tree Seed Centre, CSIRO. Six provenances from Wetar and Timor islands showed the best survival and growth which marked the arrival of a new species for planting in India. CJ is not only faster growing than CE, it also possesses many desirable qualities like drought tolerance, disease resistance, prolific seed production, high germination and coppicing ability. All these traits helped CJ to become a widely planted species within a short period of ten years. Propagation of juvenile coppice shoots from outstanding trees resulted in the commercially successful release of clone CJ-9 in 2014. Casuarina clonal plantation area rapidly expanded due to the adaptability and impressive growth of CJ9 and wood production increased to 150 tonnes per hectare in a four-year rotation period (Table 5; Figure 2). The availability of two Casuarina species with the same chromosome number resulted in creation of interspecific hybrids between them. The hybridization programme started in 2004 resulted in the release of five interspecific hybrid clones (CH- series) in 2017. Faster growing than all the currently grown seedling and clonal accessions of the parent species, the CH clones are rapidly expanding in planting area. Currently it is an important component of farm forestry programmes undertaken by major paper industries in the Peninsular India. A summary of casuarina varieties and their productivity is provided in Table 5.

3.4 Leucaena

Leucaena is a multipurpose tree planted extensively for food, fodder, fuelwood and pulpwood. In India it is grown in around 100,000 ha and is the third major source of pulpwood next to Eucalyptus and Casuarina with an annual pulpwood production of over 1.7 million tonnes. Despite the high socio-economic importance of this nitrogen-fixing tree, it has undergone only a limited tree improvement. IFGTB initiated Leucaena improvement programme in 2014 with multilocation testing of 29 seed sources from India and Hawaii, USA. These seed lots were found to significantly differ in term of growth, stem form and fecundity (Durai et al. 2015) and in general the arboreal accessions (K636) from both India and Hawaii possessed better traits than others. The seed source trials were converted into seed production areas (SPA) by thinning all trees of inferior seed lots and poor individuals of others. Seeds collected from the SPAs were supplied to farmers and industries for raising plantations. Genetic gain trials showed that SPA seeds producing 15-20% more pulpwood compared to unimproved local seed source. Twenty five individuals with outstanding growth and stem form were clonally propagated and deployed in multilocation testing. Significant clonal variation was observed for growth and 10 clones that showed growth on par or better than the commercial clone were shortlisted for further testing. Low and inconsistent rooting of shoot cuttings is the major problem faced in Leucaena clonal development programme. Further research is in progress to improve rooting percentage for efficient utilization of Leucaena clones.

Table 5. Salient features of high-yielding varieties of casuarina developed by IFGTB.

Species	Variety	Salient features	Productivity (tonnes per acre per year)	Pulpwood production in 4 years (tonnes per acre)
Casuarina equisetifolia (CE)	Seed orchard seeds	Low tree to tree growth variation; faster growth than unimproved seeds; suitable for coastal areas; straight stems for use as poles.	12	48
Casuarina junghuhniana (CJ)	Seed orchard seeds	Low tree to tree growth variation; faster growth than CE seeds; highly drought-tolerant; suitable for inland and rain-fed areas.	14	56
	Clone Cj9	Faster growth than CJ seeds; straight stems for use as poles; highly drought-tolerant; suitable for inland and rain-fed areas.	16	64
Casuarina hybrids (CH)	Clone Ch1 Clone Ch2 Clone Ch5	Suitable for both coastal and inland areas (except clay soils and waterlogged sites); faster growth than all other varieties; straight stems for use as poles; drought-tolerant; can be grown under rain-fed conditions from the second year.	18	70

3.5 Gmelina

Gmelina arborea (Family Lamiaceae) is a fast-growing tree with many uses like timber, pulp, fodder, manure and medicinal value. Its timber is widely used for construction, furniture, handicrafts, plywood and particleboard manufacturing. Roots are used in ayurvedic medicine to treat many ailments. IFGTB has selected about 150 trees with superior growth and stem form from south India and obtained seeds of around 100 such trees from Eastern and North Eastern regions to establish multilocation progeny trials. Sixty trees were vegetatively propagated and a vegetative multiplication garden was established. Clones propagated through mini-cutting techniques were deployed in multilocation clonal tests. Early evaluation of these trials has helped in identifying a few clones with superior growth and stem form for public release in the near future. Gmelina is an ideal tree for growing in a multi-crop system involving silvi, horti and pasture crops. In particular cultivating pepper on Gmelina trees in the plains is becoming highly popular among farmers.

3.6 Melia

Melia dubia (Family Meliaceae) is a fast growing tree having a straight and cylindrical bole. The wood is durable and is most sought after in the plywood industry. It is well suited for cultivation in farmlands at different spacing regimes. It attains an average girth of 80 cm in four years with a spacing of 5 x 5 m. As a part of Melia improvement program, IFGTB has assembled around 175 accessions from southern India. About 75 clones were selected from this assemblage, clonally propagated and established in vegetative multiplication garden. A further subset of clones with high adventitious rooting efficiency were mass multiplied and deployed in multi-location testing for the assessment of growth performance. Initial observations showed that soil types, spacing, irrigation, management practices and agroclimatic conditions all had a significant impact on the wood production in Melia plantations.

3.7 Other Species

Thespesia

Thespesiapopulnea (Family Malvaceae) is a multi-purpose tree used for timber, fodder, green manure and afforesting water-logged and salt-affected areas. The timber is highly sought after in rural areas for house construction and making furniture, agricultural implements and carvings. It helps in meeting the rural timber need as it is widely available and affordable. Thespesia generally possesses a crooked stem form which limits timber production. IFGTB selected nearly 140 trees from south India with straight stems and vigorous apical growth. They were vegetatively multiplied and planted as clone bank and clonal trials. Early observations show that certain accessions possessing the desired traits of straight stems, axis persistence and fast growth which may likely to be released as tested clones in the near future.

Haldina

Haldinacordifolia (Family Rubiaceae) is a multipurpose tree widely found in moist deciduous forests and possessing high quality timber and various medicinal properties. Many phyto-chemicals and pharmacological compounds have been identified from this tree. Despite its high value Haldina has hardly undergone any tree improvement so far. IFGTB has identified around 90 CPTs with fast growth and straight stems from different locations in Kerala. With a few more selections, it is planned to establish clone banks and progeny tests in multilocation to carry forward the improvement programme.

Ailanthus

Ailanthus excels (Family Simaroubaceae) is highly preferred for match splints and fodder. Its wood has desirable qualities like colour, wax stability, consistent burning and splinting ability for use as matchwood. Due to poor domestic production, the industry is importing softwood from Europe to meet the demand. IFGTB has established provenance-progeny trials with a broad genetic base. Outstanding trees of the best provenance / family were vegetatively propagated and deployed in multilocation clonal tests. Those clones with early vigorous growth are being used to evolve a large-scale clonal propagation technique for their commercial utilization.

The new initiatives are expected to result in periodic release of high-yielding varieties of native tree species for increasing plantation productivity. Similar programmes for other indigenous species like Azadirachtaindica, Chloroxylonswietenia and Mitragynaparvifolia, Pterocarpussantalinus and Santalum albumhas just begun.

4. DNA technologies for tree improvement

Forest biotechnology is an advancing field in forestry encompassing genetic- and biology- based technologies to enhance the yield of tree plantations. Breeding pattern of forest trees throws massive amount of genetic variation to sustain in the dynamically changing environment and itvaries among the tree species. Conventional genetic improvement strategies slowly but surely reduce the diversity in order to improve productivity. Thus, to reap the positive benefits of tree improvement sustainably, tailoring of simple to complex biotechnological tools has become indispensable. IFGTB has introduced high throughput DNA markers based breeding techniques to expedite the release of improved varieties. Both dominant and co-dominant DNA markers are employed to understand the diversity of breeding populations, seed orchards and clonal lines of eucalypts, casuarina, and teak. Putative hybrids of eucalypts generated through controlled pollination were DNA diagnosed for their genetic purity. Clonal lines have been tagged for their uniqueness using DNA markers. Chromosome locations controlling quantitative traits such as adventitious rooting, salinity tolerance, cellulose and lignin content in eucalypts were identified. SSRs and SNP maker based high density linkage maps were generated and utilized in localization of QTL influencing stomata, adventitious rooting, pulp yieldand salt tolerance related traits (photo). In teak and sandal, next generation sequencing based approaches provided huge information on genomic scale of polymorphism to precisely estimate population genetic parameters. Presence of millions of genomic variations and structural alterations are likely to play a major role in productivity, adaption and evolution.

5. DUS Characterization and Registration

The Protection of Plant Varieties and Farmers' Rights Act (PPV & FR Act), 2001 offers a powerful system for safeguarding plant varieties, farmers' rights and plant breeders' rights. The legislation promotes the creation of new varieties and includes provisions giving breeders exclusive rights to permit and regulate the multiplication and sale of reproductive material. Protecting plant breeder's rights is vital to encourage investment in research and development for the creation of new plant varieties, which will hasten forest tree improvement leading to increased wood production. The varieties generated through breeding program can be tested for their distinctiveness, uniqueness and stability (DUS). In forest trees, clonally propagated plant materials are required for DUS testing. IFGTB has developed guidelines to facilitate the registration of new varieties under the PPVFR Act, 2001 for the tree species such as Casuarina equisetifolia, C. junghuhniana, Eucalyptus camaldulensis, E. tereticornis and Meliadubia. In the case of Tectona grandis and Ailanthus excelsa DUS testing guidelines have been finalized and submitted to the PPVFR Authority for approval and notification. Six varieties of Casuarina and one variety of Eucalyptus have been registered so far under the Act which provides IPR in favour of IFGTB. This is the first instance of varietal registration under the Act for forestry species.

6. Industry-institute collaborations

IFGTB works in partnership with various wood-based industries to develop products and technologies that are compatible with the requirements of the end user. In particular, the breeding objectives are designed keeping in view the needs of principal industry for that species and the area in which its farm forestry programme is concentrated. Once the new varieties are released for public use, they are extended to the relevant industries through various kinds of mutual agreements. The new clones of pulpwood species like Casuarina and Eucalyptus have been licensed to paper industries in south India for large scale commercial propagation and supply to farmers in their respective areas of operation. The details of annual production of clonal plants by different industries are provided in Table 6. At present nearly 50,000 ha is under planting IFGTB's clones of pulpwood species raised through the farm forestry programmes of industries. As a step forward in this, multilocation testing of new clones is now done in partnership with the industries. Clonal tests are jointly established by IFGTB and partner industries in areas where farm forestry programmes are taken up by the industries.

7. Overview

The significant contribution of IFGTB through its three decades of consistent tree improvement efforts is that it has effectively linked research output and commercial wood production activities. The impact of the new high yielding varieties on the productivity of plantations is substantial for the short rotation crops and show promise in case of medium and long term species as data on yield from harvests is awaited. These initial gains have firmly set benchmarks for each species which will have sustained and surpassed in the future. Alongside IFGTB is also focusing on making the new varieties accessible and affordable to resource-limited farmers and minimize cultivation costs through precision silviculture techniques and securing the plantations from threats of biotic and climate change threats through need-based and end-user driven research programmes.

Table 6. Production of clonal plants of pulpwood species by industries during 2021-22.

Industry	Annual production of clonal plants(in lakhs)	
	Casuarina	Eucalyptus
Tamil Nadu Newsprint and Papers Limited	400	124
Seshasayee Paper and Boards Limited	10	13
Andhra Paper Limited	75	-
JK Paper through licensees of IFGTB	05	56
Tamil Nadu Forest Plantation Corporation Limited (TAFCORN)	-	07
Private nurseries (licensees of IFGTB)	150	30.5

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Incentivizing Carbon Sequestration Service from Coffee Agroforests: A Tool for Sustainable Management

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Introduction

The increasing concentrations of carbon dioxide (CO_2) due to industrialization, fossil fuel burning, forest degradation, etc. have resulted in the current environmental crisis. Carbon dioxide is the main heat-trapping gas largely responsible for climate change (Forster et al., 2007) and its concentration has increased drastically from 280 ppm during the pre-industrial era to 383 ppm during post-industrialization. There is a growing interest in the role of diverse types of land use systems in stabilizing the atmospheric CO_2 concentration, reducing CO_2 emissions and increasing the terrestrial carbon sink. Agroforestry has been recognized as a means to reduce CO_2 emissions as well as enhance carbon sinks. Although pristine natural ecosystems represent the world's largest vegetation and soil carbon sinks, much of this has already been lost, particularly in less developed and developing countries. It is unlikely that these degraded and deforested sites will return to their natural forest cover. Therefore, there is a significant need for transforming some of the lower biomass land uses (such as arable croplands and fallows) into carbon–rich tree-based systems such as plantation forests and agroforestry.

Agroforestry provides an unique opportunity to combine the twin objectives of climate change adaptation and mitigation strategies. Although agroforestry systems are not primarily designed for carbon sequestration, many recent studies substantiate the evidence that agroforestry systems are capable of playing a major role in storing carbon in the soil and in above- and below-ground biomass. Agroforestry is appealing for carbon sequestration because of the following reasons: (a) it sequesters carbon in vegetation and soils depending on the pre-conversion soil C, (b) the more intensive use of land for agricultural fabrication reduces the need for slash-and-burn or shifting cultivation, (c) the wood products produced serve as an alternative for similar products unsustainably harvested from the natural forest, (d) agroforestry increases the income of farmers, it reduces the incentive for further extraction from the natural forest for income augmentation, and finally, (e) agroforestry practices have dual mitigation benefits, especially when fodder species is an agroforestry component, it provides high nutritive value diets for methane–producing ruminants and can also sequester carbon.

Agroforestry in India contributes to the target set for increasing forest cover from the present level of 23% of land area to 33%. The Report of the Task Force on Greening India for Livelihood Security and Sustainable Development (Planning Commission 2001) has suggested that 10 million hectares of irrigated land and 18 million hectares of rain-fed land should be managed under agroforestry systems. The International Panel on Climate Change (IPCC) Third Assessment Report on Climate Change has recognized the potential of agroforestry for addressing multiple problems and delivering a range of economic, environmental and socioeconomic benefits. Estimates of the carbon sequestration potential of agroforestry systems range from 0.7-1.6 Gt – 6.3 Gt. Secondary environmental benefits include food availability, security of land tenure, increased farm income, restoration and maintenance of above-and below-ground carbon storage capacity, restoration and maintenance of biodiversity, and maintenance of watershed hydrology and soil conservation. Agroecosystems can be designed to assist the adaptation of communities and households to local and global change.

The Report of the Task Force on Greening India for Livelihood Security and Sustainable Development (Planning Commission 2001) has suggested that 10 million hectares of irrigated land and 18 million hectares of rain-fed land should be managed under agroforestry systems.

Figure 1: Multistoried coffee agroforestry in Kodagu.

Valuing ecosystem services and getting payment from beneficiaries are generally termed as Payments for Ecosystem Service (PES) schemes, and they focus on ecological/environmental services provided by forest conservation, reforestation, sustainable utilization, agrobiodiversity and agroforestry, for which there is an existing market demand, or for which such demand can emerge in the future under appropriate conditions.

Agroforestry provides an unique opportunity to combine the twin objectives of climate change adaptation and mitigation strategies.

In the Central Western Ghats, Kodagu district is one of the most heavily wooded regions in India, with 81 % of the landscape under tree cover, representing all the major tropical forest types. The tree-covered landscapes include 1214 sacred forests under community management and, shade-grown coffee plantations under private ownership which cover 33% of the area of the district and produce 38% of India's coffee. Themultistoried coffee agroforestry system developed and sustained by the farmers based on their local knowledge is one of the most diverse production systems in the world. In addition to their contribution to employment and economic development, the coffee plantations sustain biodiversity in the form of flora and fauna and in turn contribute to valuable ecosystem services such as carbon sequestration and hydrological services. The natural landscape of the district provides an excellent opportunity for the promotion of the recently emerging concept of the 'green economy'. The ecosystem services provided by the 'greenscape' of Kogadu are not only confined to the district. In terms of water, climate regulation, and timber and fuelwood needs, the Cauvery river provides a variety of life-sustaining and sustaining benefits to communities downstream. The contribution of Cauvery to the economic development in Bangalore and agricultural productivity in Karnataka and Tamil Nadu is well known.

Landscape dynamics

The forested landscape of the district is currently undergoing dynamic changes concerning land use and land cover. This diverse, multistorey agroforestry system is undergoing a transformation with respect to canopy density and diversity due to changes in the production systems under the current liberalized market situation. Coffee plantations are becoming more open, and native trees are being replaced by exotic Silver oak. Natural forests under the management of the forest department are also subjected to biotic pressures, and considerable proportions of the natural forest have been converted to Teak and other plantations. Sacred forests are being encroached on and degraded. The paddy fields are either abandoned or converted to other land uses or human settlements. Unregulated tourism is resulting in impacts on the environment and natural resources. Therefore, it is imperative to promote sustainable management of the landscape that contributes to the protection of the environment through incentive based mechanisms like PES. The present article is therefore aimed at quantifying the carbon sequestration potential of the Kodagu landscape and devising PCSS mechanisms that suit the landscape since it plays a crucial role as a sink of Co_2

Carbon sequestration in different land uses

The total carbon pool from the major components of carbon sinks in the natural forest of Kodagu (Table 1) was found to vary from 207 t/ha in sacred groves to 77 t/ha in dry deciduous forest, while evergreen forest had a slightly lesser carbon pool of 170 t/ha as compared to semi-evergreen forest and sacred groves. These estimates are comparable with the values from other tropical ecosystems.

Table 1. The total carbon from different components of forest and sacred groves in Kodagu district,

Vegetation type ground biomass	Above (Mg ha^{-1})	Litter (Mg ha^{-1})	Herb biomass biomass (Mg ha^{-1})	Soil carbon content (Mg ha^{-1})	Total carbon (Mg ha)
Evergreen	115	2.11	3.05	50.07	170
Semi Evergreen	112	1.72	2.11	63.12	179
Moist Deciduous	48	0.13	0.13	42.00	90
Dry deciduous	43	0.10	0.18	33.45	77
Shola grassland	61	1.92	4.73	56.13	124
Sacred groves	140	0.38	__	67.00	207

Earlier studies showed that coffee agroforests composed of Arabica shaded by either native or exotic tree species sequestered carbon at the same rate as reference forests (Table 2). To a lesser extent, this also appears to be the case for Robusta shaded with native species. With values in the range of 138-206 Mg ha^{-1}, the total carbon sequestered in the present coffee agroforests is well above the median carbon sequestration potential of other agroforestry systems estimated at 95 Mg ha^{-1}in the tropical regions.

Table 2. Above ground biomass and carbon distribution in coffee agroforests of Kodagu as compared to adjacent natural forests

	Carbon storage in different pools (Mg ha^{-1})				
Land-use system	**Tree Layer**	**Coffee**	**Soil**	**Litter**	**Total**
Natural forest	97	__	97	2.4	196
Arabica native	88	4.8	112	1.6	206
Arabica exotic	73	3.3	105	2.2	183
Robusta native	78	13.0	90	1.8	182
Robusta exotic	47	10.1	78	1.9	138

Above ground biomass and carbon pool at landscape level

A recent study has revealed that Kodagu district contributes 70% of the total above ground biomass and carbon pool quantified from three other adjoining districts in the Western Ghats region of Karnataka. Above ground biomass ranged from 0.05 – 250 Mg $ha^{-1}$with a mean density of 92 Mg ha^{-1}while the vegetation carbon density in the coffee agroforestry systems ranged from 0.03 t/ha – 120 Mg $ha^{-1}$with a mean density of 44 Mg ha^{-1}.

Valuation and payment mechanism

Economic valuation of carbon sequestration services offered by the natural forest ecosystem or any wooded ecosystem is essential for successful implementation of the PES mechanism. There are many efforts around the world to value forests or tree based land use systems as a source of carbon sinks and for their contribution to mitigating global climate change. From the literature, it was observed that the values range from 5 – 125 USD per Mg C. Studies conducted in Kodagu on the landscape have revealed the carbon sequestration potential of different land use types ranges from 40-150 Mg C/ha. Even if we assume a modest estimate of 90 Mg C/ha sequestered by the vegetation, it amounts to USD 900 or Rs. 40,500 per hectare of vegetation at an assumed rate of 10 USD per Mg C in the international market. Possible models that could generate carbon credits for the Kodagu landscape include; Best Management Practices (BMP), Afforestation and Reforestation (ARR) and avoiding deforestation or forest degradation through REDD and REDD+. Under BMP, coffee agroforestry systems will qualify, and the suitable mechanisms are CDM and REDD+. It is now widely recognized that sink related CDM projects can promote sustainable development and resilience of smallholders' production systems. The Bio-carbon Fund (www.biocarbonfund.org) established by the World Bank, is a prominent source of funds for such projects. Another option is to utilize the benefits of Forest Certification (FSC), eco- certification and landscape labelling for sustainably managed landscapes like coffee agroforests. Activities that increase biomass accumulation in community forests such as village forest committees (VFC) areas and sacred groves and in forest plantations and natural forests could be brought under REDD and REDD+ mechanisms as envisaged under the Green India Mission of the Ministry of Environment and Forests and Climate Change, Government of India.

Recent CDM related developments in India under forestry sector

The Indian Council of Forestry Research and Education (ICFRE) has become the first Designated Operational Entity (DOE) in India to be accredited by the Executive Board of the Clean Development Mechanism (CDM EB) to validate and verify/certify Clean Development Mechanism (CDM) projects in the sectoral scope of 'Afforestation and Reforestation' (A/R). The ICFRE applied for DOE status under the UNFCCC in July 2009 and received accreditation in February 2011 at the 59th meeting of the Executive Board of the Clean Development Mechanism.

Possible payment vehicles

Levying taxes could be the payment mechanism for carbon. It may be envisaged to collect Green Tax from new vehicles as a one-time tax equivalent to the amount of lifetime tax that can be collected at respective Regional Transport Offices, and the distribution of the collected tax should be made based on the percent of forest cover in respective districts. The payments for carbon must be based on carbon sequestered per year rather than carbon stocks and this could be linked to high end car companies and other carbon emitting industries.

It may be envisaged to collect Green Tax from new vehicles as a one-time tax equivalent to the amount of lifetime tax that can be collected at respective Regional Transport Offices, and the distribution of the collected tax should be made based on the percent of forest cover in respective districts.

Studies undertaken in Kodagu district provide enough indications that the landscape as a whole has high carbon stocks and sequestration potential. Carbon sequestration service from the land use system consisting of tree cover is a well known service for 'Incentive Based Payment Mechanism' to the land owners. Further, in the current context of global climate change, there is an urgent need to formulate PES mechanism for Sustainable Carbon Management (SCM) to halt further degradation of the landscape.

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Status and Developments of Industrial Agroforestry in Tamil Nadu: A Consortium Approach

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Introduction

Forests in India have played a significant role in extending wood and non-wood forest resources until the recent past. However, with the enactment of forest laws,, followed by the enunciation of forest policies, there has been a paradigm shift in forest management from production-oriented forests to conservation-oriented forests. These developments limit or completely stop the availability of timber and timber products from natural forests. The growing population, industrialization, and urbanization coupled with science and technological advancements have increased the utilization of wood and non-wood resources. The low forest cover, poor productivity, along with policy and legal restrictions have resulted in a reduced availability of wood resources (Parthiban and Fernandaz 2017).

The increased demand and restricted supply from natural forests have necessitated the promotion of agroforestry as a potential land use system, not only to create self-reliance in raw material security but also to protect natural forests. Considering this, the Government of India, as early as 1988, through its National Forest Policy, directed all wood-based industries in the country to develop their own raw material resources by establishing suitable linkages with farmers and extending technology and market support (GOI 1988). This has further gained attraction after the enunciation of an exclusive National Agroforestry Policy (2014) by the Government of India. This policy advocated increased participation of wood-based industries in agroforestry. Barring a few industries, others have not taken the seriousness of policy directions, which ushered in a total mismatch between demand and supply, and attracted massive imports.

The lack of institutional mechanisms and the challenges and constraints that existed in agroforestry were identified as potential factors for the slow progress of agroforestry development. Against this backdrop, the Forest College and Research Institute of Tamil Nadu Agricultural University has innovated a value chain model on agroforestry that has been implemented in the Tamil Nadu state in association with a wide range of wood and non-wood-based industries through a consortium approach (Parthiban 2016). This paper details the status and development of industrial agroforestry in the state of Tamil Nadu, which has a greater scope of replication potential across India.

Wood demand and supply in India

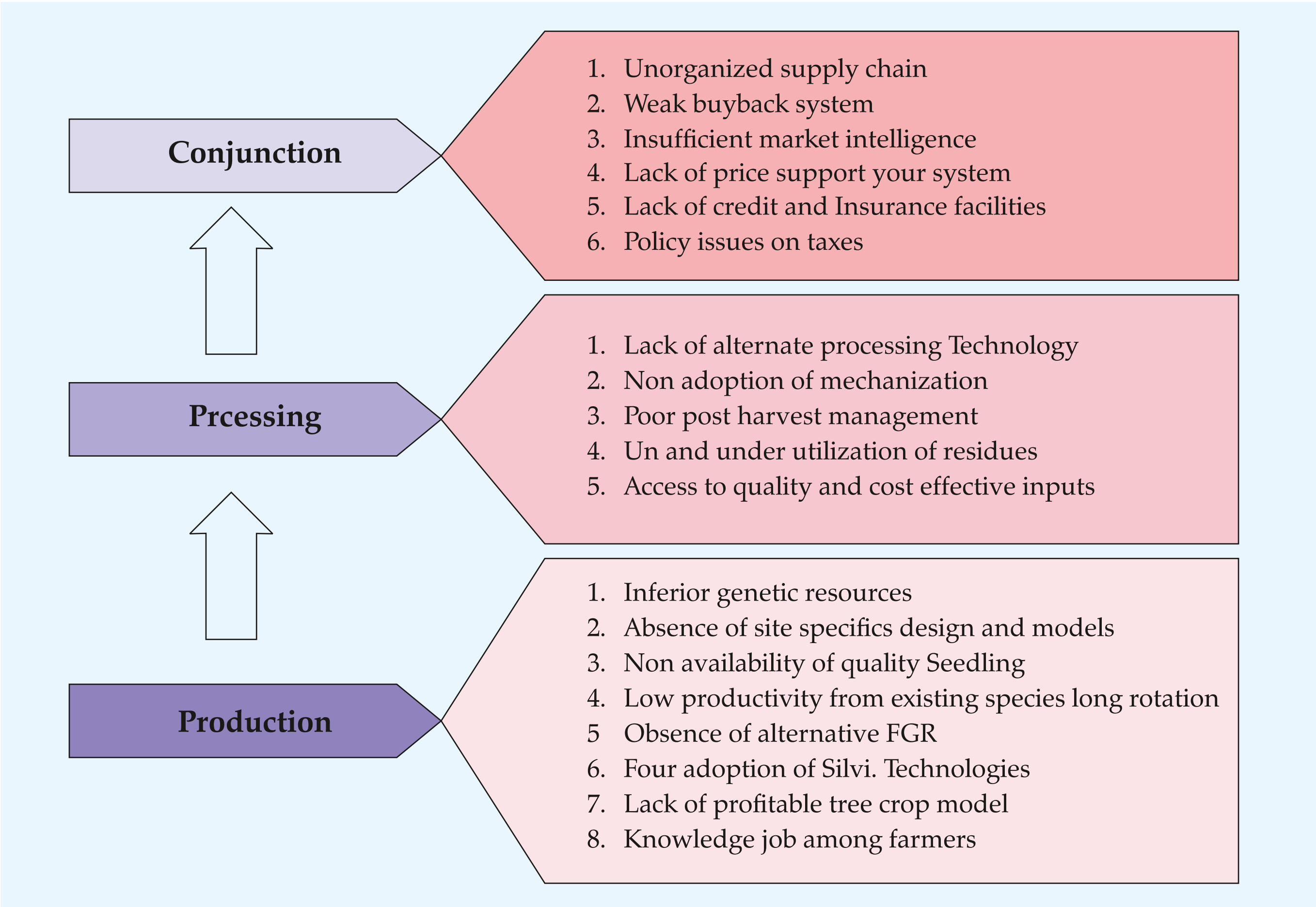
India is one of the most robust producers and consumers of wood. It is estimated that the country would require more than 150 million m^3 of wood to meet the raw material resources of organized wood-based industries (FAO 2009). However, in the existing reality, it is well known that the country has a greater number of unorganized sectors of industries, which again demand an equal quantity of wood. Besides, the country's wood requirement for both domestic and industrial energy utilities has been estimated to be more than 400 million m^3 (Parthiban et al. 2021). Although the data indicated by various sources is highly variable, it is very clearly evidenced that the country's imports for wood and non-wood production have been steadily increasing over the last decade. Under such circumstances, it is very clear that the wood requirement for multiple utilities in the country is increasing at an exponential rate, which necessitates systematic planning for forestry and agroforestry development.

Wood demand and supply in Tamil Nadu

Tamil Nadu state is home to a wide range of wood and non-wood-based industries like timber, plywood, pulp and paper, matchsticks, packing cases, pencils, truck and bus body building, value addition industries, biomass power generation industries, co-firing industries, tannin, gums, toys, dyes, oil and essential oil, etc. Among all these industries, the wood requirement for six major sectors of industries is alone estimated to be more than 74 lakh tonne/annum. However, the estimated supply from government sources is hardly 1–1.5 lakh tonnes of pulpwood raw material from Tamil Nadu Forest Plantation Corporation (Parthiban et al. 2020; Parthiban et al. 2021). The remaining wood is sourced on the open market through agroforestry and farm forestry. It is very clearly visible that demand for wood in Tamil Nadu has increased, but the supply chain is highly unorganized and multipartite (Parthiban 2008), which demands the systematic promotion of agroforestry. However, agroforestry promotion exhibited a wide range of challenges and constraints.

Challenges and constraints in agroforestry

The issues suggested above have attracted increased attention and attraction towards organized agroforestry developments; however, agroforestry promotion and development exhibit a wide range of challenges and constraints, which are identified through baseline analysis (Parthiban 2008) and continued evaluation annually through mutual consultation, deliberation and discussion with a wide range of stakeholders. Accordingly, the major challenges and issues that existed in agroforestry are categorized into production, processing, consumption and marketing levels (Parthiban et al. 2019). The detailed constraints at all the levels, from production to consumption system are furnished below.



Innovations and intervention

The Forest College and Research Institute, TNAU, designed a value chain model for agroforestry in 2008 and implemented it successfully in Tamil Nadu in association with two paper industries, Tamil Nadu Newsprint and Papers Ltd (TNPL) and Seshasayee Paper and Boards Ltd. This was further expanded to other industries like plywood, timber, match, energy, biofuel, floss, tannin and the medicinal industry. This value chain system resolved the challenges and constraints that existed in agroforestry through technological, organizational and marketing interventions, which attracted increased participation from industries and farmers.

a. Technological interventions

The success of industrial agroforestry plantations is possible through technological intervention. The technology interventions involve the development and deployment of high-yielding short rotation (HYSR) clones, the introduction of new and alternate genetic resources, practising smart silviculture, incorporating multifunctional agroforestry, engaging mechanization in the entire Supply chain management and utilizing value-added technology for the utilization of plantation and industrial residues. These technological interventions help increase production levels from 10 m^3/ha/year to 25 m^3/ha/year and profitability to levels greater than 3:1 (BCR).

b. Organizational interventions

The success of the value chain model in industrial agroforestry is possible through organizational intervention, which facilitated linking all stakeholders involved in the entire production to consumption system. Through research institutions, the design and deployment of a quad-partite model contract farming system linked efficiently tree growing farmers with consuming wood-based industries. Financial institutions facilitated institutional credit and insurance support. This organizational intervention is further strengthened by the establishment of an innovative institution called the Consortium of Industrial Agroforestry (CIAF), which links almost all stakeholders involved in the entire agroforestry PCS, thereby helping to resolve the challenges and constraints in a systematic and organized manner.

c. Marketing interventions

The major constraints that existed in agroforestry were the unorganized market and trade of farm-grown trees. This was resolved through the contract farming system, which extended the assured buyback and market support system and attracted several farmers to tree husbandry. The market support system that is tenable and extended to a wide range of species is furnished below.

Table 1. Market support system for multiutility species.

Species	Price support rate/mt in rupees	Industry associated
Timber		
Teak	20000	Suresh Timbers
Gmelina	8000–10000	RSK Timbers
Leucaena leucocephala	5500	
Paper		
Casuarina sp.	6100	TNPL and
Eucalyptus	5250	Seshasayee Paper and Boards
L. leucocephala	3900	
Melia dubia	4400	
Plywood		
Eucalyptus	5600–6000	Century Ply / Sharon Ply/ Ambiply/ Sri Ranga Ply/ Sri Krishna PlyM. dubia 9500
Toona ciliata	8000	
Swietenia macrophylla	7000	
Neolamarckia cadamba	6500	
Acrocarpus fraxinifolius	6000	
Match splints		
Ailanthus excelsa	6500	Vasan Match and Ideal Splints
Energy		
All wood chips	4500–6000 depending	All Energy Co-firing Industries on the size of the hips
TBOs		60/kg Coromandel group of companies

Impact

The value chain model on industrial agroforestry conceived and implemented by Forest College and Research Institute, TNAU, has made a significant impact in terms of productivity, profitability, socio-economic and environmental as indicated below.

a. Expansion of area under industrial agroforestry

Implementation of the value chain in industrial agroforestry over the past decade has been the reason for bringing over 80,000 ha under organized industrial agroforestry plantations in association with pulpwood, plywood, timber and other consortium wood-based industries and is responsible for meeting at least 40% of organized raw material supply.

b. Impact on productivity

Before the implementation of the value chain system, the productivity levels were less than 10 m^3/ha/annum. However, after implementation of the value chain model by deploying high-yielding short rotation clones, mini clonal technology and precision silviculture, the productivity level has increased over 25 m^3/ha/annum and the maximum recorded productivity was up to 50 m^3/ha/annum.

c. Impact on rotation

Before the introduction of the value chain model, the rotation period for various tree species was more than six years. For certain tree species, there was a lack of organized felling. After the implementation of value chain model, the rotation/felling period has drastically reduced, to even as low as 18 months. For species like Melia (MTP 2) the rotation has been reduced to less than two years for use as raw material in the paper industry. In most cases, rotation has been fixed based on technical specifications in the form of the girth of the tree, which in turn has had a significant impact on the promotion of agroforestry.

d. Economic impact

Species and industry-specific industrial agroforestry model has been characterized for its economic benefits through financial analysis. The financial analysis indicated that the B:C ratio of industrial plantations exceeded 3:1 compared to baseline status, thereby increasing the profitability of tree-growing farmers.

e. Social impact

Promotion of value chain-based Agroforestry plantations have extended continued employment and income generation activities in the form of nursery establishment, pitting, plantation establishment and management, felling, conversion, loading, value addition and transportation. It is estimated that organized agroforestry development has created 300 man-days of employment per hectare in the entire Supply Chain management. This approach is also able to create over 25 new business enterprise developments and has enhanced income generation activities through the business incubator.

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f. Environmental Impact

Value chain-based agroforestry plantations have created a significant impact on the environment through their carbon sequestration potential, which is estimated at an average of 50 tonnes of carbon per hectare. It is estimated that the industrial agroforestry plantations established over a decade in Tamil Nadu in association with various wood-based industries have sequestered more than four million tons of carbon and thus addressed the issues of climate change through clean development mechanisms.

Summary and conclusion

Agroforestry has received attention as a potential alternate land use system, as a source of generating industrial raw materials, and as a land use system amenable to climate change mitigation and adaptation. Although agroforestry has been practiced since time immemorial, its contribution towards industrial raw material generation and the associated income and economic development is only of recent origin. This is possible and predominantly due to the value chain model created and implemented for industrial agroforestry development, which has natural replication potential across a wide spectrum of industries. This model needs to be strengthened by suitable incorporation and replication not only within the country but also across the tropical regions of the world.

Acknowledgement

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Agroforestry and Remote Sensing: Perspectives for Characterization and Monitoring

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Abstract

Agroforestry is gaining significance as a key element in enhancing the farm income as well as serving global functions of mitigation and adaptation against climate change. Advent of high resolution imaging from different platforms has brought in the element of detecting agroforestry formations from space which was otherwise muted in medium resolution remote sensing. Challenge of processing image content corresponding to agroforestry stems from the fact that conventional approaches using pixel based techniques will not apply in this case. They have to be based on Object Based Image Analysis (OBIA) methods to start with, followed by machine learning approaches addressing elements consisting of trees and associated land covers. Limitations in applying OBIA, followed by evolving strength of neural network has developed into a reliable method of delineating the agroforestry elements. Challenges may crop up wherein complex land cover situations, with trees and in continuation with elements from other tree planting initiatives.

1. Introduction

Agroforestry is intentional introduction or retention of tree elements to benefit from the synergy of crops, trees and dependent fauna in a cropped or cleared landscape. The obvious visual elements that strike any casual observer in an agro-forested landscape is the regular geometry of trees that intersperses the cropped landscape. Though agroforestry also includes plantation forestry as farm forestry, often occupying the entire parcel, presence of trees either on bunds or in alleys comes closer to the current issue being deliberated. The sense of integration either in time or space as an intelligible interspersion through a design, in fact brings in highest synergy over time, as tree elements strengthens the overall soil status and ameliorates it, apart from the usufructs furnished within a meaningful period after introduction. Obvious focus garnering in now, on tree elements in a farmed landscape stems from the fact that climate change related extremities are pushing the agroecosystem very hard in terms of intense yet unpredictable squalls, storms, droughts, chills and snowing events, which pushes us to find more resilience. Introduction of medium term to long term interventions such as trees has ability to withstand the extremities and add the bio-physical benefits such as wind sheltering, climate moderation, run off abatement as well as site amelioration. Hence any effort to observe them, recognize the increase of their spread and use this to enthuse farmers elsewhere who are reluctant and demotivated to adopt this beneficial practice is most welcome. Current discourse focuses on how remote sensing has developed potential to do this and how it can be exploited for nuanced policy.

Observing agroforestry as a cover fraction or landscape element using space borne or aerial borne imaging, using various spectral regions of light offers unique advantage of panoramic view leading to a clear planimetric assessment of the element. Planimetric assessment can lead to map with georeferencing in place, hence further amenable to all other spatial datasets prepared for various themes related to land, climate, ocean as well as environmental vulnerability. However, conventional remote sensing using spatial resolutions about 20 m hardly could depict the agroforestry elements since this theme has specificity of minor objects building a context, which is not gregarious in the sense of imaging. All the cover themes related to land cover such as cropped land, water bodies, forest cover, mineral tracts, mined areas, contiguous habitations, coastal patterns could be imaged confidently using medium resolution remote sensing on space borne platforms, which dominated the Earth Observation to begin with. Only the advent of high resolution remote sensing imaging better than 5 mts started revealing the detail of the entities such as large to medium sized tree crowns as objects that lead to attempts to characterize trees outside forests or agroforests (Figure 1). Though aerial images or photographs contained substantial amount of information regarding the tree cover and its individual depiction, restrictive policy environments enveloped in secrecy, hardly promoted any regional assessments especially in the context of India and several other nations having colonial legacy. Efforts in African contexts to characterize prevalence of trees started yielding astounding insights about the size of the stock prevalent in such systems. In addition to this, unrecognized essence, and importance of decentralized approach in managing natural resources such as agriculture, water conservation, greening also relegated mapping distributed resources such as trees outside forests and agroforests to fringe only. Advent of site level stock assessment using very high resolution sub meter panchromatic data from international sensors on board satellites like IKONOS, Quickbird etc, brought in the need to improvise use of remote sensing towards individual tree detection.

property since it enables a comprehension of a biophysical situation at coarse level while obscuring the detail that generally appeals to human eye. Detailed images currently available have solved this constraint, but presented challenges in using automated image analysis techniques. Often scientific approach overloaded by operational requirements, especially in land related themes, tries to straitjacket the response of an Earth cover to preconceived notions driven by conventional ground based conceptualization of cover or land use. While remote sensing provides signals about vegetation, institutions try to map forest. Latter is mostly an administrative term due to its importance for State as a resource base and any conflict with ground reality conflicts with recorded status. Hence, diversity of cover configurations lead to a trade off in adopting working definition to delineate the spatial information from

Figure 1. A typical agroforestry landscape observed in ISRO-Bhuvannear Nadiad , Guajarat , India, AS High resolution Natural Color Composite, depicting characteristic bund planting surrounding farms.

satellite images.

1. Specialty of Agroforests as Process and Structure

Spatial science always strives to extract best information from otherwise fuzzy images so that it represents a best possible reality in representing process and the structure that is manifested over time on the date of imaging. Fuzziness of imaging is an interesting

Agroforests are resultant of a cultivation process influenced by need of a farmer duly supported by policy or commerce related scope/know how to get inputs in realizing the same. Risk of unknown or unmanageable situations related to market, climate, pests of course is inherent to land based activity. Structure realized or aimed to be realized from the process of establishing agroforests or agroforestry, presents as mix of woody elements of various heights encircling cropped units in various manner. Structural patterns as visualized in the high-resolution image essentially comprise of various shadows of large and small trees, shadowless crop cover as well as individual or contiguous blobs referring to single or cluster of trees or shrubs. Since imaging happens in high resolution domain interplay of shadows defines the main characteristic of any agroforestry context.

Process of agroforest planting has minimal detectability in the initial stages, unlike a crop which manifests herbaceous cover soon after planting. Hence early stage of agroforestry is having less tree fraction as opposed to its established stage. If contrast allows, gaps in cropped continuum with respect to tree planting may be distinguished at times but not with regularity. So temporal constancy of agroforests as a mappable entity is fuzzy in the beginning. Various configurations of agroforests such as bund planting , alley cropping, home stead, avenue planting, silvi-pasture are instances of resulting structure as interspersion of crops and trees in various proportions. Structure referred here purely with respect to planimetric reference can only be extrapolated to vertical structure with sufficient field data and reliable models of three-dimensional representation. Each structure has its specialty in getting detected, so, from images and can not be characterised by using pixel-based image analysis methods alone.

While assessing agroforestry contexts (using remote sensing as of now) using visual interactive visual approach offers plausible solution as operational approach, digital methods require iterative techniques involving machine learning segmentation based expertise and further standardization since limitations in machine learning require frequent interventions by experts in handling the errors.

However, definitions of constituents of agroforestry need to be deliberated thoroughly so that conflicts in terming cover with respect to institutional affiliation needs to be ironed out. While avenue planting is a typical entity funded by the state and has association with roads, any farm bund tree planning abutting an avenue plantation always bears the risk of getting committed in to former by a machine based approach. Similarly, a bund planting can always merge with a fringe forest or gallery forest or stream bank vegetation unless they have distinct species level difference or crown size distinction. Matured bund planting can hardly be differentiated from stream vegetation.

3 Digital Image Analysis for Agroforestry

Major question that drives detection of agroforestry elements from using digital image processing revolves around the fact that agroforestry is a mix of two domains of land covers , viz., crop and trees, in various configuration in space and time. Configuration in space means at an instance of imaging followed by that in time meaning how cropped landscape turns in to a tree clad landscape. Capturing such patterns using per pixel classification is a challenge. Per pixel classification approaches follow the principle of maximum likelihood algorithm where a pixel is considered as member of a particular cluster depending on its probability density function when more than two distributions are prevalent as correlated spreads. Earliest efforts of delineating agroforestry elements centered around mapping trees outside forests or tree resources outside forests. Latest exhaustive review (Sharma et al, 2022) of attempts to characterize agroforestry in terms of planimetric and functional traits provide comprehensive understanding of the agroforestry geospatial panorama.

Each band of remotely sensed image is a distribution of one or more normally distributed digital numbers. Since medium resolution remote sensing pixels never explicitly depicted tree crowns in a cropped landscape all efforts in the early stage was confined to subpixel level approaches, where in end members of crop, trees and other land cover were presented as fractions of a given pixel. This resulted in to a set of digitally processed map or surface conveying the fraction under each pixel corresponding to the cover type. So it was not an explicit spatial map of entities, but of a fraction. Such an approach was termed sub-pixel classification.

Advent of high-resolution imaging and coinciding application of principle of medical image processing to process them as consisting of image objects gave the next stage of evolution of information extraction. Medical image processing principle relied on detection of edges for each entity and considering each group of pixel surrounded by an edge as input to mathematical handling in to an identity, called image segment. This unit resulting out of segmentation was considered as object and hence was amenable to be characterized using its inherent properties as a spectral reflectance homogeneity or as geometric traits intrinsic or extrinsic to each object. Since object exists as member of larger universe of objects, all those relations with other objects in geometric configuration could also be used by the software architecture. Such an approach called Object Based Image Analysis (OBIA) commands sizeable proportion of image analysis approaches and enhanced the analysis potentially substantially. Studies involving OBIA towards delineating Trees Outside Forests (TOF) yielded accuracy levels ranging around 75-85 per cent delineation (Pujar, 2014; Rizvi, 2019) accuracies of tree individual and population detection depending upon the type of aggregation targeted. Potential to integrate various components extracted from OBIA in to an agroforestry aggregate or theme exists with commercial off the shelf (COTS) softwares. Software e-cognition comprises highest capability in processing segmentation based approaches. Many other software licenses offer segmentation based routines for extracting information out of high resolution images. Multi-resolution segmentation based approach reveals scope to extract various configurations of tree formations from high resolution combined images of LISS IV and Cartosat 1 Panchromatic sensor. Harnessing the shape geometry of cluster resulting from segmentation, classification was

Instances of TOF cintent delineation for typical section of the Agriculture Landscape studied using OBIA

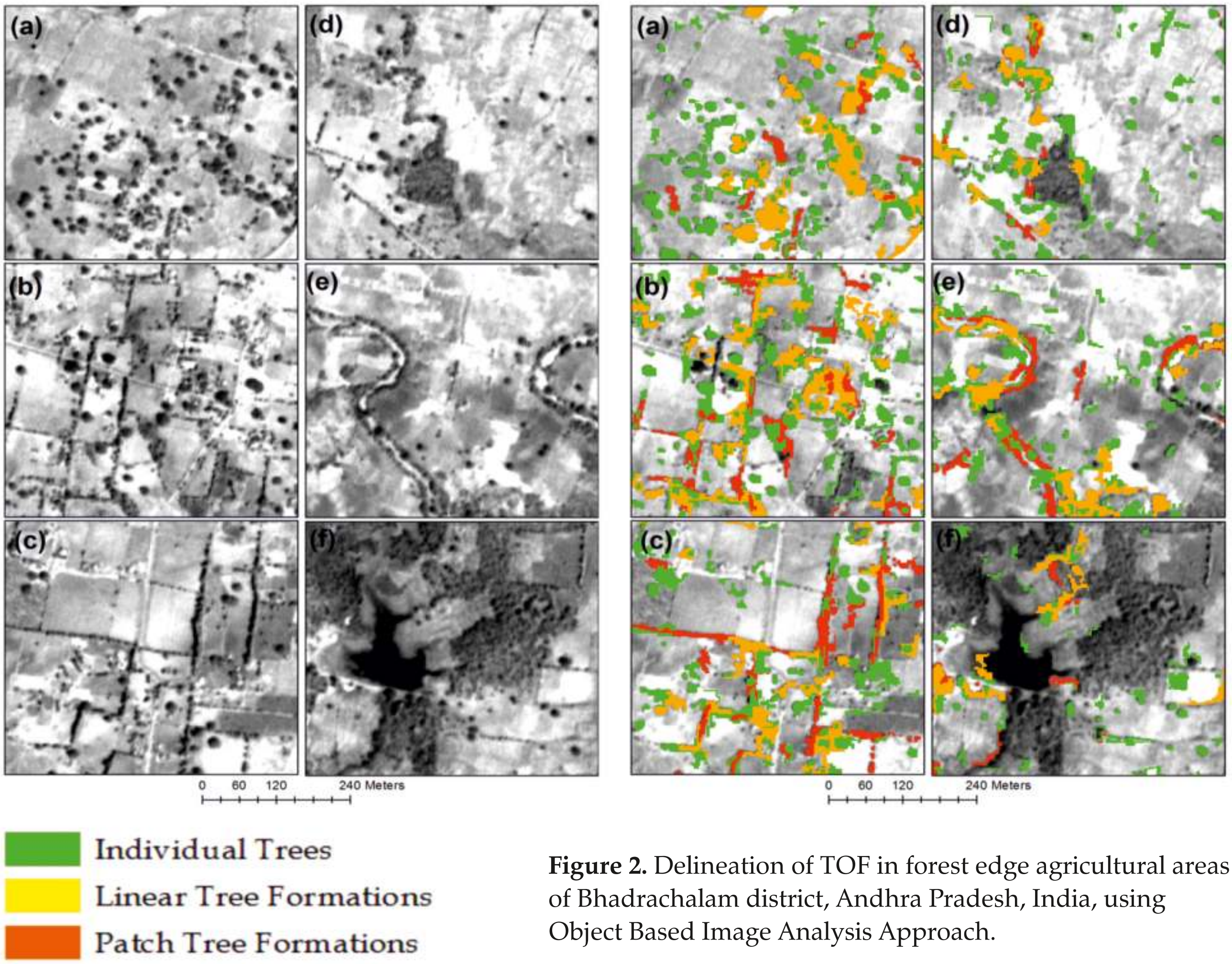

Figure 2. Delineation of TOF in forest edge agricultural areas of Bhadrachalam district, Andhra Pradesh, India, using Object Based Image Analysis Approach.

achieved in terms of single trees, linear formations and block formations of trees outside forests.

Development in applying neural network based algorithms for content extraction from images of various origins (medical, remote sensing, social media, defense etc) based on the logic of 'learning' from given labels has reached high degree of maturity. Artificial intelligence technology employing various types of neural networks emulating biological learning and enabling extraction of information using multitude of rule set combinations and establishing a weightage relation of entities and image inputs is quite promising. Since neural network based algorithms can learn the relations using a set of labels, in a non parametric approach, it has evolved into a distinct yet reliable routine. Very high resolution imaging of Earth for land cover elements has opened the scope of observing entities at hyperlocal scale almost akin to observation by a human eye at non orbital altitude. Amenability of such images to conventional image processing is quite low, unless gregarious cover formations exist such as grassland, water surface, dry soils without much shadows etc. Attempts to apply neural network algorithms such as convolution neural networks (CNN) for extraction of tree elements is showing promise. Study of trees outside forests in selected districts across India using such a neural network has yielded 85 to 90% accuracy in delineating such elements from high resolution sub meter color images having responses in near infrared, red, green and blue spectral regions. Efforts to build meaningful and reliable label at a sufficient statistical representation is key to induce learning of the U-Net, a special case of CNN, is central to success of the experiment. Each tree formation or category of aggregated prevalence (eg., woody vegetation on bunds, plantation, individual trees, avenue tree lines etc) has been depicted as labelled for further use in deep learning approach using algorithm. Total number of label windows employed to classify 25,500 sq km, covering 366 high resolution satellite scenes, was 12,628. Approach yielded validation accuracies of deep learning method, between 91 to 97% (FAO, 2022). Detailed approach may be referred from the report available. It is quite interesting to note that neural behavior is inherent to the AI performance. For instance a partially interpreted tile of high resolution of images submitted for learning, would lead to equivalent detection of elements across entire scene of the same resolution and leaving rest of the crowns undetected. So the approach has magnitude of distinction against the conventional image analysis approach.

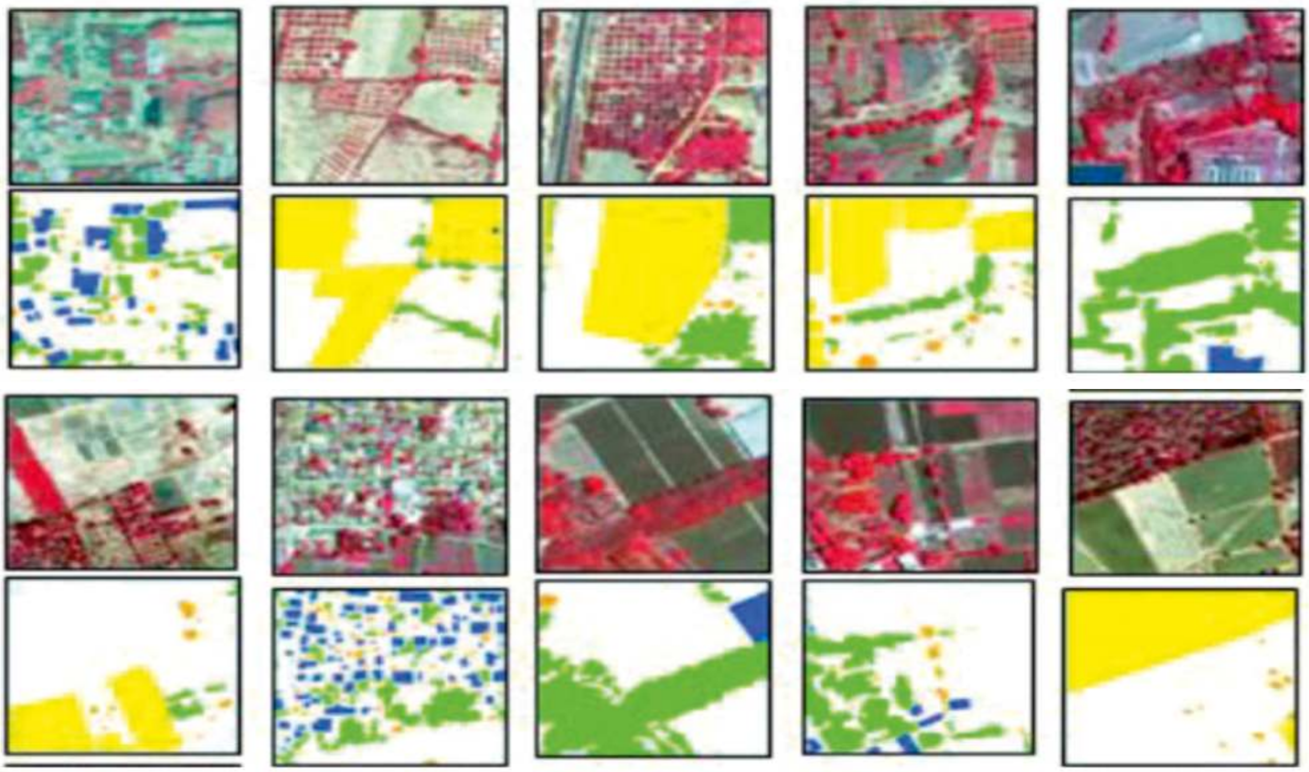

Figure 3. Sample windows to develop agroforestry formation labels to train Deep Learning approach involving U Net algorithm used in a national level pilot in Indian Districts (FAO,2022).

However, it is important to keep in mind that, CNNs can detect individual elements of a image panorama precisely, while conventional approaches process entire carpet area of imaging in to an information. Analogy would be that CNNs can answer one question very precisely (eg., How many big trees prevail?) but address multiple questions (eg., What are all the land covers prevalent in the scene?) in a more overlapping manner. The hierarchical approach to detect object based image elements therefore has to be based on multi-thematic rationale and partition the error in best possible way.

Scope clearly exists to pick up agroforestry configurations such as image windows or polygons covering crops and trees, that can be submitted as learning labels to CNN so as to pick the overall entity as such. Strong possibility exists that such studies are being initiated but with degree of failure due to obvious factors associated with generating complex object information. Instance of generating a thermal power station theme extraction, in China, from high resolution image exists wherein at least at 2 to 3 instance in 10 failed to pick the entire campus totally, probably due to the fact that geometry of outlay of each element of an industrial unit has difference in lay out across geography.

3.1 Scope of participatory monitoring of groforestry

Agroforestry is a theme of natural resource management having highest intervention component, with respect to stakeholders at practitioner level. Sheer willingness to incorporate trees with crops, by farmers, itself is hard to manifest in many landscapes across nation. However, ongoing thrust on agroforestry implementation by national and international bodies, in the light of needs of mitigation and adaptation, requires a concerted effort to bring in multi-institutional mechanism yet involving farmers/field functionaries/volunteers at field level to generate input content for AI based monitoring through a geospatial information central database. A mechanism of crowd sourcing, that feeds artificial intelligence based delineation system, suitably synced to monetized value requirement of wood, nutrition and ecosystem services, through a transparently regulated digital mechanism can take the entire effort to a newer level, benefitting all the stakeholders of agroforestry.

NITI Aayog has applied remote sensing derived inputs to analyse the potential of taking up agroforestry across nation and reporting as Greening of Wastelands through Agroforestry.

Regular strengthening of samples from across various strata of the country that can be harnessed through a cloud based or appropriate data processing set up can provide framework for assessing the status of tree elements, then followed by a regular monitoring of tree element dynamics. Different districts depending upon market and socio-economy exhibit diverse patterns of establishment and harvest of tree elements detectable on images. Even horticulture crops get replaced by new or different types of crops. Therefore, machine learning based methods may be appropriate to prepare maps of tree elements across large areas, that can be verified for accuracy and value added for monitoring purpose.

As a multi-institutional effort involving various technology and biology related centres addressing agroforestry, NITI Aayog has applied remote sensing derived inputs to analyse the potential of taking up agroforestry across nation and reporting as Greening of Wastelands through Agroforestry. Whole effort is prepared in to a digital database that would be served through ISRO Bhuvan as Web GIS based service across country along with a tool to set up prioritization by user's choice through varying the local weightage factors. National level suitability mapping involved factoring the weightage gradients of determinants such as wastelands, degraded lands, land cover, slope and soil carbon patterns. Spatial representation of suitability will enable decision making in a more informed manner in terms of distribution of potential areas as well as alignment with infrastructure.

Conclusion

Agroforestry being a strongly spatial theme, has vast scope of being characterized through various scales Earth observation. However current needs of addressing characterization requires high resolution satellite datasets spread across large geographic extents. Conventional remote sensing offered minor scope to detect formations per se and could hardly indicate the agroforestry dominant parts of the landscape. Advent of high resolution datasets and data analysis approaches can help in handling spatial information on this valuable resource far easier to prepare and disseminate appropriately. Strength of Geo-ICT tools involving android techniques can be further used to build a crowd sourced or strongly participatory inventory of samples for building a machine learning based model. Pilots carried out and those underway point to a possibility of robust framework to build a nationally useful framework to address information needs of implementing agroforestry policy to the last detail.

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Mahogany: A Potential Tree for Rural Livelihood Promotion in Agroforestry

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Introduction

Mahogany is one of the most highly prized timbers in the world for its excellent timber quality, decorative grain and colour. There are two categories of mahogany, namely 'genuine mahogany' and 'true mahogany'. *Swietenia macrophylla* (Honduran or big-leaf mahogany) and *S. mahagoni* (Cuban mahogany) are genuine mahoganies. The others, such as Khaya, *Entandrophragma, Dysoxylum* spectabile, *Toona sinensis, T. sureni, T. ciliata, Melia azedarach* and *Chukrasia velutina* are grouped as 'true mahogany'. As of today, Indonesia has the largest area of mahogany plantations among mahogany growing countries in the world. Among the mahoganies, *S. macrophylla* has become the most promising agroforestry tree species and has a good timber market. Farmers are cultivating mahogany along with many other agricultural crops in their farmlands.

Ecological requirement

The big-leaf mahogany is a large deciduous tree with an umbrella-shaped crown, reaching a height of over 30 m and a diameter at breast height (DBH) of more than 1.5 m. The trunk is straight and cylindrical, slightly grooved, with well-developed spurs and a narrow crown. The outer bark of older trees is scaly, shaggy, deeply longitudinally furrowed and brownish grey to reddish-brown in colour, and the inner bark is red-brown or pinkish-red colour. It can tolerate a wide range of soils and environmental conditions. It grows well on the alluvial soils, volcanic soils, heavy clays, lateritic soil and limestone soil, igneous or metamorphic rock formations. It is considered as a pioneer species for revegetating degraded agricultural land. It is a wind resistant species. It can grow on a very low-quality soils but performs best on deep, fertile, well-drained soils with a pH of 6.5–7.5. Within its ecological range, the optimum annual rainfall is between 1000 and 2500 mm, with a dry period of 4 months. Annual precipitation of 1000–2000 mm, a mean annual temperature of 24°C and a potential evapotranspiration ratio of 1–2 are required for optimum natural development of this species in tropical regions. Mahogany can grow from sea level up to 1500 m above sea level in areas with a mean annual temperature of 20–28°C.

Establishment and maintenance of plantation

Big-leaf mahogany is easily propagated by seeds. The fruits ripen during the dry season, when the trees begin to lose part of their foliage and the warm air dries the fruits and promotes dehiscence. Fully-ripened fruits or capsules are light coffee coloured and should be harvested. The ripened fruits should be collected directly from the tree or as soon as they fall to the ground. The capsules can be dried in the sun. Alternatively, they can be placed on a rack over electric lamps at a temperature of 38°C for *36–48* hours to encourage them to open. The fruits will split open, and seeds will be easily released by gentle shaking or raking of the fruits. Fresh seeds show 80–90% germination. However, the seeds will retain viability up to 3 months. The seeds are sown in the sand bed in furrows or holes 3–7 cm deep. Germination of seeds begins on the 15th day after sowing. At 2–3 leaf stage, seedlings are transplanted into polybags, and seedlings are ready to plant after six months. The seedlings can be planted in the field when they are about 50–100 cm tall. The spacing for planting mahogany is usually 2–3 m. A wider spacing of about 4–5 x 4–5 m is common in agroforestry systems to obtain multiple yields by intercropping the mahogany trees with cassava, corn, peanut, pumpkin and other agricultural crops, including fodder grasses. Weeding is required to ensure maximum growth and survival of the seedlings. Weeds that are as tall as or taller than the seedlings should be removed. During the first two years after planting, the weeding and hoeing should be done four times every six months. It is reported that fertilizing mahogany seedlings may reduce their susceptibility to shoot borer damage by altering the chemical composition of the apical shoots and/or enhancing tolerance by improving vigour. In Indonesia, fertilizers are usually applied after planting at a dose of 75–100 grams of NPK per plant in a ring shape around the seedlings. Pruning is usually done for the first three years. The best time for pruning is just before the rainy season. First thinning should be around 5–10 years, depending on the site quality and initial stand density. Multiple thinning is only appropriate at closer spacing (3–3 m) or 2–3 m. The number of thinning required in a rotation also varies depending on the initial density and site quality.

Mahogany-based agroforestry systems

Due to the narrow crown, fast growth and nutrient demanding nature of mahogany, it is being widely planted in farmlands and in agroforestry systems as boundary plantations. In the Philippines, mahogany is recommended for revegetating scrubland and denuded areas. It is being cultivated along with maize, upland rice, cassava, corn, peanuts and pumpkin in Indonesia, Java and South Kalimantan. Mahogany-based agroforestry farming in Maharashtra is being promoted and practised through a buy-back agreement with farmers. In Maharashtra, mahogany trees are intercropped with many agricultural crops (table 1), namely maize, cotton, soyabean, bajra, black gram, onion, ladies finger, sugarcane, etc. (figure 1). The mean height and girth at breast height of two to three years old mahogany trees in agroforestry systems are 6 m and 22 cm, respectively. Further, it was also observed that the yield of agricultural crops is reduced in mahogany-based agroforestry systems over time.

Mahogany + maize

Mahogany + cucumber

Mahogany + cotton

Mahogany + bengal gram + redgram

Mahogany + sugarcone

Mahogany + ladies finger + redgram

Figure 1. Mahogany-based agroforestry models in Maharashtra.

Table 1. Growth of mahogany and yield of intercrops in different districts of Maharashtra.

	Age of mahogany		District	Name of intercrops	Mean height (m)	Mean GBH (cm)	Yield of intercrops (Quintal/acre)
	Months	Years					
1	2	5	Pune	Maize	6.0	20	22.0
2	2	–	Sambhaji Nagar	Cotton	6.0	22	0.0
3	3	–	Sambhaji Nagar	Soyabean	6.2	25	4.0
4	2	1	SambhajiNagar	Bajra	6.0	24	3.0
5	1	9	Beed	Udid	4.2	18	4.0
6	3	–	Pune	Maize	7.5	31	20.0
7	1	9	Ahmednagar	Onion	5.5	16	50.0
8	2	10	Satara	Soyabean	5.3	16	4.0
9	2	10	Solapur	Maize	7.5	28	25.0
10	2	10	Solapur	Udid	6.0	24	5.0
11	2	–	Jalgaon	Ladies finger	6.0	18	11.0
12	2	6	Buldhana	Soyabean	6.0	20	20.0

(Lavate and Shelke 2022, *personal communication*).

Growth and yield

Mahogany plantations in Indonesia are predicted to reach a maximum volume mean annual increment (MAI) of 38.1 m^3/ha/year in 15 years in the best sites, producing up to 572 m^3/ha over the rotation, and in medium-quality sites, a volume MAI of 19.7 m^3/ha/year can be attained in 25 years, producing up to 493 m^3/ha. If the rotation is set to 30 years, stands growing in moderate sites can attain a mean height of 24.4 m and a mean diameter of 35.4 cm, producing a basal area of 30 m^2/ha and a total volume including thinning of 583 m^3/ha. According to Krisnawati et al. (2010), the total timber volume yielded over the rotation of 15–30 years was between 200.5 and 501.6 m^3/ha with a MAI of 7.7–19.3 m^3/ha/year. In Java, the economic rotation for mahogany plantations was defined to be around 30–50 years. In the Philippines, it is suggested that the harvesting age is around 15–20 years. The feasible rotation age for mahogany plantations in Indonesia is around 15–30 years, depending on the site quality and initial stand density.

Figure 2. Two-year mahogany plantation in Maharashtra (Lavate and Shelke 2022, personal communication)

Quality of wood

Mahogany is a soft, medium-weight timber. The heartwood is reddish or pinkish timber, the colour darkens with age to a deep red or brown; the sapwood is usually yellowish. It has an attractive appearance, could be easily worked with hand tools, and has excellent finishing qualities and dimensional stability. It polishes well and does not crack or bend, making it valuable for the manufacture of quality furniture. The timber is valued particularly for its colour and workability. The wood density is in the range of 485–850 kg/m^3 at 15% moisture content. The grain of the wood is interlocked, sometimes straight, with a fine to moderately coarse texture. The surface is glossy, and the timber is often nicely figured because of the irregular grain.

Utilization

As mahogany wood has excellent workability and is durable, it is used for construction, plywood, high-grade furniture and cabinet making. It is also suitable for panelling, framing, flooring, automobile bodies, interior trim of boats, radio and phonograph cabinets, bodies of musical instruments, mouldings and other ornaments. Much of the first-quality furniture made in the American colonies from the mid-18th century was made with mahogany. Mahogany is still widely used in Western countries for fine furniture mahogany. The United States and the United Kingdom are leading importers, and at present Peru is the largest exporter of . Mahogany is the national tree of the Dominican Republic (Alan 1997) and Belize (Victoria 2012). In 2015, the price of export quality mahogany wood was $US 1570 – 1655/cu.m (₹.102,050 – 107,575) in the US market.

Figure 3. Wood products derived from mahogany.

Besides timber use, the mahogany tree has many therapeutic values. It is being tapped as 'cure-all medicine' for common illnesses, namely diabetes, arthritis, rheumatism, gout, diarrhoea, fever, malaria, cough and high blood pressure and is known as 'queen of plants' in the Soloman Islands, considering its medicinal uses. In Malaysia, mahogany fruits are used as a folk medicine for treating diabetes and high blood pressure and a decoction of the crushed seeds is used to treat skin ailments and wounds. Among the Amazonian Bolivian ethnic groups, the seeds are traditionally used to induce abortion by drinking decoction of the seeds and to heal wounds and various ailments of the skin via external application of the mashed seeds. For generations, local healers in east Midnapore, West Bengal (India), have used mahogany seed to treat diabetics and diarrhea. In India, mahogany seeds are being sold for the diabetic treatment under different names in the open market (figure 4). Mahogany seed contains many useful chemicals, namely, flavonoids, saponins act alkaloids and vitamins A, B1, B_6, D and E, dietary fibre, folic acid, protein and carbohydrate.

Figure 4. Mahogany seeds sold in different names as anti-diabetics agent

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Wood Properties and Utilization of a Few Important Tree Species Grown in Agroforestry in India

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Background

Short-rotation plantation wood species are emerging as a major raw material resource due to the ban on felling of trees in the forests. A variety of tree species are cultivated extensively in India under major afforestation programmes. Fast growing wood species are generally grown as plantations under various agroforestry practices in the form of block plantations, dispersed trees on agriculture land, tea/coffee plantations, farmstead, homesteads, social forestry programmes and urban areas as well as tiny woodlots located next to the linear features like roads, canals, and bunds as trees outside forests (TOF).

As most of the agroforestry tree species are fast growing in nature, the wood obtained from such short-rotation agroforestry plantations is different from the mature trees grown in forest. Hence, utilization of the short-rotation fast-grown plantation wood species is also beset with number of problems and requires advanced processing methodologies/techniques. The anatomical microstructure has profound influence on the physical, strength and other properties/wood quality parameters of wood. Various end-uses of timber species prompted studies on their anatomical, physical and strength properties, which provides the information on their suitability to different end use applications. It is important to have data on wood quality parameters in terms of their physical and strength properties and working quality parameters. Such information has practical utility in plantation forestry for determining end use applications of different wood species. Basic data on the properties also helps in predicting the timber behaviour in different usage and provide better understanding of the nature of the material as well as its rational and appropriate utilization. Following description on wood properties, working qualities and end use applications of a few important wood species from the literature is presented below.

1. *Acrocarpus fraxinifolius* Wight (trade name: mundani).

Local name: Mayahnin, nyi, taungdama, yetama (Burm.), belanji, havulige (Kan.), dieng- ji-rep (Kh.), ling-kung (Lep.), karingodi, kurangan, kuranjan, malaveppu, narivenga (Mal.), mandane (Nep.), kurangan, malankonnai, nelrai (Tam.)

Tree: A large deciduous tree with a straight, cylindrical, and often buttressed stem. It reaches 30–36 m occasionally up to 60 m in height and over 3 m in girth, with a clear bole of 45 m.

(a) (b)

Figure 1. (a) A. *fraxinifolius* wood and (b) anatomical microstructure of its cross-section.

Properties: Sapwood and heartwood are sharply differentiated. Sapwood is light yellowish to greyish-white colour, heartwood is light pinkish or reddish-brown with darker streaks. Wood is soft to moderately hard, moderately heavy (sp.gr. 0.52–0.70 air dry); lustrous but turning rather dull with age; straight to slightly interlocked grained occasionally producing ribbon grained figure; coarse textured.

Table 1. Physical and mechanical properties of *A. fraxinifolius.*

Wood properties		*A.fraxinifolius*	Teak
Specific gravity (at 12% moisture content)		0.587	0.604
Radial shrinkage (%)		3.0	2.2
Tangential shrinkage (%)		5.2	4.1
Volumetric shrinkage (%)		9.7	6.5
Modulus of rupture, MOR (kg/cm^2)		1129.83	883
Modulus of elasticity, MOE (1000 kg/cm^2)		136.185	109.68
Maximum crushing stress (kg/cm^2)		557.18	487
Compressive stress at elastic limit (kg/cm^2)		126.55	97.0
Hardness (kg)	Side	1109.94	469
	End	972.95	462
Shear (kg/cm^2)	Radia	1126.55	98.5
	Tangentia	1133.58	104.9
Tension (kg/cm^2)	Radial	36.56	53.5
	Tangential	76.28	64.8

Working qualities: The timber is easy to saw and work. Sometimes clogging of the saw is said to occur due to the resinous nature of the wood. It finishes well and takes a high polish and the quarter sawn surface has attractive appearance. The timber can be peeled easily without any pre-treatment and is also very amenable to gluing.

Uses: The timber is used for planking, flooring and shingles, furniture, heavy packing cases, crates, boxes and plywood for tea chests. Suitable for life-boat oars and may also do well for floating fenders in harbours. After treatment, it can be used for railway sleeper, leaves of doors and windows.

2. *Artocarpus heterophyllus* Lamk. Syn. *A. integrifolia* Linn. F. (trade name: kathal)

Local names: Kanthol (Beng.), alasu, halasu (Kan.) pilavu (Mal.). phanas (Mar.) pilapalam (Tam.), panasa (Tel.). **Tree:** A large evergreen tree.

(a)

(b)

Figure 2. (a) A. *heterophyllus* wood and (b) anatomical microstructure of its cross-section

Properties: Sapwood yellowish-white to greyish-white or grey; heartwood yellowish-brown to golden-brown with darker streaks, turns dark brown on exposure, lustrous when fresh, soft to moderately hard to hard, light to moderately heavy or heavy (sp. gr. 0.33–0.85), straight to interlocked-grained and coarse-textured.

Working qualities: Easy to saw, plane, turn and finish. **Uses:** general carpentry woods, much in demand in building, construction for beams, rafters, windows and door frames, furniture and cabinet work, specified for brush backs, drawing equipments, mallet heads, tent accessories, artificial limbs and turnery.

Table 2. Physical and mechanical properties of *A. heterophyllus*

Wood properties		*A.heterophyllus*	Teak
Specific gravity at 12% moisture content		0.531	0.604
Radial shrinkage (%)		2.5	2.2
Tangential shrinkage (%)		5.6	4.1
Volumetric shrinkage (%)		8.5	6.5
Modulus of rupture, MOR (kg/cm^2)		693.2	883.0
Modulus of elasticity, MOE (1000 kg/cm^2)		94.6	109.7
Maximum crushing stress (kg/cm^2)		372.6	487.0
Compressive stress at elastic limit (kg/cm^2)		232.7	97.0
Hardness (kg)	Side	514.8	469.0
	End	503.54	62.0
Shear (kg/cm^2)	Radial	92.8	98.5
	Tangential	95.6	104.9
Tension (kg/cm^2)	Radial	44.3	53.5
	Tangential	49.2	64.8

3. *Azadirachta indica* A. Juss. (trade name: neem)

Local names: Neem (Beng. & Hindi.), limba, libado (Guj.), bevu, bevina (Kan.), veppu (Mal.), limba nimbay (Mar.), vepa (Tam.), yapa (Tel.).

Tree: A medium sized to large tree, up to 2–2.5 m in girth.

Properties: Sapwood yellow to yellowish-grey, turns pale yellowish brown on exposure; heartwood reddish to reddish-brown darkening on exposure; wood somewhat lustrous; hard to very hard; usually heavy (sp.gr. 0.72–0.83 air-dry); interlocked grained; sometimes exhibiting ribbon-grain effect on the longitudinal surface; usually medium to somewhat coarse textured; when fast grown fine in texture; aromatic when fresh.

Working qualities: The timber is not difficult to saw and work. It can be turned on a lathe and can be brought to a fair finish. The wood is suitable for carving but does nottake good polish.

Uses: The timber is mainly used in making carts, furniture and cabinets, carving of images of gods, toys, agricultural implements and for general carpentry.

Figure 3. (a) A. indica wood and (b) anatomical microstructure of its cross-section.

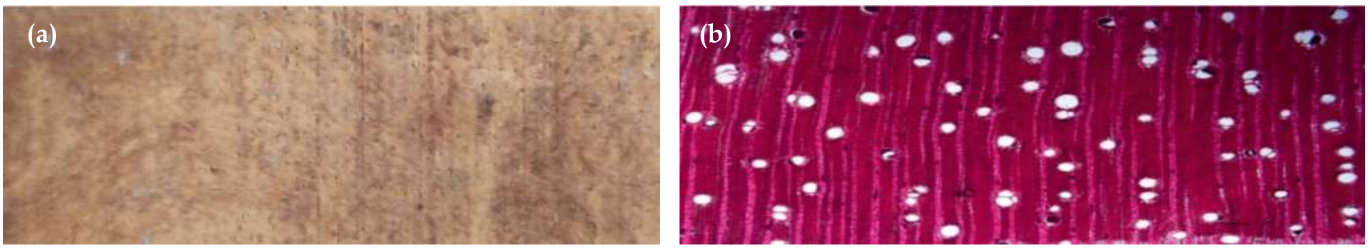


Table 3. Physical and mechanical properties of *A. indica.*

Wood properties	*A.indica*	Teak
Specific gravity at 12% moisture content	0.740	0.604
Radial shrinkage (%)	4.5	2.2
Tangential shrinkage (%)	6.2	4.1
Volumetric shrinkage (%)	11.6	6.5
Modulus of rupture, MOR (kg/cm^2)	551.0	883.0
Modulus of elasticity, MOE (1000 kg/cm^2)	84.8	109.7
Maximum crushing stress (kg/cm^2)	406.0	487

4. *Dalbergia sissoo* Roxb. (trade name: sissoo)

Local names: Shishma, (Assam, Guj., Hindi), agara, agaru (Kan.), iruvil (Mal.), gette, yette (Tam.), errasissu, sinsupa (Tel.).

Tree: A tree with somewhat crooked bole, attains a height of 30 m in height and 2.5 m in girth, but timber with clear length and in large girths are usually not available.

Properties: The sapwood is pale yellow or greyish white sharply demarcated from the golden brown to deep brown heartwood with darker streaks. It is a hard and heavy wood (sp. gr. 0.63–0.83 air-dry) with medium coarse texture and straight to interlocked grain.

(b) **Figure 4.** (a) *D. sissoo* wood (a) and (b) anatomical microstructure of its cross-section.

Table 4. Physical and mechanical properties of *D. sissoo.*

Wood properties		**D. sissoo**	**Teak**
Specific gravity at 12% moisture content		0.700	0.604
Radial shrinkage (%)		2.5	2.2
Tangential shrinkage (%)		4.5	4.1
Volumetric shrinkage (%)		9.0	6.5
Modulus of rupture, MOR (kg/cm^2)		1028.0	883.0
Modulus of elasticity, MOE (1000 kg/cm^2)		130.0	109.68
Maximum crushing stress (kg/cm^2)		498.0	487.0
Compressive stress at elastic limit (kg/cm^2)		133.0	97.0
Hardness (kg)	Side	749.0	469.0
	End	832.0	462.0
Shear (kg/cm^2)	Radial	125.0	98.5
	Tangential	102.0	104.9
Tension (kg/cm^2)	Radial	84.0	53.5
	Tangential	60.0	64.8
Nail holding power (kg)	Side	195.0	89.0
	End	146.0	71.0
Screw holding power (kg)	Side	420.0	398.0
	End	312.0	294.0

Working qualities: The timber is easy to saw and work except when the grain is excessively interlocked; turns well and good for carving. It takes good polish but requires a filler. The wood is very similar to rosewood in properties.

Uses: The timber is most popular in north India for furniture and cabinet making as well as for carving and engraving. It is a popular timber for printing blocks and used for turnery articles like bed legs and hookahs. It is suitable for shoe lasts and the root wood of sissoo is suitable for tobacco pipes. Also used for leaves of doors and windows. This wood is suitable for high class furniture, door and window frames, shutters, tool handles, heavy duty utility block flooring, parquet and board flooring. It is also suitable for cabinet making and carving.

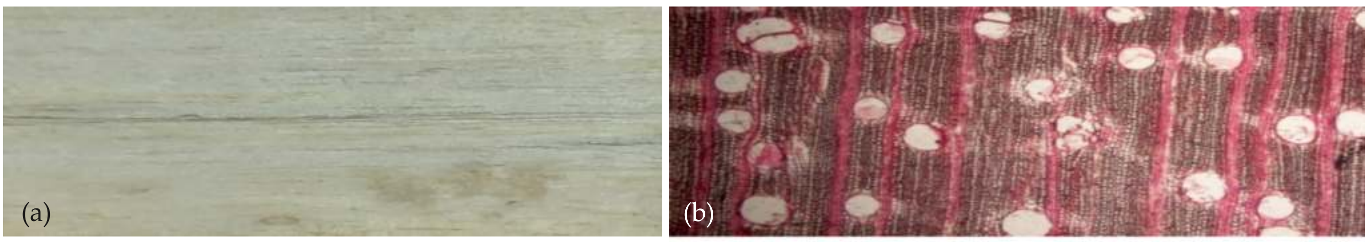


Figure 5. (a) G. arborea wood and (b) anatomical microstructure of its cross-section.

5. *Gmelina arborea* Roxb. (trade name: gamari)

Local names: Shwan, sinog (Guj), shivan (Hindi. Mar.), kulimavu, shivani, umi (Kan.), kumbil (Mal.), gamhari (Or.), gummadi (Tam.), Gummertek (Tel.).

Tree: A tree of variable habit; in Bengal and Assam it is usually 12–18 m in height with a clear bole of 4.5–7.5 m and a girth of 1.5–2 m.

Properties: Heartwood not distinct from sapwood in colour. Wood pale yellow to cream coloured or pinkish-buff when fresh, turns yellowish-brown on exposure; soft to moderately hard; light to moderately heavy (sp.gr. 0.39–0.66 air-dry), lustrous when fresh, usually straight to irregular or rarely wavy-grained and medium coarse-textured. Working **qualities:** Timber is easy to saw and work, and fairly good in turning and boring.

Uses: Used for bentwood articles. It is a popular timber for turnery articles and toys. Door and window panels, joinery, furniture, plywood and block boards.

Table 5. Physical and mechanical properties of *G. arborea.*

Wood properties		G. arborea	Teak
Specific gravity at 12% moisture content		0.445	0.604
Radial shrinkage (%)		2.7	2.2
Tangential shrinkage (%)		4.8	4.1
Volumetric shrinkage (%)		8.8	6.5
Modulus of rupture, MOR (kg/cm^2)		532.6	883
Modulus of elasticity, MOE (1000 kg/cm^2)		75.9	109.68
Maximum crushing Stress (kg/cm^2)		244.7	487
Compressive stress at elastic limit (kg/cm^2)		157.5	97.0
Hardness (kg)	Side	258.6	469
	End	313.0	462
Shear (kg/cm^2)	Radial	75.2	98.5
	Tangential	70.0	104.9
Tension (kg/cm^2)	Radial	42.5	53.5
	Tangential	48.9	64.8

Table 6. Physical and mechanical properties of *G. robusta.*

Wood properties		G. robusta	Teak
Specific gravity at 12% moisture content		0.525	0.604
Radial shrinkage (%)		2.6	2.2
Tangential shrinkage (%)		6.0	4.1
Modulus of rupture, MOR (kg/cm^2)		742	883
Modulus of elasticity, MOE (1000 kg/cm^2)		92.4	109.7
Maximum crushing stress (kg/cm^2)		336	487
Compressive stress at elastic limit (kg/cm^2)		54.9	97.0
Hardness (kg)	Side	348.5	469
	End	433	462
Shear (kg/cm^2)	Radial	67.6	98.5
	Tangential	78.1	104.9
Tension (kg/cm^2)	Radial	415	3.5
	Tangential	48.6	64.8
Nail holding power (kg)	Side	44.9	89
	End	35.7	71
Screw holding power (kg)	Side	100.7	398
	End	46.1	294

6. *Grevillea robusta* A. Cunn. (trade name: sillver oak)

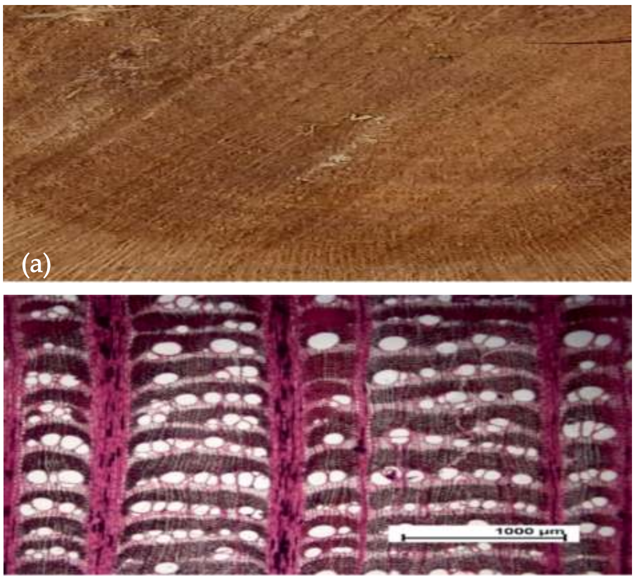
Local name: Savukkumaram (Tam.)

Tree: It is a tall beautiful evergreen tree with long conical crown and dark grey, rough bark. It has been planted in several parts of India.

Properties: The sapwood is greyish-white, and the heartwood is light reddish-brown. It is a moderately hard and moderately heavy wood (air-dry weight 640 kg/m^3), with coarse texture and straight grain, having prominent silver grain figure on radial surface.

Working qualities: The timber seasons without any degrade provided it is protected against rapid drying. It is durable for indoor work. It is an easy timber to saw and work and also turns well. The wood works well with hand and machine tools and dresses smoothly. It takes good polish and glossiness can be obtained by application of artificial films of finish.

Uses: The timber is suitable for joinery, furniture, parquet flooring, turnery and light construction work. The timber is also used in pencil making, slate frame, plywood and several other wood industries. The timber can be carved, veneered, bent and glued with equal readiness. The timber is usually used for panelling and general carpentry in house building. It is also used for cores of block broads and flush doors, and for decorative plywood.



(b) **Figure 6.** (a) *G. robusta* wood and (b) anatomical microstructure of its cross-section.

7. *Mangifera indica* Linn. (trade name: mango)

Local names: Ghari am (Asm.), am (Beng.), amb-nujhada (Guj.), am, amba, ambi (Hindi), mavena mara, mavu (Kan.), amram, manna, mavu (Mal.), amba, ambi (Mar,), manga, mamaram (Tam.), amramu, mamadi, mavi (Tel.)

(b) **Figure 7.** (a) *M. indica* wood and (b) anatomical microstructure of its cross-section.

Tree: A medium to large evergreen tree with a short unbuttressed trunk and spreading crown, 12–18 m high and 1.0–2.5 m in girth with a 4.5–9.0 m clean bole, sometimes attaining a height of 45 m.

Working qualities: Mango is a soft and easy wood to saw and machine, finishes to a moderate surface, and with proper filling takes a good and lasting polish.

Uses: Cheap furniture, lining, backing and shelf boards, floor and ceiling boards, planking, door and window frames, and general carpentry. The figured stock (curly grained) is suitable for high grade furniture and cabinet work. Other important uses are light and heavy packing cases, ammunition boxes, rifle and tool chests, agricultural implements, foot boards, bottom and frames of carts, hulls of boats, oar blades and dry cooperage. It is suitable for carving and turnery and is largely used for making various types of wooden utensils, particularly for bowls, spoons and plates and is also suitable for certain type of bobbins.

Table 7. Physical and mechanical properties of *M. indica.*

Wood properties		M. indica	Teak
Specific gravity at 12% moisture content		0.590	0.604
Radial shrinkage (%)		3.0	2.2
Tangential shrinkage (%)		4.9	4.1
Modulus of rupture, MOR (kg/cm^2)		891.49	883
Modulus of elasticity, MOE (1000 kg/cm^2)		110.94	109.7
Maximum crushing stress (kg/cm^2)		437.66	487
Compressive stress at elastic limit (kg/cm^2)		272.08	97.0
Hardness (kg)	Side	495.32	469
	End	623.68	462
Shear (kg/cm^2)	Radial	90.34	98.5
	Tangential	97.37	104.9
Tension (kg/cm^2)	Radial	36.91	53.5
	Tangential	22.15	64.8

8. *Melia dubia* Willd. (trade name: Malabar neem)

Local names: Aming-gok, gingsimok (garo), hebbevu (Kan.), dieng-jarasanh, soh-dieng-lang (Kh.), silot-kung (Lep.), Kattuveppu (Mal.), kuriaput, limbara, nimbara (Mar.), hanti-pli-arong (Mik.), mahalimbu (Or.), malai vembu, masa veppu (Tam.), munnuthikaraka (Tel.).

Tree: A large deciduous tree up to 20 m in height with a clear bole of 9 m. and 1.8 m in girth.

Properties: Sapwood greyish-white when fresh; heartwood light pink to reddish-white, soft, light to moderately heavy, (sp.gr. 0.4–0.5 air-dry), straight-grained, uneven and medium coarse textured, somewhat lustrous when fresh.

Working qualities: Easy to saw and work, both by hand or machine and can be brought to a smooth finish. Found to take good polish, easy to cut, easy to turn, satisfactory smooth finish and suitable for lacquerware craft.

Uses: Timber is found to be ideal for plywood manufacture. The timber is suitable for applications such as tool handles, construction, musical instruments, sports goods, furniture and toys besides its wider potential application in wood panel-based industry and packing cases. It is important resource for plywood and pulp industries.

Table 8. Physical and mechanical properties of *M. dubia.*

Wood properties		M. dubia	Teak
Specific Gravity at 12% moisture content		0.463	0.604
Radial shrinkage (%)		5.6	2.2
Tangential shrinkage (%)		13.2	4.1
Volumetric shrinkage (%)		19.9	6.5
Modulus of rupture, MOR (kg/cm^2)		820	883
Modulus of elasticity, MOE (1000 kg/cm^2)		93.1	109.7
Maximum crushing stress (kg/cm^2)		377	487
Compressive stress at elastic limit (kg/cm^2)		316	97.0
Hardness (kg)	Side	306	469
	End	277	462
Shear (kg/cm^2)	Radial	91.1	98.5
	Tangential	94.2	104.9
Tension (kg/cm^2)	Radial	40.5	53.5
	Tangential	41.9	64.8
Nail holding power (kg)	Side	85	89
	End	62	71
Screw holding power (kg)	Side	212	398
	End	163	294

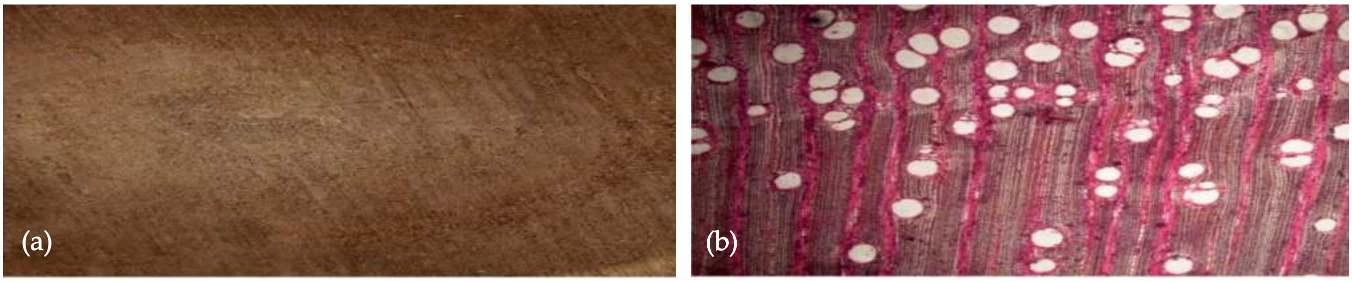


Figure 8. (a) *M. dubia* wood disc and (b) anatomical microstructure of its cross-section.

9. *Swietenia macrophylla* King. (trade name: mahogany)

Tree: A large to very large evergreen tree. In its natural habitat, it sometimes grows to a very large size reaching up to 45 m in height with a clear bole of 18–24 m. and 3–3.5 m in diameter, the average being 1–2 m. In India under favourable conditions, the tree grows fast and may reach a height of 30 m. with a girth of about 2.5 m. in 39 years.

Properties: Sapwood yellowish-white to pale brownish-grey; heartwood usually pinkish when fresh, darkening on exposure to varying shades of red-brown to brick red, often with a satiny or golden lustre, usually moderately hard and medium coarse to somewhat fine textured.

Working qualities: It is one of the foremost timbers among the hardwoods from the point of natural beauty and working qualities. It can be easily worked by hand or machine with very little ill-effects on the tools. Based on the results of tests like planning, boring, shaping, turning etc. Mahogany can be ranked among first-grade timbers. It finished extremely well particularly when the timber is straight grained and takes a high polish on account of which the timber has come into special prominence in the furniture industry in Europe and America holding a premier position among the high-class cabinet woods. Due to its pleasing colour, lusture and grain, the timber produces a beautiful figure well-known in the timber trade.

Uses: Excellent wood for veneer and plywood work and can be peeled without any soaking treatment. Home and office furniture, fixtures, panelling and ship building.

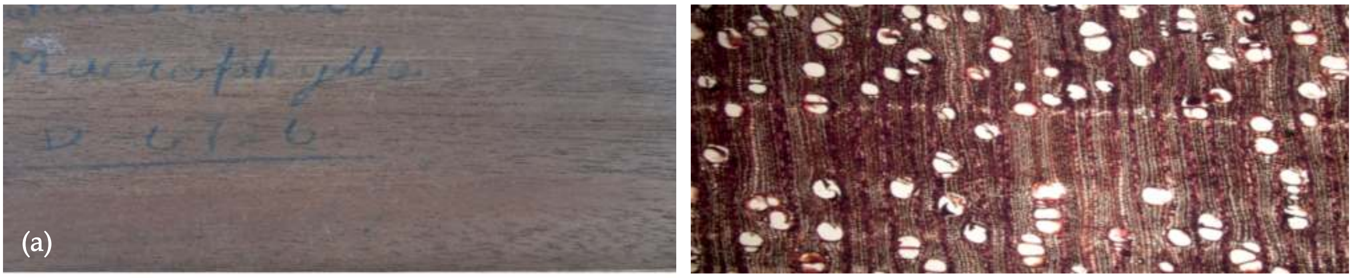


Figure 9. (a) *S. macrophylla* wood and (b) anatomical microstructure of its cross-section

10. *Tectona grandis* Linn. F. (trade name: teak)

Local names: Segun (Beng.), saga, sagach (Guj.), sagwan, sagon (Hind.) tega (Kan.), tekku, thekku (Mal.), saga, sagwan (Mar.), tekku, tekkumaram (Tam.), adaviteeku, peddateeku (Tel.).

Tree: A deciduous tree with a rounded crown which under favourable condition attains large size with a clean cylindrical bole often becoming buttressed and fluted towards the base.

Properties: Sapwood white or pale yellow; heartwood light golden-brown when fresh, turning brown or dark brown on exposure, with an oily feel and characteristic odour reminiscent of old leather when fresh, moderately hard, moderately heavy (sp. gr. 0.51–0.77 air dry); usually fairly straight grained, but the samples from the drier regions often exhibit rather irregular grain; coarse and uneven-textured.

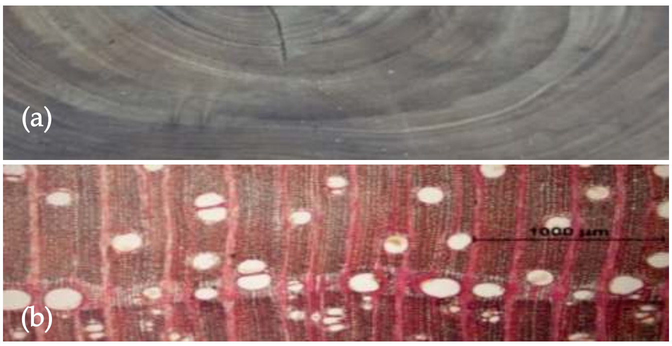


Figure 10. (a) *T. grandis* wood disc and (b) anatomical microstructure of its cross-section.

Table 9. Physical and mechanical properties of *T. grandis.*

Wood properties		Teak
Specific gravity at 12% moisture content		0.604
Radial shrinkage (%)		2.2
Tangential shrinkage (%)		4.1
Volumetric shrinkage (%)		6.5
Modulus of rupture, MOR (kg/cm^2)		883
Modulus of elasticity, MOE (1000 kg/cm^2)		109.7
Maximum crushing stress (kg/cm^2)		487
Compressive stress at elastic limit (kg/cm^2)		97.0
Hardness (kg)	Side	469
	End	462
Shear (kg/cm^2)	Radial	98.5
	Tangential	104.9
Tension (kg/cm^2)	Radial	53.5
	Tangential	64.8
Nail holding power (kg)	Side	89
	End	71
Screw holding power (kg)	Side	398
	End	294

Working qualities: Relatively easy wood to saw and work and operate well in most of the common wood working operations. It is one of the best timbers for mortising, fairly good for boring. The timber can be glued satisfactorily on freshly machined or newly sanded surface. Teak does not corrode metals and takes nail and screws fairly-well. It takes polish well and by the application of artificial films of finish glossiness can be achieved.

Uses: Engraving, carving, vases, god's statues, toys, photo frames, home decor, boxes, furniture, etc.

References: contact author at srshukla@icfre.org.

Agroforestry Systems for Sustainable Wood Production and Livelihood Improvement of Farmers

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1. Introduction

Land-use options that increase livelihood security and reduce vulnerability to climate and environmental change are necessary. Traditional resource management adaptations, such as agroforestry systems, may potentially provide options for improvement in livelihoods through simultaneous production of food, fodder and firewood as well as mitigation of the impact of climate change. Agroforestry is a land-use management system in which trees or shrubs are grown around or among crops or pastureland. This intentional combination of agriculture and forestry has varied benefits, including increased biodiversity and reduced erosion. This integration is intended to diversify production systems to create environmental, economic, and social benefits through complementary interactions between the system components. The benefits of agroforestry are reduced poverty through increased production of wood and other products, increased food security by restoring soil fertility for food crops, multifunctional site use, reduced global warming and hunger risk by increasing the number of drought-resistant trees and the subsequent production of fruits, nuts and edible oils, reduced deforestation and pressure on woodlands by providing farm-grown fuel wood, reduced need for toxic chemicals, improved human nutrition through more diverse farm outputs, growing space for medicinal plants, etc. Agroforestry has been a solution to environmental problems as well as to many social ills. Agroforestry bridges the gap that often separates agriculture and forestry by building integrated systems that address both environmental and socioeconomic objectives. Agroforestry can improve the resiliency of agricultural systems and mitigate the impacts of climate change. Agroforestry has received much attention in India from researchers, policy makers and others for its perceived ability to contribute significantly to economic growth, poverty alleviation and environmental quality. Today, agroforestry is an important part of the 'Evergreen Revolution' movement in the country.

2. Agroforestry systems in India

Agroforestry practices in India have existed since time immemorial and are evidenced in all parts of the state with little or no scientific management. In India, just as there is great diversity in climate, there is also a great diversity in agroforestry systems of various forms and types. There are three basic types of Agroforestry systems viz., Agrisilviculture (Crops+trees), Silvopastoral (Pasture/animal+trees); and Agrosilvopastoral (crops+pasture + trees).

I. Agrisilviculture system: Here agricultural crops are inter-cropped with tree crops in the inter-space between the trees. Agricultural crops can be grown for up to two years under irrigated conditions and up to four years under rain-fed conditions in this system. The crops can be grown profitably up to the above-mentioned period, beyond which it is uneconomical to grow grain crops. However, fodder crops, shade loving crops and shallow rooted crops can be grown economically. Wider spacing is adopted without sacrificing tree population for easy cultural operation and to get more sunlight to the inter-crop. Performance of the tree crops is better in this system when compared to monoculture.

II. Silvopastural system: The production of woody plants combined with pasture is referred to as the silvopastoral system. The trees and shrubs may be used primarily to produce fodder for livestock or they may be grown for timber, fuel wood, fruit or to improve the soil. This system is classified into three categories viz., Protein bank, Live fence of fodder trees and hedges and Trees and shrubs on pasture.

a) Protein bank: Various multipurpose trees (protein rich trees) are planted in or around farmlands and range lands in this Silvipastoral system for cut-and carry fodder production to meet the feed requirements of livestock during the fodder deficit period in winter. Example: *Acacia nilotica, Albizia lebbeck, Azadirachta indica, Leucaena leucocephala, Gliricidia sepium, Sesbania grandiflora, etc.*

b) Live fence of fodder trees and hedges: In this system, various fodder trees and hedges are planted as live fences to protect the property from stray animals or other biotic influences. Example: *Gliricidia sepium, Sesbania grandiflora, Erythrina sp, Acacia sp., etc.*

c) **Trees and shrubs on pasture:** In this system, various tree and shrub species are scattered irregularly or arranged according to some systemic pattern to supplement forage production. Example: *Acacia nilotica, Acacia leucophloea ,Tamarindus indica, Azadirachta indica, etc.*

III. Agro silvopastoral system: The production of woody perennials combined with annuals and pastures is referred as Agro silvopastoral system. This system is grouped into two categories viz., Home gardens and Woody hedgerows for browse, mulch, green manure and soil conservation.

a) Home gardens: This system is found extensively in high rainfall areas in tropical South and South-East Asia. This is practised in the states of Kerala and Tamil Nadu which have humid tropical climates where coconut is the main crop. Many species of trees, bushes, vegetables and other herbaceous plants are grown in dense and random, or spatial and temporal arrangements. Most home gardens also support a variety of animals. Fodder grass and legumes are also grown to meet the fodder requirements of cattle.In India, every homestead has around 0.20 to 0.50 ha of land for personal production.

b) Woody hedgerows: In this system various woody hedges, especially fast growing and coppicing fodder shrubs and trees are planted for the purposes of browse, mulch, green manure, soil conservation etc. The following species *viz., Erythrina sp, Leucaena luecocephala, Sesbania grandiflora* are generally used.

IV. Other systems:

a) **Apiculture with trees:** In this system various honey producing trees frequently visited by honeybees are planted on the boundary of the agricultural fields.

b) **Aquaforestry:** In this system various trees and shrubs preferred by fish are planted on the boundary and around fish ponds. Tree leaves are used as feed for fish. The main role of this system is fish production and bund stabilization around fish ponds.

c) **Mixed wood lots:** In this system, location specific Multipurpose Trees (MPTs) are grown together or separately planted for various purposes such as

Table 1. Major Agroforestry systems followed in India.

Agro Forestry Systems	Agroecological region adaptations
Agrisilvicultural systems	
Shifting cultivation	In tropical forest areas
Taungya	In all regions
Plantation-based cropping system	Mainly humid tropical regions
Scattered trees on farms, park lands	All regions, especially semiarid and arid regions
Shelterbelts and windbreaks	In wind-prone areas, especially coastal , arid, and alpine regions
Boundary planting and live hedges	In all regions
Woodlots for soil conservation	In hilly areas, along sea coast and ravine lands
Industrial plantations with crops	Intensively cropped area in northern and southern India
Silvo-pastoral systems	
Silvipastures	Sub tropics and tropics with bio-edaphic sub climaxes
Horti-pastoral	In hilly orchards for soil conservation
Tree on rangelands	In all regions
Plantation crops with pastures	Mostly humid & Sub-humid regions of south regions of south East Asia and South with less grazing pressure on plantation lands
Seasonal Forestry Grazing	Semi-arid and mountainous ecosystem
Agro-silvo-pastoral systems	
Home gardens	Mainly tropical region
Others	
Aqua forestry	Low Lands
Apiculture with trees	In all regions

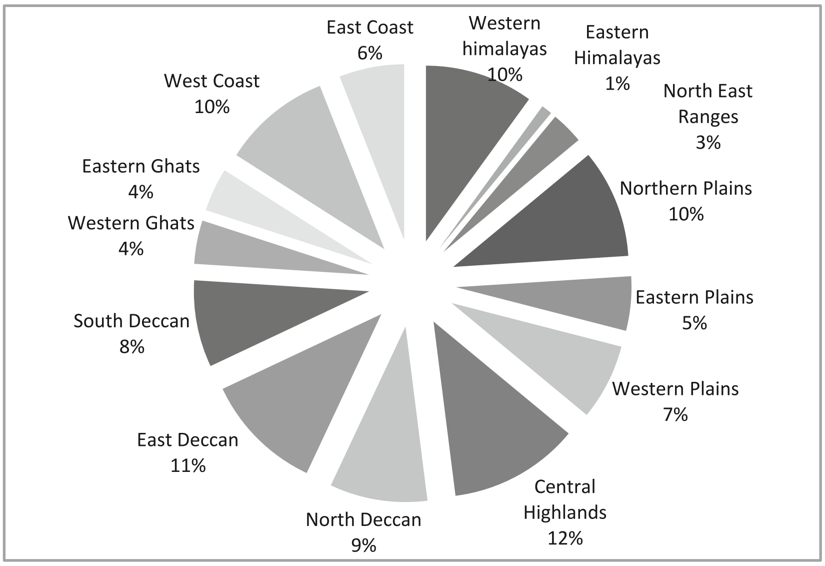


Figure 1. Physiographic zone–wise agroforestry areas in India

wood, fodder, soil conservation , soil reclamation etc.

The current area under agroforestry in India is estimated at 25.31 million hectares, or 8.2% of the total reporting geographical area of the country. India is estimated to have between 14,224 and 24,602 million trees outside forests, spread over an equivalent area of 17 million hectares (ha), supplying 49% of the 201 million tonnes of fuel wood and 48% of the 64 million cubic meter of timber consumed annually by the country. The Forest Survey of India previously estimated that there are 2.68 billion trees in agroforestry across an area of 9.99 million hectares. More recent estimates suggest that an equivalent area of 92,769 km^2 (i.e., 2.82% of the geographical area) is under tree cover in India. The current growing stock has been estimated at about 1.616 billion m^3. Trees in agroforestry have increased the extent of area under forest and tree cover to 6.63 percent. These plantations sustain about 670 wood-based veneer, plywood and board, manufacturing units, one large paper mill and about 4300 sawmills that depend on agroforestry produce. Similarly, the case of Kerala suggests that the state has a surplus of 0.027 million m^3 of wood in terms of consumption, and the total wood production in the state is 11.714 million m^3.

3. Functions and benefits of agroforestry systems

Agroforestry systems are used in a variety of different ecological and economic conditions. All agroforestry systems are based on two functions, productive and protective functions. Under the productive function category, it provides food, fodder, fuel wood, clothes, shelter and Au: expand... (NTFPs). Under the protective function category, agroforestry systems will act as wind breaks, shelter belts, soil conservation and soil improvement. Further, under socioeconomic conditions, agroforestry systems will be classified as commercial agroforestry systems (used whenever the scale of the production of the output is high), intermediate agroforestry systems (between commercial and subsistence scales of production and management) and subsistence agroforestry systems (the use of land is directed towards satisfying basic needs and is managed mostly by the owner and his family). Under ecological classification, agroforestry systems will be classified as Humid/sub humid, Semiarid/arid Highlands.

4. Agroforestry and wood production

By spearheading agroforestry through systematic plantations, they have played an important role in catering to more than 80% of the domestic timber demand for furniture and stabilizing the forest and tree cover of the country. The well-defined harvesting cycle of various important agroforestry tree species also provides an excellent opportunity to lock the carbon sequestered in the form of furniture and re-use the land for additional carbon sequestration through new plantations. At present, agroforestry meets almost half of the demand for fuel wood, two thirds of that for small timber, 70–80% wood for plywood, 60% raw material for paper pulp and 9–11% of the green fodder requirement of livestock, besides meeting the subsistence needs of households for food, fruit, fibre, medicine etc. Agroforestry practices have shown that by carefully selecting tree-crop combinations, productivity can be safely increased to 10 tons/hectare/year..

5. Industrial agroforestry

Technology based farm-forestry plantations with genetically improved, high yielding and fast growing clonal planting stock of various species have tremendous potential to meet the growing shortages of industrial timber on a sustainable basis. The steady decline in supply of industrial round wood from government-owned forests, rising demand from wood-based industries, and commercial-scale introduction of genetically improved, field-tested, and high-yielding clones of various species supported by technical extension services have accelerated the expansion of agroforestry plantations in many Indian states. Scientifically managed agroforestry plantations, based on genetically improved clonal planting stock, have ensured unprecedented improvements in the productivity of plantations and the quality of their timber, ensuring far better net returns to farmers compared to returns from traditional crops. The average productivity of clonal Eucalyptus and Poplar plantations at 5-6 years is 20-25 tonnes per hectare. However, many farmers have achieved 100 tons/hectare from such clones, confirming the tremendous potential of agroforestry plantations to meet our national needs for timber and fuel wood.

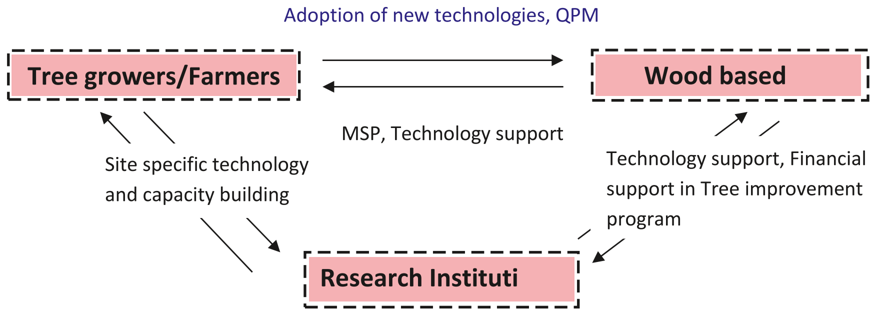
6. National Agroforestry Policy (2014)

India is the first country in the world to introduce a separate policy for 'Agroforestry'. The National Agroforestry Policy of 2014 came into the spotlight to address the issues of quality planting material, tree insurance, restrictions on transit, marketing of agroforestry produce, research and extension. The policy aims to bring coordination, convergence and synergy among various elements of agroforestry scattered in various existing missions, programme, and schemes. Thus improving the productivity, employment, income and livelihood opportunities of rural households, especially of smallholder farmers along with meeting the ever increasing demand for timber, food, fuel, fodder, fertilizer, fibre, and other agroforestry products. Moreover, agroforestry is the only viable option to achieve the 33% of green cover required by the National Forest Policy (1988). In the present day context, considerable funding is required for agroforestry projects to enhance the productivity and sustainability of smallholders' agroforestry. The new policy talks of coordination, convergence and synergy between various elements of agroforestry, scattered across various existing missions, programme and schemes under different ministries; agriculture, rural development and environment. The policy also discusses amending unfavorable legislation and simplifying regulations relating to forestry and agriculture.

7. Value chain based agroforestry systems

Agroforestry provides ample opportunity for the bio-economy and for the support of forest based industries, hence plays an important role in shifting India towards an innovative, resource efficient and bio-based economy. Agroforestry value chain involves activities such as harvesting, cleaning, transport, design, processing, production, transformation, packaging, marketing, distribution and support services. Such activities are important to add value to a product as it moves along the chain from the local to the global level. In the value chain, all the stakeholders involved in agroforestry systems are brought together under a single platform that will benefit each other. The roles and responsibilities of various institutions in the agroforestry value chain are clearly defined in order to achieve the objectives. In the value chain, the role of each stakeholder is specified and aimed to achieve 33% tree cover through agroforestry, maximum benefit to farmers, reduction in the import of wood and wood products, etc. It is important to develop a well-structured market for agroforestry products mainly for trouble-free sales and quick economic returns to the tree-growers.

The value chain in industrial agroforestry plays a major role in the marketing of agroforestry products. In this value chain, wood-based industries are coming forward to accept the agroforestry products with assured marketing and MSP. Also, they have entered into MoUs with the tree-growers, which will encourage the latter towards the adoption and expansion of agroforestry in a larger area. These industrial approaches influence/motivate farmers to adopt agroforestry practices on a large scale. The private-public-partnership (PPP) in agroforestry is also gaining traction in the state, with the goal of delivering harvested agroforestry products from farms to industry at market rates with a buy-back guarantee. The agroforestry consortium also identifies appropriate farmlands for plantations with various industrial tree species, and improves the interface between farmers and industries for better market linkage. The goal and objectives of the value chain in agroforestry are networking and establishing linkages with all stakeholders to augment the production to consumption system, promoting effective collaboration among public agencies, private industries and organizations engaged in industrial agroforestry. In addition to this, other goals include developing suitable research and development (R&D) mechanisms for industrial agroforestry and formulating policy guidelines for the promotion of agroforestry among farmers.



8. Agroforestry research in India

Agroforestry research in the country is more than 100 years old, and there has been research on forage/firewood plantations since the 1950s. In India, the practice of growing scattered trees on farmlands is quite old and has not changed much over the centuries; these trees are used for multipurpose such as for shade, fodder, fuel wood, fruit, vegetables and medicinal uses. The agroforestry systems in India include trees on farms, community forestry, and a variety of local forest management and ethnoforestry practices. Besides, India has been at the forefront ever since organized research on agroforestry was started worldwide. Agroforestry research in India was initiated more than a hundred years ago with trials on tree-crop interactions in the tea estates, studies on silvopastoralism, intercropping experiments in plantation crops and succession studies in the ravines.

A diagnostic survey and appraisal, initiated in the early eighties under the AICRP on agroforestry, revealed that agroforestry practices abound in the country. Agroforestry initiatives also resulted in a significant amount of wood production outside the forest lands and promoted rural industrialization in certain localities, which benefited small landholders and marginal farmers. The institutes of the ICFRE have done significant research in the field of agroforestry and the same has been demonstrated successfully in farmers field's for further expansion and adoption on a large scale. The technical knowledge produced by ICFRE to utilize the multi purpose trees in agroforestry systems has made it an attractive option for State Forest Departments, NGOs and farmers.

Table 2. Agroforestry models developed by ICFRE for various agro-climatic zones of India.

Region	Agroforestry models developed
Trans Himalayan Region	1. Salix fragilis and S. alba, Populus. euphratica, P. alba, P. nigra based agroforestry model and 2. Apple (Pyrus malus) based horti-medicinal model.
Western Himalayan Region and Indo-gangetic Plains	1. Melia composite - Emblica officinalis based agri-silvimedicinal model 2. Populus deltoides based agri-silviculture 3. Populus deltoides based silviculture-medicinal models 4. Melia composite based agri-silviculture model 5. Eucalyptus teriticornis-Wheat/Paddy silvi-block model 6. Populus deltoides-Wheat agroforestry model.
Eastern Himalayan Region	1. King chilli (Capsicum annuum)-Arecanut based hortispice model 2. Gmelina arborea based agri-silvi agroforestry model
Gangetic Plain Region	1. Populus deltoids -Wheat agri-silviculture model 2. Populus deltoids - Maize agri-silviculture model 3. Populus deltoids -Banana silvihorticulture model 4. Populus deltoids - Turmeric agrisilviculture model 5. Populus deltoids - Jimikand (Pachyrhizus erosus) silvihorticulture model
Plateaus	1. Tectona grandis -Turmeric silvimedicinal model 2. Bamboo based silvi-agri model 3. Bach (Acorus calamus) - Paddy agri-medicinal model 4. Flemingia based silvi-agrilac model 5. Agri-lac culture model 6. Babul (Acacia nilotica) - Paddy model 7. Sandalwood-Teak-Eucalyptus-Redsanders based silvi-agri model 8. Sandalwood (Santalum album) based agroforestry model

Western Dry Region	1. Hardwickia binata based agroforestry model 2. Emblica officinalis based agroforestry model 3. Colophospermum mopane based agroforestry model 4. Prosopis cineraria-Zizyphus mauritiana agroforestry model
Coastal Plains and Ghats	1. Casuarina equisetifolia - Maize agrisilviculture Model 2. Casuarina equisetifolia – Moringa - Maize agri-silvi-horticulture model 3. Acacia auriculiformis-Napier grass silvi-pasture model 4. Tectona grandis-Phaseolus mungo agri-silviculture modelv. Acacia mangium-Beans (Vigna species) agri-silviculture model 5. Acacia mangium -Pepper silvi-horticulture model vi. Acacia mangium -Pepper silvi-horticulture model vii. Casuarina spp. based windbreak agroforestry model

9. Agroforestry - Scope and opportunities

Agroforestry systems in India include both traditional and modern land use systems and have significant potential and use in many aspects like providing employment to rural as well as urban populations through production, processing and value addition. According to an estimate, one ha of the plantation in wood-based industries creates about 450 man-days of employment, thus, 30 million ha have the potential to create approximately 15,000 million man-days of employment besides creating job opportunities in the wood based value chain. Agroforestry is the only viable option to increase forest and tree cover to 33% of the total geographical area of the country. There is scope for increasing the area under agroforestry by another 28.0 m ha for a total of 53.23 m ha or 17.5% of the country's reported area under agroforestry. Most of this area will come from fallows, cultivable fallows, groves, degraded and wasteland and has the potential to change the fortunes of small and marginal farmers and rural people by providing the resources to meet livelihood and food security along with the economic growth in the region. Furthermore, agroforestry systems have the potential to produce 100 m m^3 timber/pulpwood for industrial and domestic use, which fulfills 65% of the country's timber demand, 2/3 of the small timber demand, 70–80% of the plywood demand, and 60% of the raw material demand for paper pulp. Furthermore, it produces 150 million metric tonnes of firewood, meeting half of the country's firewood demand. Likewise, 9–11% of the green fodder requirements are met from the trees grown on the farms i.e. through agroforestry.

As a result, agroforestry practices can be a valuable tool in achieving the 4% sustainable growth target in agriculture. It is noteworthy that, as per IPCC reports, agroforestry is one of the important tools to fight climate change and build the resilience of farmers against threats of climate change and natural calamities because agroforestry provides services like microclimate moderation, biodiversity conservation, carbon sequestration, protecting water resources, soil erosion and pollution. Agroforestry systems have the potential to sequester up to 10 t C $ha^{-1}y^{-1}$ with average sequestration potential of 25 t C ha^{-1}. India becomes the first nation to adopt a comprehensive policy on agroforestry, which is a pathbreaker in making agroforestry an instrument for transforming the lives of the rural farming population, protecting ecosystem and ensuring food security through sustainable means.

10. Agroforestry and climate change

Agroforestry is receiving immense attention, not only in terms of sustainable agriculture but also as an effective tool to deal with climate change. Agroforestry improves livelihoods and mitigates climate change in smallholder farming systems. Agroforestry is an often named solution for the dual climate and food security challenges. Agroforestry can mitigate climate change through creating and enhancing carbon sinks by capturing carbon from the atmosphere. Carbon sequestration in Indian agroforestry varies from 19.56 Mg C ha^{-1} yr^{-1} in the north Indian state of Uttar Pradesh to a carbon pool of 23.46–47.36 Mg C ha^{-1} yr^{-1} in the tree bearing arid agro-ecosystems of Rajasthan. However, carbon stocks in tropical agroforestry systems vary even among similar types of systems.

Agroforestry practices can be a valuable tool in achieving the 4% sustainable growth target in agriculture.

Table 3. Carbon absorption capacity of different agroforestry models.

Agroforestry model	Carbon storage capacity (t C ha^{-1})	Region
Agrisilviculture system (11 yrs)	26.0	Semiarid region
Block plantation (6 yrs)	24.1 – 31.1	Central India
Populus deltoids + Wheat	18.53	North western
Silvopasture	31.71	Himachal Pradesh
Agrisilviculture	13.37	
Agri-horticulture	12.37	
Silvopastoralism (5 yrs)	6.55	Kerala
Homegardens (13 yrs)	8.00	Sumatra

Table 4. Contributions of agroforestry as climate smart agriculture.

Pillars of CSA	Climate Change Strategy	Key functions	Agroforestry role
Productivity	Increase food production and security	Increase farm production through sustainable land use	Agroforestry provides diversified products with continuous flow of supply and higher income.
Adaptation	To reduce negative effects of climate changes and/or take advantage of the positive effects	Reduce threats and enhance resilience	Agroforestry reduces the impact of extreme weather.
Mitigation	Reduce emission of GHGs or increase the storage of GHGs	Enhance carbon sequestration and reduce GHGs emission	Agroforestry increases ToF enhances cumulation of carbon in both tree biomass and soil.

11. Future of agroforestry in India

Agroforestry is bound to play a major role in future, not only for its importance in food and livelihood security, but also for its role in combating environmental challenges because a country's land area cannot be stretched. In 2050, the requirement for fodder increases by 1.5 times; food grain and fuel wood by two times; and for timber by three times. Agroforestry has the potential to meet the demand for food, fodder, firewood and timber. Research should focus on developing agroforestry technologies for critical areas like arid and semi-arid zones and other fragile ecosystems such as the Himalayan region and coastal ecosystem to sustain these areas for higher productivity and natural resource management. Apart from these, researchers should also focus on the development and demonstration of agroforestry models linked to the market for enhancing productivity and profitability for small holding farmers. The state government should develop a state agroforestry policy in accordance with the National Agroforestry Policy 2014 in order to plan, prioritize, and develop agroforestry action plans appropriate for each agroclimatic zone, as well as focus on strengthening research and activities through public-private partnership modes for developing profitable, ecologically and socioeconomically viable agroforestry models for all farmers.

The future goals in agroforestry should be to enhance biomass productivity per unit area and time through agroforestry interventions; Tree improvement, post-harvest and value addition; environmental amelioration, resource conservation, mitigation of climate change effects, and participatory development of agroforestry models, HRD, refinement and transfer of technology. The promotion of sustainable agroforestry practices on a large scale in the future will only be possible through a combination of proactive government farmer policies, industry involvement, support services from NGOs, and farmer willingness. A major role for agroforestry in the near future will be to provide environmental services such as climate change mitigation (carbon sequestration), phyto-remediation, watershed protection and biodiversity conservation. However, this will require the development of mechanisms to reward the rural poor for the environmental services that they provide to society.

12, Factors hindering farmers to take up agroforestry

Based on several studies carried out on various aspects of agroforestry over the past three decades, it has been concluded that a number of socioeconomic factors like land holdings, land size, gender, marketing aspects, policy, rules and regulation regarding felling of trees and transportation, lack of availability of quality planting material, source of information, level of education, and age of farmers have an impact on agroforestry. For full adoption of all recommended agroforestry practices, it is advised to intensify extension services and training programme so that farmers can motivate themselves to adopt the latest trends in agroforestry practices. It is critical to provide farmers with adequate market facilities and complete freedom in harvesting and transporting their tree crop to market, as these are some of the most important steps to promote agroforestry.

Conclusion

Agroforestry is the key path to prosperity for farmers and rural people, leading to the generation of employment and revenue, food and nutritional security, meeting other basic human needs on a sustainable basis and cushioning farmers from the harshness of climate change. Agroforestry creates more integrated, diverse, productive, profitable, healthy, sustainable land use systems and is the only option to increase the country's forest and tree cover to 33%. The opportunities and benefits offered by agroforestry can only be realised with the help of substantial investments and coordinated efforts in research, education, extension services and appropriate national policies. The National Agroforestry Policy of 2014 has written a new chapter in the development of agroforestry in India by addressing most of the challenges faced by farmers and rural people, but the major challenge left is to move forward the National Agroforestry Policy from paper to the ground level.

Figure 2. Teak with Asparagus racemosus based Silvo-medicinal model.

Figure 3. Gmelina arborea with Banana and Pepper based multi tyre system.

Figure 5. Amla with horsegram based Agri-horti model.

Figure 6. Neem with greengram based Agri-silvi model,

Figure 4. Casuarina with blackgram based Agri-silvi model.

Figure 8. Teak in farm bund.

Figure 7. Teak with sugarcane based Agri-silvi model.

Figure 10. Swietenia macrophylla with cowpea based Agri-silvi model.

Figure 9. Ailanthus excelsa in bund.

Figure 11. Melia dubia with turmeric based Agri-silvi model.

References : Contact author at saravanans@icfre.org

AGRO FORESTRY

RURAL EMPLOYMENT

TECHNOLOGY

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YASH PAKKA

Agroforestry: An Economically Viable and Flexible Option for Wood Production

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At present, 65% of the timber produced in the country is supplied by agroforestry farmlands. In agroforestry, the efficient utilization of time and space by the inclusion of woody components in the field not only helps the farmer to get economic and ecological benefits but also provides good space for the tree to grow to its maximum. The ban on green felling in the forests has shut the door on raw materials for timber-based industries coming from natural forests. Further, the third National Forest Policy, adopted in 1988, has advised industries to grow their own raw materials. Industries with a shortage in land started their own plantations and also made agreements with farmers to raise the required planting material on the farmer's land. This has broadened the scope of agroforestry in the country.

National Forest Policy, adopted in 1988, has advised industries to grow their own raw materials. Industries with a shortage in land started their own plantations and also made agreements with farmers to raise the required planting material on the farmer's land.

Benefits for trees grown in agroforestry system

Production of trees in agroforestry is an almost inexpensive way of producing wood. Whereas Trees grown in plantations require at least some investments for the normal production of wood and need some specific operations at a specific time to realize their full potential. Due to these reasons, usually trees are not cared for much unless severe damage or mass deaths of trees occur in an area. Moreover, productive lands are not allowed for the cultivation of timber. Generally, the marginally productive wastelands are chosen for the establishment of industrial plantations. The right choice of species for a particular wasteland definitely leads to the survival and growth of trees, but the potential productivity of the species cannot be exploited in those unproductive lands. Productive lands in the country are dedicated to arable crops, and in order to maintain ecological sustainability, trees have been introduced into the farming systems.

Agroforestry provides a unique habitat for tree growth when compared to forests or plantations. Trees in agroforestry systems are exposed to varying agents, such as wind, light, varied levels of competition for water, nutrients, anthropogenic management and interactions with other components of the system such as annual crops and/or livestock. The practices in the agroforestry system that provide proper habitat for tree growth are as follows.

- **Timely pruning:** Regular removal of the lower branches to avoid shading of crops helps to produce timber with minimal knots and a long clear bole. It makes the timbers better suited for plywood, furniture industry, and construction purposes.

- **Provision of fertilizers:** Farmers should maintain a good nutrient status of the farm soil by timely applying fertilizers. Nitrogen-fixing trees help the trees acquire the required nutrients. This accelerates the rate of tree growth, allowing the farmers to access exploitable-sized timber in a shorter period of time.

- **Regular ploughing:** After harvesting crop, ploughing agriculture fields is a common practice. The loosened soil promotes tree growth by improving the soil's physical properties like aeration, water infiltration, soil structure, etc. Even though the land ploughing prunes the tree roots, they recover in some period of time due to the optimum growing environment created in the field.

- **Regular irrigation:** A disciplined irrigation schedule is crucial for water-demanding annual crops. Unintentionally, irrigation in the field fulfils the water requirements of trees. Trees can access the water with their vast distribution of roots even if water is not provided near the tree stem. The availability of water for the trees reduces water stress in dry conditions. This stressless condition may lead the trees to have more cellulose and hemicellulose content than lignin, which is more favourable for paper and plywood production.

All the activities mentioned are intended mostly to reduce competition and improve the yield of gricultural crops, but unintentionally, the tree component is deriving an advantage from them and growing at its best.

Factors affecting the quality of timber in agroforestry

The growth and quality of wood produced from agroforestry are different from the wood produced from natural forests or plantations. The quality of wood in agroforestry is determined by several management and site factors. The climate suitability and the espacement of plants contribute majorly to the physical, mechanical and constituents of wood.

Espacement: The distance between plants determines the level of competition between individuals. Adequate spaces below- and above-ground are essential for the proper growth and development of a tree. Growth of the trees in a dense agroforestry system is slender, and the quality of wood produced is more or less similar to the wood produced in nearby forests or plantations. Moderately dense agroforestry systems produce large-sized timbers. The quality of the timber varies with the choice of tree species; it produced teakwood with comparatively less structural strength, therefore, delayed tree harvesting is recommended for quality wood. In other species like Kaya and poplar, structural properties remain the same. In the case of sparsely spaced trees in an agroforestry system, this results in a more radial growth and crown area development with normal height or reduced height. Qualitatively, these timbers may have degraded with the formation of knots (without proper tree management) and, the formation of reaction wood especially in windy areas.

Site factors: The agroforestry systems established in dry, rocky localities give rise to radially and vertically less developed, more heartwood-containing timbers. Contrastingly, diametrically and vertically well-grown timber with a higher proportion of sapwood is produced in wet/moist conditions. Therefore, delayed harvesting is recommended for better structural-quality timber.

Production of trees in agroforestry is an almost inexpensive way of producing wood. Whereas Trees grown in plantations require at least some investments for the normal production of wood and need some specific operations at a specific time to realize their full potential.

Management: Anthropogenic activities like pruning, and supplying water and nutrients can also significantly influence the wood production in the system. Irrigated and/or nutrient-supplied agroforestry systems produce wood at a faster rate with more sapwood and cellulose contents. Similarly, a pruned system results in knot-free, clear bole timbers. For a limited period of time, the reduced growth rate can also be induced by tree root pruning.

Conclusion

As multistorey agroforestry systems produce timber of the same quality as wood produced from plantations or natural forests, it becomes cheaper to produce and increases the quantity of timber compared to block plantations, which helps fulfil the growing needs of industries. Further, with the ability of the agroforestry system to manipulate the properties of timber produced in the system, this technology (practice) can be specifically designed/modified which enables it to produce the maximum volume of suitable quality raw material for respective wood-based industries.

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Legacy of Agroforestry: R&D for Development in India

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Introduction

Agroforestry as an independent research field in cience was established in the 1970's. It was an emerging area until the last decade. With the Intergovernmental Panel on Climate Change (IPCC) and other international organisations emphasising the ecological implications of agroforestry adoption, there has been a phenomenal increase in acceptance of agroforestry as a land use practice. There is no denying that agroforestry continues to garner global attention due to its numerous and cross-benefits to sectors such as livestock and pastoralism, as well as additional benefits to resilient agriculture and farming systems

Perceptions on Agroforestry

It is generally perceived that agroforestry is a combination of agriculture and forestry. It is stated as - the land-use that combines aspects of both of these (including the agricultural use of trees). Agroforestry is accurately described as a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos etc.) are deliberately used on the same land management unit as crops and/or animals, in some form of spatial arrangement or temporal sequence. In agroforestry systems, there are both ecological and economic interactions between the different components. Subsequently, the definition of agroforestry was simplified and modified to highlight its contribution to the environment and natural resource management. Fundamentally, the difference was the usage of the word 'trees' instead of 'wood perennials'. This subsequently led to contextualizing agroforestry as a forestry-centric subject but on the contrary, it is more multidisciplinary. Agroforestry per se is more than multidisciplinary.

The Food and Agricultural Organization ….. (FAO) classifies agroforestry as one form of Trees outside Forests in its Global Forest Resource Assessment Reports. In the Indian scenario, two other concepts have a close resemblance to agroforestry but are distinct and unique i.e., Farm Forestry and Social Forestry.

- Farm forestry is the practice of cultivating and managing trees in a compact block on agricultural lands. The typical man-made plantations are examples of this practice.
- Social Forestry was first used by the Forest Scientist Westoby, at the 9th Commonwealth Forestry congress held in 1968 in New Delhi. He defined that,

"Social Forestry, is a form of forestry that aims at producing a flow of protection and recreational benefits for the Community". The term "social forestry" is difficult to define precisely but is generally understood to mean tree-growing (including associated products, e.g. bamboo, grasses, legumes) for rural development. There are also opinions that the social forestry concept encompasses farm forestry, community forestry, extension forestry and agroforestry. The differences between these three terminologies have been listed in Table 1.

Table 1. Above ground biomass and carbon distribution in coffee agroforests of Kodagu as compared to adjacent natural forests

Sl. No.	Parameter	Farm forestry	Social forestry	Agroforestry
1.	Ownership of the land	Owned by individual	Government lands mostly or community lands	Owned by individuals
2.	Choice of tree species	Partial control is the choice of species is guided by the forest department or programme implementation implementing agency	Full control on the choice of species by the forest department or agency	The individual has full freedom to choose the species based on edaphic climatic conditions.
3.	Remuneration	After a long gestation period to the individual to other forms.	After a long gestation period to the community	As soon as possible for the individual compared

The systematic development of agroforestry research can be traced back to the initiatives of Canada's International Development Research Centre (IDRC), Canada and FAO, which led to the establishment of the International Centre for Research in Agroforestry in 1977 (currently known as the World Agroforestry Centre). While there were debates and deliberation on the relevance of agroforestry in temperate countries, India was a pioneer in adopting and promoting agroforestry way back in 1983 . In this article, the history of agroforestry research and its contributions are narrated briefly.

Institutionalisation of agroforestry research in India

The Indian Council of Agricultural Research (ICAR) organised a National Agroforestry Seminar at Imphal in 1979, which led to the formulation of the All India Co-ordinated Research Project on Agroforestry in 1983. Initially, this project was aimed at scientific enquiry and analysis of existing tree-based land-use systems and with subsequent findings from this project, a dedicated research institute for agroforestry was created in 1988 – the National Research Centre for Agroforestry (currently known as the ICAR-Central Agroforestry Research Institute). In simple words, the institute's mandate is agroforestry research, extension and training. One of the prominent scientists in agroforestry, Dr. P.K.R. Nair, says that the period between 1977 and 1987 was the decade of agroforestry research, concept development and institutionalization at the global level. It will be apt to say that during the same period, agroforestry has been institutionalised here in India too. The ICAR-Central Agroforestry Research Institute started to coordinate the All India Coordinated Research Project (AICRP) on Agroforestry in 1997 with the following objectives:

a) Screening and genetic upgrading of selected plant species for their compatibility in different agroforestry systems.

b) To optimize tree-intercrop combination for various regions.

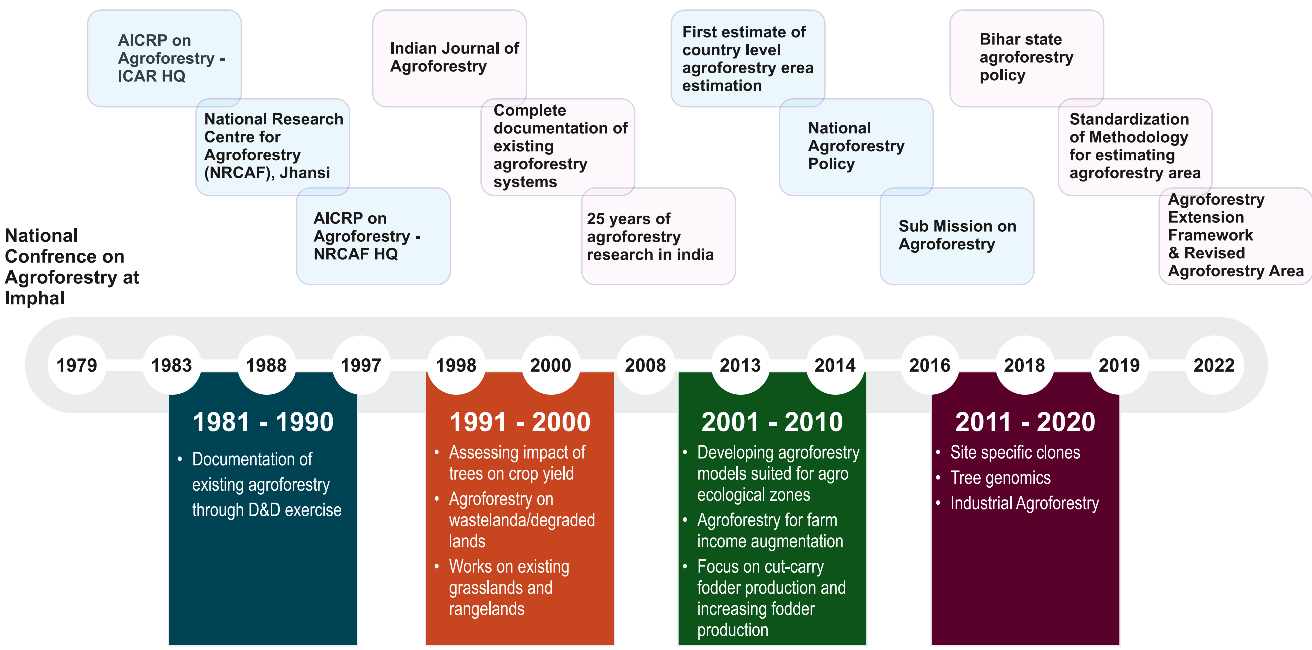
c) Performance enhancement of the pre-dominant agroforestry systems being practiced by the farmers.

d) To upgrade and refine the existing technologies for higher productivity and sustainability.

Salient achievements of ICAR-led Agroforestry research in the country

At present, the AICRP on Agroforestry is implemented in 37 centres across different agro-climatic zones of the country and all these centres are working on different aspects of agroforestry. Screening and genetic improvement of selected plant species for compatibility in various agroforestry systems was one of the major projects for all of these centers. Due to systematic efforts, approximately 184 promising tree species germplasms have been collected and are being evaluated for superiority. In this regard, registration of

Agroforestry Research Roadmap



the elite germplasm has been done like in shisham by NRCAF (Bundel-1 and Bundel-2) and GBPUAT, Pantnagar (PS 52), poplar clones (L-48/89, L-47/88) by PAU, Ludhiana, Pant Poplar by GBPUAT, Pantnagar, teak clone (PDKV/AF-1) by the College of Agriculture, Nagpur and eucalyptus (SRY-16) by MPKV, Rahuri. Similarly, in neem, elite germplasm with high yield and high, stable azadirachtin content have been identified and are being further explored for genetic gains. The AICRP on Agroforestry has also been exploring new species to be incorporated into agroforestry systems. With industrial agroforestry and contract farming gaining popularity, many fast growing species like Melia dubia, Anthocephalus cadamba and Melia azedarach were focused in recent years, and promising clones in Malabar Neem (Melia dubia) - MTP 1, MTP 2 & MTP 3; Kadam (Anthocephalus cadamba) - MTP 2 by TNAU centre; and Melia azedarach - Punjab Dek 1 & Punjab Dek 2 by PAU centre were also released. Agroforestry research does not focus on timber yielding trees alone. NTFPs trees were also screened for superior genetic gains and clones/varieties like Undi (Calophyllum inophyllum) clone KKVCI-03 by BSKKV centre; Imli (Tamarindus indica) varieties viz., DTS-1 and DTS-2 by UAS Dharwad centre; and GKVK-17 Tamarind variety for commercial cultivation in Eastern Dry zone of Karnataka was also released recently.

As the objective is also to screen plant species for their compatibility in different agroforestry systems, the AICRP on Agroforestry centres have also screened crop varieties suitable for specific agroforestry systems (models). For instance, Wheat varieties WH 1105, PBW 677, PBW 725, PBW 502, DBW 17, PBW 550 and PBW 621 are suitable for poplar-based agroforestry system in Punjab region. The findings from the RPCAU centre state that Krishna-258, a Til (Sesamum indicum) variety, is superior and suitable for intercropping up to 5 years in the Shisham (Dalbergia sissoo) based agroforestry system in Bihar.

The continuous effort of the AICRP on Agroforestry in the past 40 years has translated into developing agroforestry systems (models) specific to different agro-ecological regions of the country. For example, in Deccan Plateau having 600-1000 mm rainfall we can adopt the following:

a) three-tier agroforestry system for paddy growing area with Teak and Mango as Tree component and Paddy (Kharif), Gram, Black gram, Linseed, Lathyrus (Kharif) as crop component;

b) Sapota-Teak based Agroforestry System for Hill Zone of Karnataka with Teak and Sapota as Tree component and Paddy (Kharif); South African Maize, Sun hemp (Kharif) as crop component; and

c) Tamarind based Silvi-horticultural System with Tamarindus indica, Eucalyptus and Casuarina as Tree component and Natural grass (DTS-1, DTS-2 and SMG-13 as crop component for pasture/fodder. Similarly, specific agroforestry systems for all the 20 agro-ecological zones along with their economic analysis have been developed for the country.

India has always been a pioneer in estimating the area under agroforestry. Earlier attempts at the national level revealed estimates varying from 17.45 to 23.25 million ha, and many regional estimates are also reported. There are papers predicting the potential area suitable for agroforestry in India. Despite the predictions, there are no actual estimates to date. ICAR-Central Agroforestry Research Institute (CAFRI), a dedicated research institute for agroforestry in the Asia-Pacific region, took up the mapping of agroforestry areas using geospatial technologies. The preliminary work on 13 out of 15 agro-climatic zones reported an area of 23.25 million ha in 2019. Thus, agroforestry as a scientific discipline has evolved in the country, with the support of all stakeholders.

Conclusion

The consistent and coordinated efforts of scientists and researchers, including the entire NARS (National Agricultural Research System), in documenting traditional and commercial forms of agroforestry and designing science-led agroforestry interventions by experimenting with different tree+crop+livestock combinations for different agro-climatic conditions through long-term and coordinated trials, have resulted in agroforestry progress. These efforts set a benchmark for agroforestry potential in the country, which got global recognition as India hosted the 3rd World Agroforestry Congress where the government unveiled the maiden Agroforestry Policy for the country.

Taking the essence of the policy, the government rolled out projects and schemes in different states through the Sub-mission on Agroforestry that gave fruitful results. Thus, AICRP on Agroforestry led by the Indian Council of Agricultural Research became the unique project that laid the foundation for Indian agroforestry per se.

References: Contact author at suresh.s@icfre.org

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- Thermo gravimetric analysis of lignocellulosic material
- Determination of penetration and retention of preservative in the treated wood
- Wood polymer composites
- Preservative solution analysis
- Proximate analyser (fixed carbon content, volatile content, ash content and moisture content)
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- Wood Modification
- Field Identification of Important Timbers
- Clonal Propagation of Melia dubia
- Sandalwood: Establishment and Maintenance of Healthy Nurseries and Plantations
- Insect Pest Management
- Bamboo Agarbatti Stick Making

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Prevailing Agroforestry Practices in Gujarat for Food, Wood and Nutritional Security

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1. Introduction

Forests are one of the most important natural resources, contributing significantly to socioeconomic aspects while also providing environmental benefits to humans. People used to rely on forests for food, timber, fodder, fuel wood, medicine, essential oils, fatty oils, fiber, and other necessities. In fact, forests also provide various ecosystem services to society, which include biodiversity, pure air, water-stream, nutrient cycling, carbon sequestration, pollination, etc. There are several threats to the forests, like deforestation, fragmentation, conversion of forest land into agriculture or developmental projects and/or other activities, climate change, etc. The rate of decline in the forest cover over a period of time is about 1.5 million hectares per year. It demonstrates that, in addition to protecting existing natural forest land use systems, large-scale plantations, social forestry plantations, and agroforestry plantation programme are critical for increasing the country's green cover.These activities would reduce people's and wood-based industries' reliance on forests.

As per the ISFR report (2021), the present forest cover (21.71%) and tree cover (2.91%) of the country are estimated to be 24.62%, with a gain of 0.28% cover over a period of two years. Further, the mean growing stock of Indian forest is estimated to be 56.60 m^3 per ha. Therefore, there is a wider scope for the development and adoption of agroforestry systems in order to provide wood, food, nutritional and environmental security from the farmlands. Indeed, an agroforestry system provides farmers with additional farm income as well as diversified crop-tree-based products and other value-added products. India's domestic supply of wood is insufficient to fulfil its growing demand; hence, imports of industrial wood have more than tripled in the last decade. In India, the total availability of wood is estimated to be about 80 m^3, of which 44 m^3 (~62%) comes from the agroforestry-based land-use system. JK Paper Limited, Songadh, Tapi, Gujarat, is one of the largest integrated pulp producers in Gujarat, producing 155,000 tonnes of paper and paperboards annually. As a result, the industry requires approximately 275,000 metric tonnes of raw wood per year.

In Gujarat, the total forest cover is 7.61%, with tree cover covering 2.81% of the geographic area. For the agroforestry database, during 2013, FSI provided a special session on the tree cover of agroforestry systems in the country. It is estimated that the total tree cover in the agroforestry system of the country is around 111,554 sq. km, representing 3.39% of the country's geographical area; out of which Maharashtra (11,806 sq. km) followed by Gujarat (11,591 sq. km) represents the maximum tree green cover in agroforestry landscapes. Gujarat has a growing stock and carbon stock potential of 81.98 m3 and 26.41 m. tonnes, respectively, in the agroforestry land-use system. The net cultivated area of Gujarat state comprises 52% of the reported area. Further, nearly 20% of the area in Gujarat is drought-prone and has high rainfall variability; however, farmers are still managing to maintain varied crop patterns, enabling production vis-à-vis food security. Therefore, agroforestry plays a vital role in such situations for the production of diversified crops/agri products as well as to enhance farm income. Further, selection of intercrops also depends mainly on the edapho-climatic conditions of the area, farmers' needs, prevailing traditional knowledge, resource availability, etc. Therefore, a diversified pattern of agroforestry systems and their practices are in vogue in Gujarat state.

In India, the Central Agroforestry Research Institute (ICAR-CAFRI, earlier known as the National Research Centre for Agroforestry), located in Jhansi, is the only institute in the country focusing on agroforestry to increase the productivity and sustainability of farming systems and to increase farm income through research on different agroforestry models throughout the country, with one centre in Gujarat as well. In Gujarat, agricultural universities are taking part in research and extension activities in agroforestry. The College of Forestry at Navsari Agricultural University imparts teaching and research in the fields of forestry and agroforestry. The All India Co-ordinated Research Project (AICRP) on Agroforestry is functioning at SDAU and has undertaken several research components in different parts of northern and northwestern Gujarat. The Social Forestry Wing of the Gujarat Forest Department is also working on social forestry, farm forestry and agroforestry both in urban and rural areas of Gujarat. Furthermore, the Research Wing (Silviculture and Forest Utilization) of the Gujarat Forest Department is providing good quality planting materials as well as clones of fast growing and other commercially important tree species like teak, khair, bamboo, etc. to the farmers and foresters. Other line departments like the Department of Agriculture and the Department of Horticulture also support agroforestry practices in different parts of Gujarat.

The productivity potential of different crops, vegetables, pulses, MAPs in different tree-based agroforestry systems like teak, Melia dubia, Ailanthus, Arjuna, mango, sapota, Palmyara palm, bamboo and a few other trees has been worked out through research projects, student and faculty experiments in the College (CoF, Navsari). Aside from that, various dominant agroforestry systems in Gujarat and south Gujarat have been mapped and are compiled in this article.

2. Agroforestry systems in Gujarat

Tree components play a vital role in an agroforestry land-use system. Major tree species grown in different parts of Gujarat are neem, deshi babool, ardusa, nilgiri, bengali babool, teak, khair and bamboo. Furthermore, horticultural fruit crops like mango, drum stick, custard apple, aonla, ber, jamun, coconut, sapota and guava are most preferred by the farmers. Some of the interested farmers also started growing sandalwood, red sanders, mahogany on the farmland.

Agroforestry (AF) is structurally composed of three major components namely trees, crops and pasture/animals in a single land-use system. The agroforestry systems in Gujarat can be categorized into seven major groups viz., Agri-silviculture systems, Agri-horticulture system, Agri-silvi-horticulture system, Agri-silvi-horti-pastoral system, Silvi-horticulture system, Woodlots, and Traditional agroforestry systems. The practices of these agroforestry systems were documented regionally based on their adaptability.

a) Agri-silviculture system:

The term agri-silviculture is used to denote the combination of trees and agricultural crops as under storey component. Seven agroforestry models have been popularised in Gujarat, where the dominant species are Neem, Eucalyptus, Teak, Ailanthus, Melia azedarach, M. dubia, Bamboo and Arjun. Neem and Ailanthus based agroforestry systems are well adopted in the south, central, north, and Saurashtra regions of Gujarat. The suitable inter-crops are paddy, wheat, pearl-millet, sesamum, etc. On the other hand, teak and bamboo-based agroforestry systems are widely used in Gujarat's southern, central, and western regions. Wheat, soybean, chickpea, and soybean are the main inter-crops grown in teak-based AF systems, whereas green gram, black gram, sesamum, and chickpea are grown in bamboo-based AF systems. The Melia azedarach based agroforestry systems were mapped in the south, central, Saurashtra and Kutch regions of Gujarat wherein the wheat, cowpea, soybean and foxtail are used as inter-crop. Eucalyptus based AF system is largely distributed in the south and central parts of Gujarat having a combination of paddy, wheat, maize, spider lily. Whereas Arjun based agroforestry is adopted only in South Gujarat in combination with nagli, cowpea, paddy and wheat.

b) Agri-horticulture system:

The term agri-horticulture is used to indicate the arrangement and combination of fruit trees and crops. Under this system, four models are popularized. Mango and sapota based agri-horticulture system are widely adopted in the south, central and Saurashtra regions of Gujarat. Inter-crops with mango include paddy, wheat, cowpea, chickpea, soybean, and spider lily.In the case of the Sapota AF system, wheat, groundnut, paddy and maize are grown as inter-crop. The Aonla based agri-horticulture system is also adopted in the south, central, north, and Saurashtra regions of Gujarat. Further, the mixed plantation, like Mango-Sapota-Lemon based agri-horticulture system, is available in south Gujarat.

c) Agri-silvi-horticulture system:

The term agri-silvi-horticulture system is used for the combination of tree+ fruit trees + crops. In this system three models are popularized. Whereas, the Mango + Teak based, Sapota + teak based and Sapota + eucalyptus, Melia dubia + Citrus based are widely adopted in South Gujarat only. The inter-crops like paddy, maize, wheat, soybean, chickpea are used for all three systems.

d) Agri-silvi-pastoral system:

The term agri-silvi-pastoral system is used for tree +

crops + animals/pasture combination. Seven agroforestry models are popularized under this system in Gujarat. Sapota + Eucalyptus based, Mango + Casuarina based, Mango + Eucalyptus based, Coconut based, Apiculture based and Aqua-forestry (mostly practiced with rice crop, particularly along the coastal lines) are adopted in South Gujarat. The suitable intercrops are hybrid napier, Cenchrus spp. and some natural grasses. Whereas, Ailanthus + Prosopis based mixed plantation is adopted in the central, north and Saurashtra.

e) Silvi-horticulture system:

The term Silvi-horticulture system is used to denote the tree + fruit-tree combination. Six agroforestry models are widely adopted in Gujarat region namely Mango + Teak based, Sapota + Eucalyptus based, Sapota + Teak based, Mango + Eucalyptus based, Mango + Casuarina based systems are widely adopted in South Gujarat. Whereas Sandal + host plants like Sesbania/Casuarina/Aonla/Red sander, is distributed in South and Central Gujarat.

f) Traditional agroforestry systems:

It is age old practice of intentional intensified cultivation of trees, agricultural crops or forage crops on homestead or on boundary and bunds of the farm lands. Three agroforestry systems namely home garden, boundary plantation and bund plantation were existing. Home garden and Boundary plantation are widely adopted in all regions of Gujarat, whereas bund plantations are adopted in South, Central, North and Saurashtra region of Gujarat.

3. Scope, feasibility and further development of agroforestry in Gujarat

A scheme called "Sub-Mission on Agroforestry (SMAF)" was launched in 2016-17 to promote and support Indian farmers in adopting agroforestry in the country, and this scheme was implemented in Gujarat state along with other 19 Indian states with a 60:40 funding ratio of the central and state governments. The main purpose is to encourage tree planting on agricultural fields along with prevailing crops to get additional income as well as other environmental benefits like farm beautification, soil and water conservation, microclimate amelioration, enhanced agricultural biodiversity, carbon sequestration, pollination and other ecosystem services. The SMAF provides assistance to farmers for agroforestry activities for boundary/bund plantation and block plantation of prominent tree species including timber-yielding and other NTFP species. Apart from this scheme, the Mission for Integrated Development of Horticulture (MIDH) also provides support to the farmers to grow fruit orchards and other horticultural crops like vegetables, root and tuber crops, mushrooms, spices, flowers, aromatic plants, plantation crops and bamboo.

The production potential of wood/timber from agroforestry can be enhanced in several ways. The major one is the selection of suitable trees and their quality planting material. Forest nurseries raised by the Forest Department, universities, and pulp-wood based industries provide/supply high-quality planting materials (seedlings) as well as superior clones of certain commercially important tree species to farmers and other stakeholder groups in Gujarat at subsidised prices and with technical assistance.

For successful development and promotion of agroforestry in the state, a strong coordination between line departments like the Forest department, Agriculture department, Horticulture department with SAUs and other Universities/ institutes and industries may be strengthened for improving farm-community livelihoods through diversified products. The National Agroforestry Policy-2014 also stressed the need for the development of agroforestry in India in terms of productivity, diversity, ecosystem functioning, livelihood issues, supply of quality planting materials, marketing of agroforestry produce, product processing and value addition, certification, etc. Apart from conventional agroforestry, strategies like planting multipurpose trees in culturable (Au: or cultivable) wastelands and fallow lands of agriculture field; growing shade loving plants like medicinal plants, aromatic crops and spices under fruit orchards (mango, sapota, pomegranate, ber, guava); development of Agro-ecotourism; industrial-agroforestry; carbon sequestration and carbon trading can help in improving green cover as well as production of food, medicine, wood/timber and other NTFP resources from farm and other land use systems. Agroforestry advisory and legal support is critical for facilitating agroforestry and farm-wood trading in the market.

References: Contact author at rpgunaga@nau.in www.ilma.org.in

INDIAN LAMINATE MANUFACTURERS ASSOCIATION

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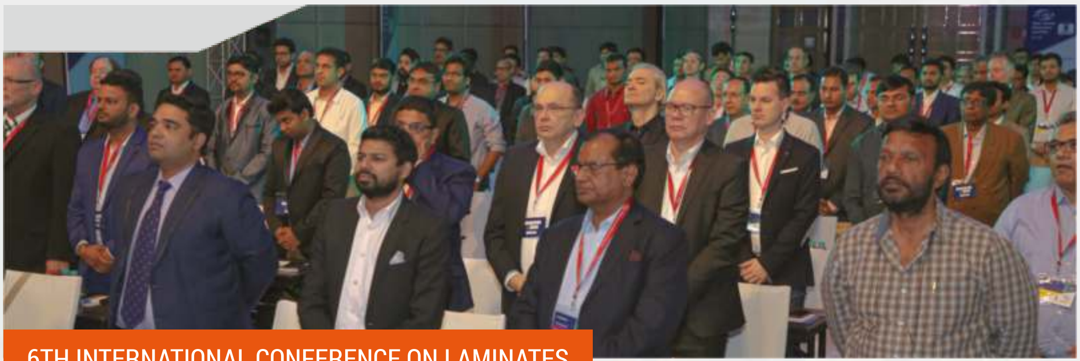

6TH INTERNATIONAL CONFERENCE ON LAMINATES

Strength of Unity

Indian Laminate Manufacturers Association (ILMA) is nonprofit making organization of manufacturers of Decorative and Compact laminates or high pressure laminates, Particle Boards, Plywood and Pre-lam (Short Cycle Laminates). It is the only registered association of the laminate industry at national level and we are proud to complete 20years since 1998. More than140 manufacturers of Laminates of India are the registered members of ILMA.

ILMA is a place where companies collaborate to get more opportunities to grow their business. ILMA is a symbol of Indian Laminate Manufacturer's unified commitment to provide seamless & world-class decorative surfaces. ILMA assembles its manufacturers on a unified platform & voices out its fair opinions. It unanimously provides a healthy competition, creating great opportunities by using different strategies and combining the views of the manufacturers.

Key Achievements

1. Organized six International Conference on Laminates between 2010 to 2018
2. ILMA Institute of Technology to enhance production capabilities of members employees
3. Restrict import of low quality laminate
4. Study on Cleaner Production
5. Launch of Technical book on laminate
6. Catalogue shows at National and International Level
7. Launch of awareness video on Laminate application
8. Networking with members for raw materials, production, market and government policy related issues
9. Export incentive benefits to laminate exporters
10. Support to PM Cares fund during pandemic

Upcoming Events

1. 7th International Conference on Laminates during Delhi wood March 2021
2. Catalogue show at Interzum, Germany 2021
3. Online technical workshop on production and environment aspects during October 2020.
4. Environment clinic with Pollution control board (December 2020)

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Wood Based Industries, Agroforestry and Quality Planting Material

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Introduction

Natural forests were the main source of timber raw material for wood-based industries until the commercial extraction of timber was banned by Hon'ble Supreme C ourt of India. The supply of roundwood is affected by stringent forest acts and policy, and trade restriction. The demand and supply gap of roundwood would be 22.44 million m^3 in 2025 (Srinivasan et al. 2018). To satisfy the growing timber raw material demand of wood-based industries, trees outside forests (TOF) emerged as promising alternate source. Plantation timber from agroforestry and farm forestry supplies a major portion of the total timber demand. As defined in National Agroforestry Policy 2014, agroforestry is the land use system which integrate trees and shrubs on farmlands and rural landscapes to enhance productivity, profitability, diversity and ecosystem sustainability. Agroforestry is the boon for wood-based industries as it is the only sustainable source of timber raw material discouraging the timber import which has a negative effect on the country's economy. Apart from its shortcomings with respect to the country's economy by consuming huge foreign exchange, timber import shall also create uncertainty in timber availability and associated market prices (Vanam 2019). Al though agroforestry is a major tool in mitigating the timber shortage, it has to overcome a major challenge which is the availability of quality planting material that will yield more timber biomass in a given area for the plantation to be successful. Survival of the trees during growth, adaptation to the regional climate, the growth rate, etc. depends on the quality of the planting material to a great extent.

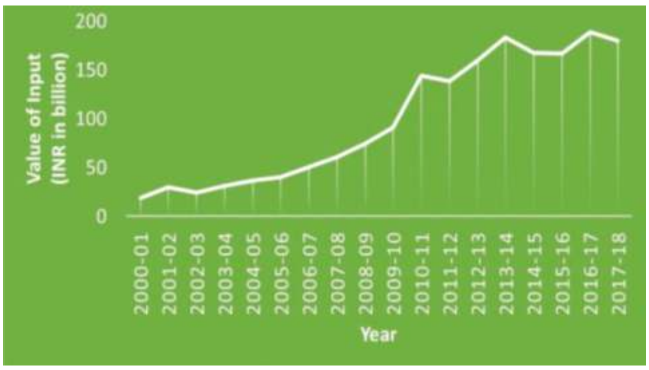

Figure 1. Growth of wood-based industries in terms of input (Kant and Nautiyal 2021).

Raw material scenario for wood-based industries

Although India's forest and tree cover has been steadily increasing for nearly two decades, India still remains deficient in timber production and an increasingly large proportion of its burgeoning demand is being met from imports. Forecast reveals a jump of nearly 70% in demand for roundwood in India in the next decade, from 57 million m^3 in 2020 to 98 million m^3 in 2030, driven largely by the construction sector (Kant and Nautiyal 2021). India's demand for industrial wood has been growing steadily by an average of 0.9 million m^3 and this growth has resulted in the increase in imports of industrial round wood. If the imports increase at the same rate, India's imports between 2025 and 2030 are projected to be 27.01 and 31.5 million m^3, respectively, which would create a negative impact on the economy of nation (Shrivastava and Saxena 2017). Commercial extraction of timber from natural forest is banned by the Hon'ble Supreme Court of India, however only a limited quantity of timber is allowed to be extracted from the forests through proper work plans and permissions. This inadequate raw material availability from the forests has forced the wood-based industries to look towards the agroforestry farms for their sustenance. Wood-based industries in India at present depends on ToF to fulfil their raw material demand. Agroforestry and farm forestry are the two main sources of ToF.

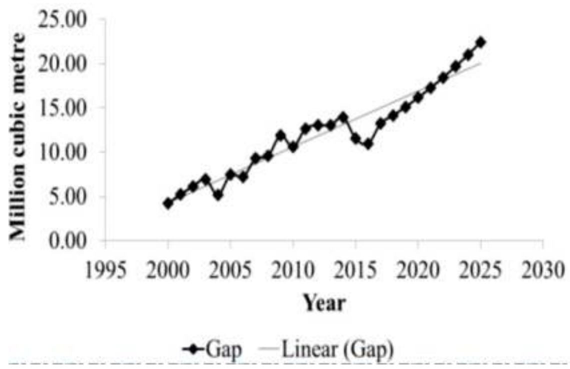

Figure 2. Demand and supply gap of round wood in India (Srinivasan et al. 2018).

Table 1. India, roundwood demand forecasts by wood-based sector, 2021-2030 (million m[3] RWE).

Year	Pulp and Paper	Furniture	Plywood and other wood-based industries	Construction	Total
2021	12.5	8.98	15.45	22.71	59.64
2022	12.5	9.47	17.88	21.79	61.64
2023	12.5	9.95	20.69	20.88	64.02
2024	12.5	10.44	23.94	19.96	66.84
2025	12.5	10.92	27.70	19.05	70.17
2026	12.5	11.40	32.06	18.14	74.10
2027	12.5	11.89	37.10	17.22	78.71
2028	12.5	12.37	42.93	16.31	84.11
2029	12.5	12.86	49.68	15.39	90.43
2030	12.5	13.34	57.49	14.48	97.81

RWE,roundwood equivalent. Source: ITTO Technical Report (Kant and Nautiyal 2021).

It is evident from the above table that by the year 2030, the forecasted demand for roundwood would be 97.81 million m^3 of which 57.49 million m^3, i.e. a whopping 59% of the total demand is put forth by plywood and other wood-based industries. Due to the demand and supply gap many wood-based industries either forced to operate below their installed capacity or to rely on timber import for their operation. Running an industry below their operational capability and timber import are the two main reasons for increased product cost of quality product which makes industries incompetent in the international market.

The ideal solution to mitigate the demand and supply gap of timber raw material for wood-based industries is to produce more timber by the way of agroforestry and farm forestry.

Agroforestry and farm forestry for sustainable raw material for wood-based industries

Agroforestry, an effective traditional land management system of integrating trees and shrubs into various crops and crop-livestock production systems has been practiced in India for centuries. Recently agroforestry has emerged as a distinct branch of science. The past three decades have witnessed a tremendous boost in agroforestry across the world, and India is among those pioneer countries that is taking major actions to step up the research, education and policy level support to agroforestry. Organized research on agroforestry started in India with the establishment of the All India Coordinated Research Project (AICRP) onAgroforestry in 1983. In addition, the Indian Council of Forestry Research and Education (ICFRE) conducts agroforestry research through its institutes and advanced research centres. These initiatives have gainned further boost with the launch of world's most dynamic National Agroforestry Policy of India in 2014 (Handa et al. 2019). Since the expansion of farms areas in the country is not possible due to limiting factor of land resources, enhancing the efficiency by the way of incorporating fast growing tree species on farmlands is realistic approach to satisfy the demand of wood. Presently, exotic species like Eucalyptus, Casuarina, Leucaena and Poplulus are dominating in the agroforestry farms as major sources of raw material for pulp and plywood industries (Chauhan et al. 2018). India being a major consumer of wood and wood products, the role of agroforestry as a viable land-use system is gaining significant attention owing to its contribution towards meeting domestic and industrial wood requirements (Parthiban et al. 2019).

Quality planting material: key to successful agro and farm forestry

Quality planting material (QPM) is a prerequisite input in agroforestry for maximizing the timber yield, improving adaptability to adverse environmental conditions to produce raw material of acceptable quality in a short rotation. The basic goal of having quality seedlings is to accomplish the best growth possible and have the highest amount of desired outputs. It is a well-known fact that more than any other input, improved planting material is the key to enhanced farm productivity and increased income generation (Hassan et al. 2001; Minot 2008). Planting material of authentic vegetative or seed origin produced in advanced technology nurseries or tissue culture labs, with proven track record of high survival percentage in the field, faster growth, higher yield, resistance to pest and diseases, adaptability to local biophysical, climatic and socioeconomic conditions, and with high market demand, will be eligible to qualify as QPM. Guaranteed performance in terms of higher yield and quality of crops could be achieved with reliable planting material and good management practices. Nursery-raised seedlings of appropriate quality to raise agroforestry plantations are of primary importance. Efforts put in planting trees in a large scale ruins the results if the poor-quality seedlings are planted. The benefits expected from agroforestry depends mainly on choice of species, seedling quality and the silvicultural management (Handa et al. 2019). Important agroforestry species such as Ailanthus excelsa, Anthocephalus cadamba, Albizia lebbeck, Dalbergia sissoo, Eucalyptus tereticornis, Melia dubia, Populus deltoides, Tectona grandis, etc. and their cultivation practices for best yield are documented (Chaturvedi et al. 2017; Handa et al. 2019).

Issues in agroforestry and farm forestry

Lack of quality planting is one of the main reasons for agroforestry not gaining the desired importance as a resource development tool. At present, most of the established plantations/orchards, and planted species, are based on planting material sold by mostly un-regulated private nurseries using non-scientific methods to produce planting material. To meet the increasing demand for agroforestry species, many nurseries do not follow the recommended practices of quality planting material production. As a result, the quality of planting material in terms of genetic makeup, varietal purity, robustness, and being free from diseases and pests is not reliable. Agroforestry is plagued with a wide range of issues that extend from production to consumption. In figure 3, various constraints faced by tree-growing farmers and the consuming industries are presented (Parthiban et al. 2009).

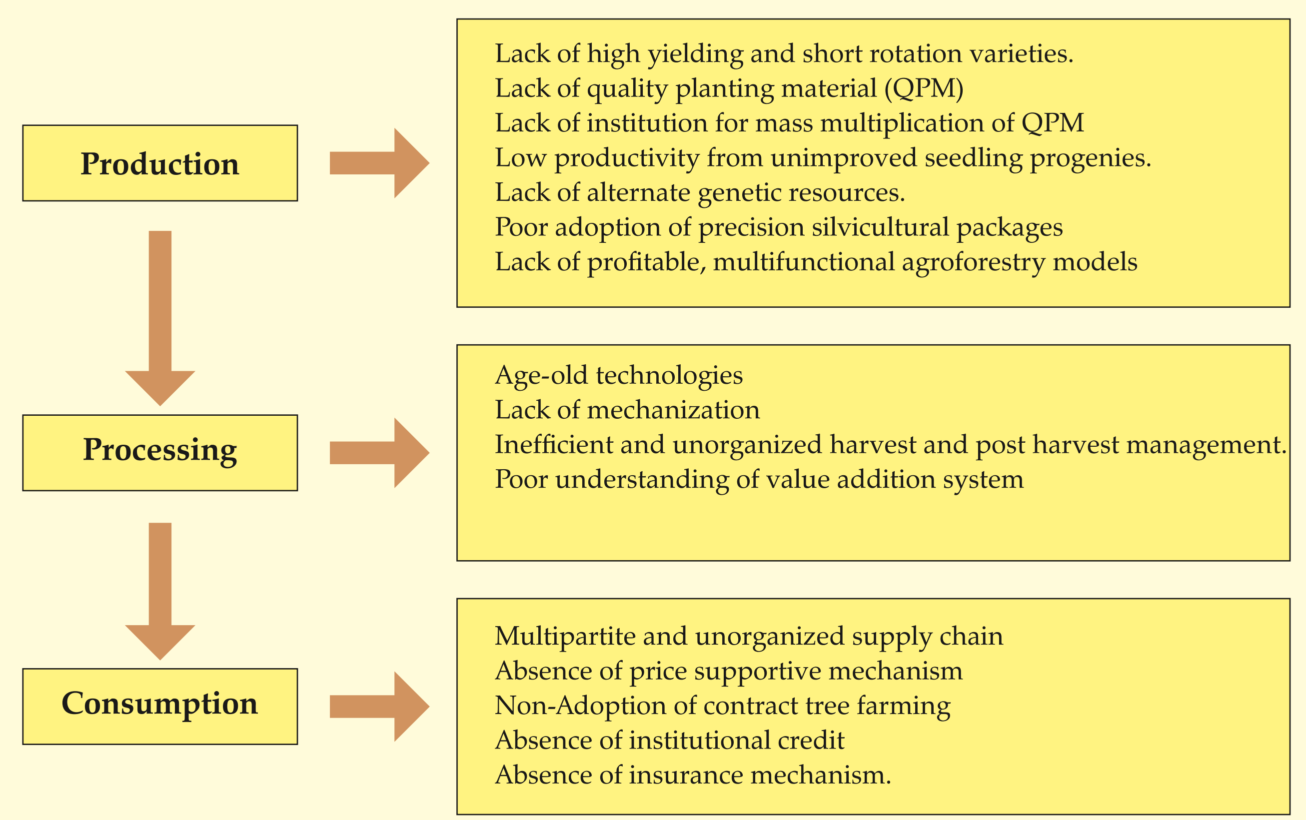

Figure 3. Constraints and problems from production to consumption system in agroforestry (Parthiban et al. 2009).

As mentioned in the above figure, lack of quality planting material is one of the major hindrances for agroforestry and farm forestry in India. Many a times planting material sold by private nurseries is not affordable by small scale farmers and also farmers are misled by the private nurseries by means of erroneous information with the sole intentions of selling the seedlings. Time and again farmers are not supported for scientifically managing the planted seedlings which lead to non-performance of the seedlings which fails the plantation miserably. Plantation should be taken up based on the anticipated timber requirement which should be arrived by suitable scientific approach and not with assumptions. Age at which the species can be harvested should be taken into consideration while making such forecast of timber requirement. Mass plantations that are taken up without any prior scientific studies leads to surplus supply of the timber which in turn causes an avalanche in the selling price of the timber which brands that particular timber as invaluable.

Melia dubia: a case study

Although M. dubia is known as a money-spinning tree among farmers and gaining their interest in taking up plantations in a large scale, the prime challenge is the availability of quality planting material. Apart from this, the gap in information in scientific cultivation and silvicultural practices to obtain best results, scientific rate for the timber grown by the farmers leading to their exploitations are other snags that are to be fought to achieve best results in agroforestry and farm forestry.

Solutions

There is a need to diversify forest plantations by increasing the number of suitable indigenous fast-growing trees species adaptive to wide range of agroclimatic condition of India (Parthiban et al. 2009). The lack of high-quality planting material has been repeatedly identified as a major constraint to greater adoption of agroforestry innovations (Takoutsing et al. 2014). Research on genetically modified planting material has to be carried out so that the end product should be conducted such that the timber harvested shall be ideally suitable for specific end use applications thereby the grown timber can be utilized in an optimal manner which contributes to minimal wastage. One such research result is based on the qualitative and quantitative traits of economic interest like stem straightness, roundness, tree height, and clear bole height, girth at breast height and disease resistance, etc. Twenty candidate plus trees (CPTs) of M. dubia were selected from different places covering Valsad, Narmada and The Dangs districts of south Gujarat, India. The selected CPT will be useful in development of superior quality planting material for mass propagation and future tree improvement programmes (Chauhan et al. 2018). The output of this plantations, i.e. the tree with stem straightness, roundness, clear bole and disease resistance is ideally suitable for veneering. Similarly, such research can be extended to produce timber suitable for different uses, viz. paper and pulp, packaging and structural timbers, etc.

The research output such as tree improvement, growing methodologies and other such technical improvements can only be realized if subsistence farmers have access to quality planting material. Improving the genetic and physical properties of planting material can trigger yield increases up to 40% and lead to substantial improvement in the agricultural production and food security, especially if farmers continue to renew their planting material (Maredia et al. 1999). Apart from the availability of quality planting material, policy must promote farm forestry and afforestation of wastelands and marginal agricultural lands, through innovative policy changes, incentives and tax benefits (Lal 2000). The research output with respect to the genetically modified planting material should reach farmer under the supervision of the government. To protect farmers from being misled by private nurseries, small groups of different stake holders, viz. farmer, industries, research institutes are to be formed which should be monitored by government run institutions as this results in taking up plantations in a planned manner based on the anticipated timber requirement after a particular time period. In doing so, the technical backup for the farmers shall also be made available through the government run research institutes so that plantations can be maintained scientifically and the output can be harvested with minimal deviation from the expectations. Such scientifically managed plantations produce quality timber which can be procured by the industries in this way both the industries and the farmers are benefited creating a win–win situation. This pattern will also protect farmers from being misled by groups having mendacious propaganda. One example of such group is the Consortium of Industrial Agroforestry (CIAF) which was established by the Tamilnadu agricultural university (TNAU) by linking stakeholders to address the issues related to production, processing and consumption in agroforestry to strengthen the value chain and promote agroforestry based on the objectives envisaged in the National Agroforestry Policy of 2014. Keeping in line with the guidelines provided by the above-mentioned Agroforestry Policy, CIAF is successful in establishing decentralized institutions which supplies quality planting materials to the farmers besides facilitating organized plantation developers, harvesting and marketing institutions. The activities of CIAF has created the much-needed database in tree cultivation, development of price supportive mechanism for important farm-grown industrial wood species and reducing the risks faced by tree growers through innovative approaches like tree insurance and value addition technologies. A success story of CIAF includes the work on species like M. dubia which is an alternate indigenous fast-growing multipurpose tree species highly suitable for agroforestry systems in India with immense potential to serve the mankind by wide range of products such as particleboard, plywood and laminated veneer lumber, etc. (Prakash et al. 2019). Efforts of CIAF has increased the area under agroforestry besides improving productivity and profitability. It has contributed towards the creation of the employment showing significant improvement in productivity of timber. Since trees acts as carbon sink, it contributes to reduce carbon load in the atmosphere addressing the worrisome concern on climate change. This consortium-mode value-chain model in agroforestry holds great potential for adoption and replication across India, which would help create self-reliance in raw material security besides augmenting tree cover in the country (Parthiban et al. 2019).

Conclusion

From the above discussions, the following conclusions can be drawn.

I. The demand of raw material for wood-based industries are ever increasing due to the growing population and rapid urbanization. The growing demand of timber has resulted in a substantial amount of timber to be imported.

ii. Imports apart from having a dark effect on the country's economy by the way of foreign exchange also takes the product cost to higher side making the industry incompetent in international market.

iii. Agroforestry and farm forestry are the need of the hour to counter the raw material shortage and its ill effects on wood-based industries.

iv. Availability of quality planting materials is one of the major challenges apart from exploitation of farmers by private nurseries during planting and timber merchants while harvesting by not providing judicious returns for the farmers time and efforts has made the concept of agroforestry and farm forestry still at infant stage at many parts of our country.

v. Research on developing quality planting material of fast-growing timber species ideal to grow in regional climate of area under consideration and suitable forspecific end uses applications, technical package on growing techniques, disease control and harvesting age, etc. are to be made available to farmers failing which expected results may not be achieved.

vi. Statistical studies are to be made to anticipate the forecast of the demand for a particular species of timber before taking up plantations in large scale else the surplus production of the timber shall result in steep fall in cost which will drastically reduce the revenue leading the plantations to fail miserably.

vii. For agroforestry and farm forestry to be successful, platforms should be created to bring various stake holders, viz. farmers, industries, scientists, research institutes and policy makers together so that the hurdles faced right from the production of quality plating material through growing, harvesting and consumption can be overcome by creating a win–win situation for all the stake holders.

viii. Apart from mitigating timber raw material shortage for wood-based industries, agroforestry and farm forestry also contributes to fight against global warming as the timber produced and converted into any wood product acts as carbon sink.

References: contact author at prakash77v@yahoo.co.in

Wood Technologist Association (WTA) is India's apex non-government organisation of plywood & other wood-panel based industries, providing a unique platform for all stakeholders: Government - Research Institutions – Industry – Machine Manufacturers - Technologists - Agroforestry Farmers, to interact and introduce path-breaking measures for progress of the industry.

WTA strives to make true the vision of Hon'ble Prime Minister Shri Narendra Modi of making wood-sector “ATAMNIRBHAR” and for past 12 years has been relentlessly pursuing the cause of its stakeholders, addressing their key issues and seeking suitable policy-changes with Government agencies (MoEFCC, FRI, IPRITI, FIPPI, IWST and others).

WTA, led by President: Shri S.C. Jolly & a team of professionals' technologists / field-experts, also collaborates with international wood-chambers / associations for mutual co-operation & adoption of best practises in the industry. WTA has organised host of conferences, seminars, training workshops, awareness campaigns and Industry-meets for taking forward initiatives of the industry.

WTA is a member of:

1. Bureau of Indian Standards (BIS) CED-9 CED-20 Committees.
2. President WTA (Shri S.C. Jolly) is a Member of Managing Committee of FIPPI.
3. President WTA (Shri S.C. Jolly) is a Member of Steering Committee of IPRITI.
4. President WTA (Shri S.C. Jolly) is a Life Member of IWST, Bangalore.
5. WTA, since the past decade, is in continuous dialogue with Ministry of Environment, Forests & Climate Change (MoEF&CC) and made representations to their Hon'ble Ministers: Shri Jairam Ramesh, Shri Anil Madhav Dave, Dr. Harsh Vardhan and recently to Shri Prakash Javdekar for bringing forth relevant issues of plywood industry.
6. WTA submitted Memorandums to MoEF&CC on various occasions for considering demands of the Industry /Stakeholders for driving suitable policy-changes like reduction in GST, lease of barren-land to farmers for enhancing green cover by plantation drives, research & development on Melia Dubia as substitute of face-veneer, foreign-currency savings through reduction in imports, transportation-subsidy and similar issues. Recently, on WTA's perusal, the e-Transport facility for farmers was agreed upon by Government of India.
7. WTA and FRI (Dehradun) collaborated under Green India Mission to organize Industry-Institute- Farmer- Meets at Ludhiana (Punjab), Yamunanagar (Haryana) and Pantnagar (U.P).
8. WTA's key role in agroforestry was explained to Shri C.K. Mishra (Secretary, MoEF&CC) by Shri Manoj Gwari (Secretary, WTA) at a meet organized at Forest Research Institute, Dehradun.
9. WTA hosted international delegations from Malaysia, China and Ghana for partnership - dialogue with Indian Plywood Business Groups. In a recent visit of Sarawak Timber Association from Malaysia, WTA coordinated and organized their meetings with IPIRTI and other agencies.
10. WTA, under aegis of Shri S.C. Jolly, started the National WhatsApp Group: “Agroforestry” bringing together key decision-making administrators, leading industrialists and other subject-matter experts, during the COVID times for suggesting and implementing the way-forward for overcoming challenges being faced. The patronage and active-participation of all members including Additional Secretary Dr. Alka Bhargava, Dr. Arun Rawat (DG, ICFRE & Director, FRI), Dr. M.P. Singh (Director IPIRTI & IWST), and other eminent personalities (Industry Association heads, Senior-Industrialists & Technical experts) has brought out innovative & viable solutions.
11. WTA participated and organized multiple webinars in which leading subject-experts shared views / opinion about how to tackle the problems being faced by each stakeholder
12. WTA (Shri G. Rajput, V.P) participated in R&D work with Senior Scientist Shri D.P. Khali, FRI.
13. WTA organized numerous hands-on trainings with the Industry for aspiring Technologists.
14. WTA assists in industry placement of Technologists pan-India as per their skill-set.

WTA, in coming times, endeavors to take forward the best-interest of Indian Plywood Industry!

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Casuarina Equisetifolia L: An Excellent Agriwood for Farmers as well as Forest-Based Industries

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1. Introduction

Casuarina equisetifolia is one of the 86 species in the genus Casuarina and is native to Australia. It stands out as a promising tree species for agroforestry and joint forest management due to its multifaceted utilisation in social, economic, and environmental aspects. It belongs to the non-leguminous group and still has nitrogen fixation ability, which improves soil nitrogen, and the roots create a symbiotic association with different mycorrhizae. Due to these characteristics this species has been introduced in the coastal regions of India for soil stabilization, reclamation, coastal protection and ecosystem rehabilitation in 1868 by the then Collector of Kanara in the Bombay Presidency. Meeting the growing fuel wood demand was one of the focal points of its introduction due to the high calorific value and low ash content of the wood (Luna, 2005).

It has been identified as one of the six commercial agroforestry tree species for livelihood security of the rural people and sustainable development through greening programmes (Planning Commission, 2001). With an estimated 800,000 ha of plantations, India ranks top as the largest Casuarina growing country (Pinyopusarerk and Williams, 2000). This is the priority multipurpose tree (MPT) among other species for agroforestry plantations in the agroclimatic regions, e.g., the East Coast plains and hills, the West Coast plains and Ghats and the Island Regions. Nicodemus (2009) estimated that about 500,000 ha are planted with Casuarina in the coastal states of Andhra Pradesh, Orissa, Tamil Nadu and the Union Territory of Puducherry. The fast-growing, drought-hardy, care-free management nature of this plantation species has made it adaptable to hot, humid tropics and even semi-arid regions. Thus, it has a presence in different parts of the country as a coastal plantation, an ornamental garden tree and an inland sand dune plantation.

2. Silvicultural requirements

Casuarina is a light demanding species and grows in almost all types of soil. It is highly tolerant to soil salinity (Anon, 1985). It thrives well in areas with an annual rainfall ranging from 250 to 2,500 mm, maximum temperature as high as 48°C and can tolerate cold up to 0°C, on altitudes up to 1,200 m or up to 1500 m (Kondas, 1983). The tree performs best on loose sandy soils, laterite, rich loamy soils and some marshy places in open areas, where pH varies between 4.8 and 8.4. The wide range of adaptation to climatic and edaphic factors and the potentiality to improve soil nutrient status identify Casuarina equisetifolia for environmental control such as sand dune stabilization, shelterbelts, erosion control and reclamation of poor soils (Kumar, 2016). Casuarina seedling growth was enhanced by the application of mycorrhizal consortia (5 g per polybag) and vermicompost (Kiruba, 2013).

3. Wood properties

The wood of most Casuarinas is not suitable for lumber production due to its hard, heavy nature and tendency to split, crack, and warp with drying. The hard and heavy wood is difficult to saw. For fencing, tool handles, pilings, beams, and rafters, round wood is ideal, but split wood is used for fencing, pilings, and roofing shingles. In India, it is used for scaffolding and structural members for buildings, as well as for making masts for country fishing boats. The wood of Casuarina equisetifolia has been found to make good paper pulp through use of the neutral sulfite semichemical process. As it is difficult to break up this extremely hard wood, it eventually becomes complicated. Casuarina wood produces better rayon grade pulp than eucalyptus wood. It requires less bleaching, has higher fibre strength, and has a higher yield.

Tree improvement research and the identification of a superior clone have been proven to increase wood production. One generation of breeding has yielded a 13-28% gain in wood production (Pinyopusarerk and Nicodemus, 2014). Since then, it has gained importance as an important fuel-wood species in the peninsular India, although it is essentially a tree of the coastal plains. Due to its minimal management needs, Casuarina has gained importance as a major pulpwood species. Warrier et al. (2015) screened various clones and found that clones CE 83, CE 100, CE 268, CE 2003/3, CE 2003/4, TCR 120203, APKKD 6 and JKCE 8 were suitable for quality pulp production.

4. Fuelwood properties

The most common use of Casuarina wood is for firewood purposes. Its wood is called one of the best firewood in the world due to the desirable properties of good firewood. The wood is dense and burns slowly with great heat and no smoke. Its calorific value is about 500 kcal per kg (Ravi et al., 2013). According to a study by Srivastava (1995), 20 kJ/g of energy was estimated to be generated from Casuarina, which was higher than several other potential tree species for energy plantings. The charcoal made from stems is of excellent quality. Casuarina loses only 2/3 of its weight in the conversion of wood to charcoal, as compared to 3/4 of its weight in the case of other wood species.

Its branches and brushwood are also used as fuel, and the needles and cones burn well. The wood can also be burned green, this is an important advantage in fuel short areas. On Orissa's coasts, the fallen branches of this tree are swept by the landless and sold in the market as firewood, and this is a source of income for the people. Different thermochemical and biochemical energy conversion techniques are now being experimented with for the conversion of Casuarina wood.

Puri et al. (1994) from their findings on the fuelwood value index in components of some ten tree species from the arid region of Rajasthan and Haryana and the order of merit as fuelwood for the tree species concerned is *Casuarina equisetifolia* > Acacia nilotica = *Dalbergia sissoo* > Zizyphus mauritiana > *Prosopis cineraria* = Acacia auriculiformis > *Acacia tortilis* > *Azadirachta indica* > Eucalyptus camaldulensis > *E. tereticornis*). Shanavas and Kumar (2003) also find the superiority and popularity of Casuarina wood from the home gardens of Kerala.

One of the studies on the gasification performance of *Casuarina equisetifolia* wood found that it is one of the best sources for the gasification process and has a gas composition of 6.08% Carbon monoxide, 2.09% Methane and 14.06% Hydrogen (Ezhumalai and Kumar, 2018). Apart from fuel, wood is extensively used for paper making and of late, is a preferred choice for biomass-based power generation.

5. Casuarina equisetifolia-based agroforestry for livelihood and industrial needs

The fast-growing nature with a short rotation period of 3-4 years and desirable stem, crown and branch characteristics makes it a suitable species for agroforestry for Indian farmers with small landholdings (Rawat et al., 2011; Viswanath et al., 2001). The primary objective behind the introduction of Casuarina as a coastal species was fuelwood. From the experience of its natural range, the species has shown tremendous ability to thrive in severe cyclones in both the East & West Coasts and island regions of our country.

The plantation of the species has been part of the rural landscape in southern coastal India for more than a century. In the coastal land, it acts as a good wind break to provide protection to the agricultural lands from the moving sands and winds. The wind energy is effectively reduced by Casuarina's heavily branched, drooping branches. About 2 to 3 rows of Casuarina belt can reduce the power of a strong, high wind, leaving the leeward air calm. A shelter-belt of 30ft in height can reduce the velocity for a distance of 130 m (Velumani et al., 2015). The establishment of a Casuarina shelter belt was taken as one of strategies for eco-restoration for the tsunami devastated coastline of the Andaman Islands, along with the creation of livelihood opportunities for the people, especially for women. Kerala government also established Casuarina windbreaks across 17 ha in Purakkad as bio-shields against wind and tides (The Hindu, 2021).

It is also planted as shade trees in coffee plantations as it produces large quantities of mulch, which helps in soil moisture conservation, suppressing weeds, improving soil structure and cation exchange capacity. The specially evolved branchlets, termed cladodes and reduced scale leaves result in minimizing the interception of light by the crown, due to which water loss by transpiration is considerably reduced (Bourke, 1985). For instance, the Casuarina-banana based windbreak agroforestry system model developed by IFGTB, Coimbatore, has been successfully implemented in the coastal districts of Tamil Nadu to make the agroecosystem more climate-resilient. IFGTB, Coimbatore identified superior clones and recommended them for coastal belts, e.g., CP-0401, CP-1501, CP-1101, CP-0302, CH-0304, CP-0108, CH-2303, CH-2602, CP-0203, CP-0110, CH-0905, CH-3702, CP-3501, APKKKK-1, APKKKK-5, APKKKK-6, APKKKK-10, APKKKK-11, APKKKK-12, APVSYM-4, APVSYM-6, APSKSK-1, APSKS-2, APVZVZ-1, APVZVZ-3, APVZVZ-8, APVZVZ-9, APVZVZ-10, APKKKK-20.

Many agricultural crops were integrated with Casuarina, although it has an allelopathic effect. For eradicating rival plant species, C. equisetifolia releases substances known as allelopathic that prevents other plants from growing, as indicated by the lack of different plant species in the understory when a mat of litter forms around the trees. The rice, cowpea, sorghum, and sunflower germination, plumule, and radical development were all drastically reduced by the leaf leachates of C. equisetifolia. Thus, it is advised to raise agricultural crops in the initial years of the establishment of Casuarina, generally the first 2-3 years (Ravi et al., 2013).

Experience from different Casuarina-based agroforestry models (Casuarina- maize alley cropping) suggests that the net income is more than one and a half times that of sole agriculture. Cultivation of groundnut in the first year alone as an intercrop with Casuarina yields 5 Mg ha^{-1} with a net profit of Rs. 40,000 per ha from groundnut farming (Buvaneswaran et al., 2010). Black gram produced 1.34 Mg ha^{-1} of yield when cultivated as an intercrop under Casuarina during a four-year period (Ravi et al., 2013). Casuarina (3m × 2m) + horse gram + cowpea system generated a land equivalent ratio of 1.14 to 1.36 (Jincy et al., 2022).

Table 1. various Casuarina-based agroforestry system in different zones

Zone	Agroforestry systems		Tree-crop combination	
		MPTs	Fruit trees	Crops
Tropical plains	Agri- Horticulture	Casuarina	Sapota, Mango	Groundnut Horse gram Cowpea Sesame
Coastal	Energy plantation/ block plantation Windbreaks	Casuarina Casuarina	- Coconut or alone	- -
	Agri- silviculture	Casuarina	-	Paddy, Groundnut
Humid, Rainfall > 250 cm	Silvi- horticulture Silvi- Horti- Pasture	Casuarina Casuarina	Cashew Sapota Mandarin	Cucurbit Bitter guard Snake guard Pumpkin Guinea grass Hybrid Napier
			orange Guava Citrus Lime	
	Silvi pasture	Casuarina	-	Guinea grass Hybrid Napier Fodder sorghum
	Silvi- Horticulture	Casuarina	Sapota Mandarin Orange Guava Pomegranate-	
Rainfall (150- 250 cm)	Agri-silviculture Agri- silviculture	Casuarina Casuarina	- -	Chillies Tomatoes Pumpkin Groundnut Paddy Cowpea Groundnut

Figure 1. Boundary planting of *Casuarina equisetifolia* in a Tamil Nadu farm (credit: Pawan Waghaye).

Figure 2. Block plantation of *Casuarina equisetifolia* in Coimbatore, Tamil Nadu (credit: Pawan Waghaye).

6. Wood production

Fuelwood and pulpwood are the two economic products from any Casuarina-based agroforestry. Wood production varies across locations, cultivation techniques, and rotation periods. The commonly followed rotation period is 4 years with irrigation and 6 years under rain-fed conditions. Plantations with irrigation and fertilizer application have a yield range of 90 to 150 metric tonnes of air-dried wood (up to 20 cm in girth) per hectare in 4 years with a plant density of 10,000 trees/hectare.

Casuarina is harvested as early as 2.5 years of age, whereas Forest Department plantations without irrigation are retained up to 8 years.

Under rain-fed conditions, an average yield of 75 to 100 tonnes per hectare is obtained in 6 years, depending upon soil quality and amount of rainfall. An additional 5 to 7 metric tonnes of miscellaneous wood is produced per acre through management practices in the form of leaves, branche, and roots. The average net income from irrigated plantations is Rs. 2,27,000 per ha with a four-year rotation period. Under rain-fed conditions, the same income is realized in 6 to 7 years. In a few places in coastal Tamil Nadu, irrigated Casuarina is harvested as early as 2.5 years of age, whereas Forest Department plantations without irrigation are retained up to 8 years. In 4-year-old C. equisetifolia plantations, Nicodemus (2009) found a wide variety of growth metrics, with heights ranging from 12 to 20 m and girths ranging from 25 to 50 cm. According to Ravi (2011), 2-year-old C. equisetifolia recorded plants have heights between 5.7 and 12 m and girths between 9.0 and 20.0 cm.

Casuarina improvement programme is now focused on improving tree growth, yield, and form. Fast growth, clear bole and short rotation are appealing characteristics of Casuarina for integration in agroforestry systems.

Table 2: Wood production potential of *Casuarina equisetifolia*

Region	Spacing/ density (trees/ha)	Age (years)	Wood production	Source
Irrigated land, Tamil Nadu	10,000	4	90-150 Mg/ha air dry wood + 12-17 Mg/ha miscellaneous wood	Nicodemus (2009)
Rain fed area, Tamil Nadu	10,000	4	90-150 tonnes of air-dried wood + 5-7 Mg/ha miscellaneous wood	Nicodemus (2009)
Irrigated area, Villupuram, Tamil Nadu	-	4	80-200 Mg/ ha	Venkatesan and Srimathi, 1989)
Rainfed area,- Villupuram, Tamil Nadu	6	60-80 Mg/ ha	Venkatesan and	Srimathi (1989)
Casuarina + cotton system in Cauvery Delta, Tamil Nadu	2 m × 1 m	-	40 Mg/ ha pulpwood + 10 Mg/ha fuelwood	Saravanan et al. (2012)
High rainfall region of Karnataka	1 m× 1 m 2 m× 2 m	5	68.9 Mg/ ha 46.6 Mg/ ha	Kushalapa (1987 (2003)
Coastal Kerala	-	-	150-195 Mg/ ha	

Conclusion

Since it thrives on sand and can withstand salt, C. equisetifolia is used to restore soil fertility and reduce erosion along waterways, riverbanks, and coasts. Though *Casuarina equisetifolia* has multiple end-uses, it is planted for fuelwood, mitigating strong winds, and scaffolding. Therefore, most of the Casuarina improvement programme is now focused on improving tree growth, yield, and form. Fast growth, clear bole and short rotation are appealing characteristics of Casuarina for integration in agroforestry systems. Although leaf litter is a great constraint in agroforestry, several crops can easily integrate with Casuarina in the initial phase of growth for livelihood and income generation. Nursery development, cultivation, and harvesting of Casuarina have an enormous potential to generate livelihood opportunities for farmers and agriculture-dependent labour forces in rural areas.

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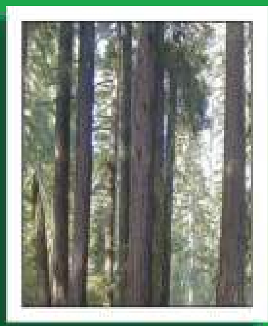
FEDERATION OF INDIAN PLYWOOD & PANEL INDUSTRY (FIPPI)

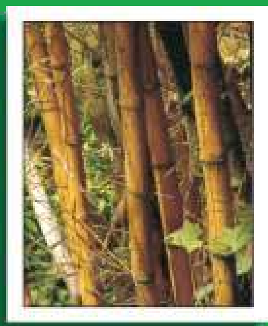
REGISTERED UNDER THE SOCIETIES REGISTRATION ACT XXI OF 1860, REGN. NO. S/2985/1968-69 DT. 4.1.1969

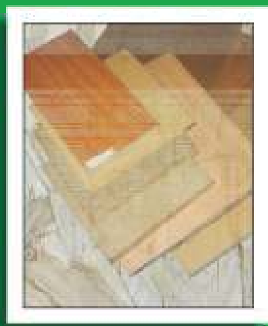
Part of FIPPI Achievements

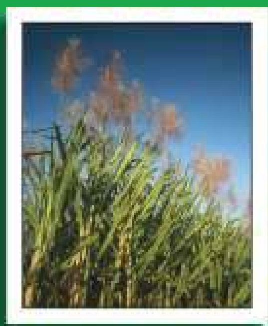
With great efforts of Federation of Indian Plywood & Panel Industry (FIPPI), an Apex representative body of Plywood / Panel / Other Allied products including Furniture and Wood / Bamboo Working Machinery Manufacturers in India alongwith close cooperation with various Ministries and Premier Institutes through Agro and Farm Forestry and other Captive Plantation programme, the dying woodbased industry is again reviving in the country to produce various standard products like Veneer, Plywood, Panelboard, Particleboard, MDF, Laminates etc. which are internationally accepted. Further with great pursuance of the President and Senior Executive members of FIPPI we are highlighting and representing the crucial issues confronting the Plywood & Panel Industry. FIPPI also publishes quarterly Journal Indian Wood & Allied Products highlighting the development taking place in India and abroad, market profile, world timber market report, statistics, international exhibition and conferences, articles, write-ups etc.

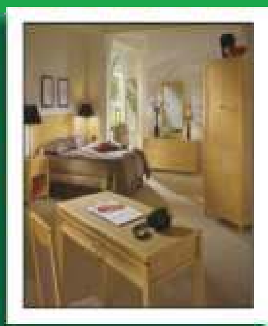
FIPPI is cordially inviting all plywood / panel / bamboo / Laminates and other allied products manufacturers to become active member for the strengthening the platform of FIPPI and working for the development of the industry which is Internationally recognized by ITTO, FAO, European Union, IWPA, BIS, MoEFCC, Ministry of Commerce & Industry, BIS, FICCI, CII and other renowned Organizations.

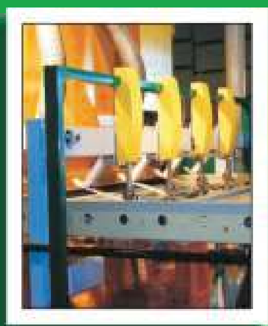












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Agroforestry in Coffee Plantations of Karnataka

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Introduction

Agroforestry refers to growing of wide range of trees of economic importance in agricultural lands along with crops, which is proven to increase the crop yield, increase biodiversity, and reduce soil erosion. This sustainable management system of agriculture has been influenced by religious as well as socio-economic aspects (Chinnamani 1993). In India, various types of shade trees are inter planted with crops based on different agro-ecological, socio-economical, financial, and climatic zones. The agroforestry system is mostly dominant in arid and semi-arid regions and these practises differ based on the regions. The demand for beverage items like tea, coffee and cocoa is increasing day by day, resulting in the expansion of the plantation land to such an extent that most of the natural vegetation that existed around the agricultural lands has been removed. This has reduced the diversity of native species, enhanced dependence on single crop usage, and increased soil erosion. By following agroforestry practises, all the above factors can be reduced and exotic timber species can be grown for commercial purposes. Coffee, the most demanding beverage crop in the world, follows a traditional agroforestry system in Karnataka, in the regions of the Western Ghats. This system has been renamed as 'shade grown coffee', where coffee is inter-planted with trees like silver oak in Coorg and jackfruit, fig and silver oak in Chikkamagaluru. This article mainly focusses on the agroforestry system followed in coffee plantations in Karnataka.

> ***Dalbergia latifolia, Lagerstroemia microcarpa,*** **or the Australian exotic shade tree silver oak *(Grevillea robusta)* are interplanted with *Coffea robusta***

Species involved in agroforestry in Karnataka

The sub-humid zones, such as the Malnad and kodagu regions of Karnataka, are known for coffee plantations and intercropping with horticultural species and also species having commercial value as timber. In the Malnad region, for example, Areca catechu (betel nut) and paddy are grown, whereas in the Chickkamagalur region, native timber species such as A. fraxinifolius, Dalbergia latifolia, Lagerstroemia microcarpa, or the Australian exotic shade tree silver oak (Grevillea robusta) are interplanted with Coffea robusta (Viswanath et al. 2018). Food crops like maize, pulses, and millets are grown along with Ficus benghalensis in the arid zone of Mandya. Bamboo is widely grown in home gardens throughout the Konkan region of Karnataka, which is a tropical humid zone.

The coconut and areca nut plantations in this region are intermixed with, or bordered by, various fruit/spice species such as jackfruit (*Artocarpus integrifolius*), mango (*Mangifera indica*), cocoa (*Theobroma cacao*), uppagi/murgal (*Garcinia species*), neral (*Syzygium cumini*), nutmeg (*Myristica fragrans*), orange (*Citrus x sinensis*), and cinnamon (*Cinnamomum species*) along with timber species like teak (*Tectona grandis*), mahogany (*Swietenia macrophylla/mahagoni*), Mesua ferrea, antavala (*Sapindus species*), and amtekai (*Spondias mangifera*). Other species that can be inter-planted are watehuli (*Artocarpus lakoocha*), nugge (*Moringa oleifera*), avocado/butter fruit (*Persea americana*), breadfruit/neerphanas (*Artocarpus altilis*), carambola/star fruit (*Averrhoa carambola*), guava (*Psidium guajava*), cashew (*Anacardium occidentale*), nellikai (*Emblica officinalis*), kaulikai (*Carissa congesta/ carandas*), sale/challe (*Cordia myxa*), sampige (*Michelia champaka*), ranjal/bakul (*Mimusops elengi*), karibevu (*Murraya koenigii*), neeranji/hole-lakki (*Salix tetrasperma*), lakkigida (*Vitex negundu*), and hoovarasi/bugari (*Thespesia populnea*) (*Sarma, 2020*).

Figure: Inter cropping of coffee plantations with betel nut and ceylon ironwood (left) and with pepper vines and mahogoni (right)

Approximately 70% of the coffee produced in India comes from Karnataka and the surrounding hills of the Western Ghats. Kodagu and Chikkamagaluru are main two districts in the Western Ghats region of Karnataka where coffee is grown. Chikkamagaluru, famously known as the 'land of coffee' majorly produces two varieties, Coffea arabica and Coffea canephora (synonym Coffea robusta) in equal quantity. Shade-grown coffee accounted for ~25% of the global coffee supply in 2021. Both the regions have their own specific coffee-based agroforestry systems (CAFS), which allow the growers to cultivate subsequent shade tolerant crops, like black pepper, cardamom, turmeric, areca nut, ginger, citrus, vanilla and citrus fruit orchards. Coffee cultivation has contributed to about 71% of the loss of natural forests in Karnataka alone (Ambinakudige and Sathish 2009). Therefore, coffee-based agroforestry is a major breakthrough in improving the livelihood of the farmers and reducing biodiversity loss. G. robusta in agroforestry plantations is preferred mainly because of its fast growth rate and minimal competition with robusta coffee. In Chikkamagaluru, a three-tiered shaded coffee cultivation system is used, which includes the cultivation of jackfruit, fig, and silver oak (Viswanath et al. 2018).

Role of agroforestry in coffee plantation

The coffee production in Karnataka has been hampered by socioeconomic and environmental issues, resulting in low yields in terms of both quality and quantity, an increase in fertiliser costs, labour issues, and so on. Scientists have worked excessively in the field of agroforestry and it has brought significant advantages to this system of cultivation. Coffee grown under shaded conditions directly influences the soil health and qualities, as the shade bearing plants regulate temperature changes and enrich the soil by recycling the bases from lower layers (Nair et al. 2016) and prevent soil erosion by planting agro-based crops on slopes (Karthika 2020). In terms of both production and income stability, it is seen that agroforestry systems can offer the farmer a combination of market and non-market goods and services (McGinty et al. 2018).

Ecological role

With increased global warming, plants must capture more atmospheric carbon. Carbon is stored in the biomass and other organic matter in the soil, which helps in the fixation of atmospheric carbon dioxide. Coffee agroforestry has emerged as a promising land use system for sequestering carbon and contributing to climate change mitigation (Dossa et al. 2008). The amount of carbon stored in vegetation varies, depends on the density and diversity of plants, soil types and crop management. It is observed that intercropping plants with trees increases CO_2 absorption. (Padjung et al. 2019). One hectare of shade-grown coffee can store 70--80 tonnes of carbon per hectare, which is roughly equivalent to the carbon stored in an equivalent area of forest, whereas an hectare of open coffee can only store less than 10 tonnes of carbon (Anil Kumar et al. 2019). Traditional native tree-shaded coffee agro-ecosystems generally support greater floral and faunal diversity with high structural complexity (Perfecto et al. 1997).

The reproductive traits, including the number of nodes per plant, number of coffee fruits per node, and bean density obtained from native shade trees were comparatively superior to the coffee grown under the shade of silver oak (Dhanya et al. 2014). A. fraxinifolius, a fast-growing potential native species was preferred to exotics, such as silver oak, under suitable ecological conditions (Nath et al. 2011). Coffee yield, its consistency, and the cupping quality of coffee beans are much improved under native shade trees (Viswanath et al. 2018). There is considerable loss of organic carbon and degradation of land quality with the conversion of natural forest to coffee land. Soil health is one of the major factors that is influenced by shade grown coffee. In general, soil properties were found to deteriorate with the clearing and cultivation of forested lands (Islam and Weil 2000). Due to the constant supply of leaf litter, leaf shedding and tree pruning, the soil is always covered with a thick layer of mulch, which enhances microbial activity. A huge amount of leaf litter contributes to the organic manure, which is specifically seen in deciduous species that accumulate the organic matter into the soil.

The primary shade, or the lower shade, is taken care of by nitrogen-fixing legumes like Erythrina indica or Glyricidia maculata. The secondary shade of plants like jackfruit is specifically selected because they act as factories, providing tremendous biomass and thereby keeping the soil temperatures comparatively low. Lastly, the tertiary shade is contributed by hardwood species like teak (Tectona grandis) and mahogany (Swietenia macrophylla/mahagoni), which attract rain-bearing clouds (Sarmah 2020). Care should be taken while selecting woody tree coverage. Over-shading can significantly reduce light penetration, potentially reducing the crop growth and increasing disease emergence (Durand-Bessart et al. 2020). Moreover, interplanting leguminous plants with coffee creates an increased consumption of fruits and leafy vegetables containing high amounts of vitamin A in rural areas (Mukhlis et al. 2022).

Socio-economical role

Shaded coffee enhances the quality of its product while ensuring a good yield and also reduces external input costs, thereby increasing profit margin (Viswanath et al. 2018). In view of the economic and social perspective, additional income from the timber and fruits, if produced from the woods, can be a counterbalanced benefit from the cultivated land due to tree planting. (Bullock et al. 1994). Based on the wood-crop combination, an additional crop harvest may occur at different times of the year and not necessarily in the crop cultivation periods, thus ensuring a continuous income for farmers. Thus, an increased benefit-to-cost ratio can be achieved through agroforestry.

Some practices include the cultivation of woody plants with low inputs of chemical fertilizers and pesticides, thus minimizing the production costs, releasing low levels of chemical toxicity into the environment and improving the annual revenues of the farmers (Maia et al. 2021). The implementation of agroforestry also opens up new job opportunities in rural areas for off-farm activities such as crop drying, wood cuttings, and furniture making (Iskandar et al. 2016). Furthermore, some woods with higher economic value can provide additional income for the community apart from the earnings generated from annual crops.

The implementation of agroforestry also opens up new job opportunities in rural areas for off-farm activities such as crop drying, wood cuttings, and furniture making

Conclusion

Agroforestry in general brings up the concept of cultivating woody trees with crops. Many commercial crops are being grown, posing high advantages in agriculture, including increased biodiversity and species richness, greater yields of coffee in terms of both quality and quantity, and a reduced need for climate mitigation. Trees and other replacement crops grown alongside coffee have shown to increase farmer revenues. A breakthrough in the coffee production sector to satisfy demand and quality is thus brought about by the introduction of coffee-based agroforestry. Agroforestry must be spread throughout the entire state of Karnataka, especially in the eastern plains and in the interiors of the state because these areas are largely devoid of natural forests due to the extensive clearing of trees in the past for expanding crops. Introduction of agroforestry in these areas is analogous to the restoration of the forests that were once present.

References:

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Working Office: Institute of Wood Science & Technology Campus,
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Individual	US $ 20	US $ 200

(To be Photocopied for Use)

The Advent of Agroforestry Initiatives by Indian Plywood and Panel Board Industry – Mitigating Teething Challenges Through Applied Research & Development

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1. Preamble

In the realm of global climate change mitigation action, India has pledged ambitious Nationally Determined Commitments (NDCs) including augmentation of forest and tree cover from 25% to 33% and aiming to sequester an additional 2.5 to 3 billion tons of CO_2 equivalent by 2030. The augmentation plan is congruent to the stipulations of the National Forest Policy, 1988. A major impetus towards achieving this will be through scaled-up coverage of Trees Outside Forests (TOFs).

It is well acknowledged that agroforestry is the most effective alternative for achieving the target of increasing forest or tree cover by 33%, besides offering the means to address to a significant extent the present challenges of industrial round wood supply, food security, nutrition, energy, employment, environmental security, additional farm income, and better livelihood opportunities.

The National Agroforestry Policy of 2014 further provided a significant push to the ongoing agroforestry initiatives in India. The forward-looking NAP-2014 highlighted the need for an integrated approach towards agroforestry by addressing myriad aspects like appropriate research interventions, adequate investment, suitable extension strategies, incentives to agroforestry practitioners, enabling legal and regulatory environment, market linkages for agroforestry produce, post-harvest processing, development of new products, and above all, people and industry participation.

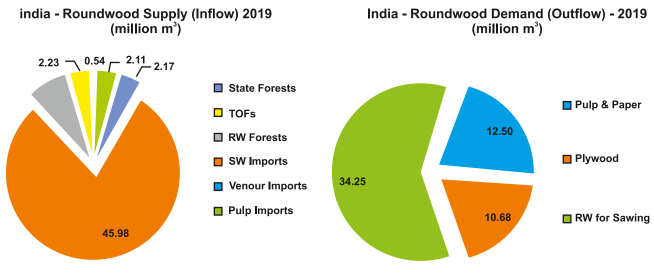
The role of wood based industry has been significant and path breaking in triggering and strengthening the agroforestry initiatives during the post NFP-88 era. Consequently, over the ensuing three decades, rural landscapes have witnessed paradigm shifts in many states across the country. The augmented resources of Trees Outside Forests now cater to almost 80% of the roundwood requirements of the country.

According to the (ITTO) Report – India Timber Supply and Demand – 2010-2030 (Kant and Nautiyal; Sep-2021), the total roundwood equivalent demand of India is estimated at approximately 57 million m^3 of which around 47 million m^3 is met from domestic sources and the rest from imports and substitutes. Of the 47 million m^3 of roundwood equivalent supply from domestic sources, only about 2 million m^3 comes from state-owned forests where harvesting is severely restricted, and the remaining, 45 million m^3 comes from TOF.

ISFR 2021, further validates the effectiveness of Agroforestry initiatives in India. It reports a total forest cover of 713,789 km^2 which is 21.71% of India's total geographical area. This is a marginal increase from 712,249 km^2 (21.67%) in 2019. The tree cover outside forests is 95,748 km^2 (2.91%), marginally up from 95,027 km^2 (2.89%) in 2019. The area of combined forest and tree cover outside forests currently comprises about a quarter of the total geographical area of the country. The total estimated growing stock is 6,167.50 million m^3 of which 4,388.15 million m^3 lies inside forests, while the growing stock of trees outside forests is estimated to be 1,779.35 million m^3.

2. Background

Considering the share of roundwood demand (consumption) in India, while pulp & paper ndustry's share is roughly 22%, the Plywood Industry alone has a share of almost 19% besides a whopping 60% share of sawing industry including construction timber.



Source: ITTO Report (Kant & Nautiyal: 2021)

The responsibility for developing wood resources through agroforestry should ideally be shared by all sectors of the wood-based industry. Agroforestry initiatives in India have been largely promoted by the large wood-based pulp and paper industries only in recent decades. Though a few players in the Panel Board and Plywood industries have also been undertaking agroforestry in isolated pockets, the overall efforts are insignificant vis-à-vis the large share of RW demand.

It is good to note that in recent years, the Indian Plywood and Panelboard mill owners have started to realize and discuss the need for sustained resource development. Many efforts have been initiated which will provide the required impetus for long term agroforestry. The plywood and panelboard sector is deliberating on this subject intensely on more and more platforms. The policy push for agroforestry and proposals to ease the legal, regulatory, and licensing regimes are adding to the momentum. Large scale plywood and panel board mills are progressively joining the league of responsible wood sourcing through the promotion of agroforestry initiatives. However, in totality, the efforts are at the start of a cusp while the trend indicates the advent of new agroforestry promoters in India, akin to the role played by pulp and paper mills during the 1980s. While the trend is quite welcoming in this sector, it is clear that there is a long road ahead to be traversed before significant results can be achieved.

The responsibility for developing wood resources through agroforestry should ideally be shared by all sectors of the wood-based industry. Agroforestry initiatives in India have been largely promoted by the large wood-based pulp and paper industries only in recent decades.

Owing to the very nature, genesis and age old traditions of plywood and sawn wood mills in India, the sector has its own set of deterrents and challenges. These are great barriers to the transition of the sector from an archaic approach to a new age approach and thus retard the speed of adaptation and adoption of responsible sourcing, which is key for promoting agroforestry initiatives by a greater number of mills. These challenges have been highlighted in further sections.

3. Intrinsic Challenges

a. Unorganised & Fragmented Industry

The Indian Plywood, Panelboard and Sawnwood industry is largely unorganized and highly fragmented. Officially, more than 80% of the sector is dominated by small unorganized players, while the percentage could be much higher if one adds up the unregistered and unlicensed players below the threshold. When a market is dominated by a large number of small and unorganized players, the rules of the game get shaped accordingly. Focus is mainly on daily sustenance while there is very little room for long term actioning.

b. Mindset Transformation towards a Long Term Vision

The historical legacy of sourcing wood 'easily' from nearby forests or cheap imports has shaped the mindset of many generations of mill owners. Naturally, strategic initiatives like agroforestry for long term wood resource development do not easily merit a serious consideration in business plans. The transformation is gradually happening and will reach a point of influx if other factors become favourable.

c. Financial Commitments

Financing agroforestry initiatives remains a major deterrent for plywood, panelboard and sawn wood industry. Unlike pulp and paper industry, which have deeper pockets as the value-addition in paper is much higher (and so is the Capex), the Plywood and panelboard industries do not have this luxury. Further, due to small, fragmented and unorganized markets, margins are always under pressure, leaving too little for long term investments like agroforestry.

d. Professional Involvement & Scientific Approach

Since very few mills in this sector have embarked on systematic agroforestry promotion, there are limited professional engagements and scientific approaches for agroforestry promotion in this sector. As smaller mills cannot afford to hire professional and scientific experts on an individual basis at the sector level, there is an unmistakable need for a consortium-based dedicated and long-term clonal research and development programme for evolving standard technologies and products specific to this industry.

e. Cluttered Clusters

Unlike the pulp and paper industries, which are spread out in larger geographic areas, the plywood, panelboard and sawn wood industry have grown profusely in a few clusters where the concentration of mills is very high. Such high density or rather cluttered clusters pose a different set of challenges as large demand is concentrated in a smaller geographic area.

Agroforestry development in and around such clusters can create unwarranted land use competition. Further, in such a scenario, agroforestry initiatives will be vulnerable and prone to high volatility triggered by wood demand and supply cycles. The consequence of such a scenario can be seen by the debacle of large scale uprooting and paused new planting of poplar and eucalyptus in Punjab, Haryana and Western UP owing to a demand glut and a steep rise in prices a few years later.

However, as the Indian plywood, panelboard, and sawnwood industries are expected to grow exponentially in the coming years, the above mentioned inherent challenges will gradually diminish. Larger players, consolidations, integrated operations, and consortium based approaches will stimulate the sector. When major players demonstrate a few success stories of agroforestry initiatives, it will trigger many others to follow suite.

4. Extrinsic Challenges

While the intrinsic challenges will be addressed through intra-sector dynamics as the sector grows and matures, many other extrinsic challenges that impede progress will need to be mitigated through external push-start. This is where the role of competent national level agroforestry research organizations can play a major role – to kick start a process in the sector through applied research and development, enabling agroforestry promotion as a viable, affordable and achievable initiative even for mid-size players in the Indian plywood, panelboard and sawn-wood industry. A few of these extrinsic challenges are elaborated here.

a. Land-use Competition & Sector Specific Agroforestry Models

This sector's roundwood demand is not the same as pulpwood in terms of nature and quality. Multiple demands on existing land parcels in limited catchments across the country are bound to trigger stiff competition for land use. This challenge can be mitigated through systematic research in various agroclimatic zones. Agroforestry models in vogue for pulpwood crops need to be finetuned to suit the quality and specifications needed to cater to plywood, particleboard, MDF and sawn timber requirements.

b. Access to QPM

This is one of the major challenges in most agroforestry catchments. There are few producers of Quality Planting Material (QPM) and more often than not, farmers compromise on the quantity, quality and delivery schedule of planting stock, resulting in failed crops / poor yields, high mortality and sub-standard quality. Smaller players in the plywood, panelboard and sawnwood industries do not have adequate know and how experience in raising / promoting the QPM. It is possible to overcome this if standardised low-cost clonal nursery technology is evolved for each species and duly made available to industry through training and development.

c. Species Spectrum

Currently, only a few species are being used by the plywood, panelboard and sawnwood industries. The limited bouquet of species makes the promotion program prone to high risks. While there are many more species known to be fast growing and highly suitable for plywood, panelboard and sawnwood requirements, these need to be identified through systematic research for widespread adoption.

d. Clonal Bandwidth

Most of the clonal stocks in vogue for agroforestry today have been developed since 1990s through dedicated research wings of industry or research institutions. In recent times, the emphasis on the evolution of new clones has been limited to a couple of organisations. The pipeline isn't filled adequately to address the needs for the next few decades. There is an urgent need to initiate clonal development by identification of new populations, breeds, hybrids, etc for futuristic needs.

5. Need for Applied Research to Mitigate Extrinsic Challenges

The pulp and paper industry model of agroforestry promotion evolved over two decades through a series of learnings, successes, and failures, while the industry remained committed to consistency, R&D, resources, and a long-term vision. To trigger a similar transformation in the Indian plywood, panelboard and sawnwood industries, impetus can be created by organizing integrated sector specific research at the national level through farmer-industry-institutional collaborations under win-win models. Some of the research needs which will help overcome the barriers and deterrents in this industry are suggested below, along with a brief objective of the research.

a. **Agroforestry species for the plywood & panel board industry**

To identify, develop and create a pool of fast-growing tree species suitable for the plywood and panelboard industries in different agro-climatic zones of the country. This will provide much needed versatility to agroforestry initiatives and make the programme more risk-free.

b. **Clonal research & development**

To identify and develop new clones specific to the needs of the plywood, panelboard and sawnwood industries and suitable under different agroclimatic conditions in India. To evolve next generation clones through intra-clonal and inter-clonal hybrids.

c. **Low cost clonal nursery techniques**

To develop low cost and innovative clonal nursery techniques with easy replicability and high success rates for different species and under different agroclomatic zones.

d. **Silvicultural practises**

To evolve an ideal set of Silvicultural, Agro-Silvi, and Hort-Silvi packages of practises for different species under distinct agro-climatic zones.

e. **Methodologies for rural extension**

To study the most effective rural extension methodologies and success stories of agroforestry promotion in different states and create a user manual for extension staff.

f. **Tree traceability – Develop digital tool at national level**

Taking cues from some pioneering work by few organisations like Isha Foundation in the development of farmer-friendly digital applications for tree tracability, tracking, monitoring, and support, one has to develop a unique Government of India's Digital Application for standardized data capturing of agroforestry plots with back-end integration with land records, felling & transit permits, wood traceability, supply chains, logistics, buyers, QPM sellers etc.

g. **The national agroforestry research repository**

While adequate agroforestry-based research has already been conducted and is in the pipeline at the national level, the findings, reports and data of individual research are often inaccessible to new entrants. Sometimes, the wheel is reinvented for want of adequate information on already conducted research. There is a need to create an online 'National Agroforestry Research Repository' where all the research by any organization should be uploaded in the form of projects and should be made available in the public domain. This will help to spread the good works of all and will serve as a major information resource.

The plywood and panelboard industry in India is poised for major growth in the years to come with a CAGR projection of 10% to 12% till 2030. The roundwood demand of this industry is likely to double by the end of this decade.

Conclusion

The plywood and panelboard industry in India is poised for major growth in the years to come with a CAGR projection of 10% to 12% till 2030. The roundwood demand of this industry is likely to double by the end of this decade. Though the industry has been traditionally clouded by its own set of challenges, practices, prejudices and perceptions, the awakening has already begun as the industry stands at the start of a new cycle. The adage "Great power comes with great responsibility" is highly relevant in this context.

Industry majors have already commenced actions towards responsible sourcing of wood through the promotion of agroforestry in the command areas of their respective plants. Long term visions are being evolved and resources are being mobilized for fast-track execution of massive plantation drives through agroforestry and farm forestry models.

This is a crucial juncture for the industry. With great intent but with limited experience and resources, the industry plans to set an example by executing massive plantations through agroforestry promotion and addressing myriad external challenges to remove obstacles.

These challenges can be well addressed if time bound applied research and development is undertaken by nationally reputed research organisations and results are shared with industries. Once the initiative is perceived to be a viable proposition, replication across the sector will follow. This could transform the entire industry.

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Acrocarpus Fraxinifolius (Balangi): A Prospective Agroforestry Species in Coffee Plantations of Kodagu

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Acrocarpus fraxinifolius is one of the shade trees grown predominantly in the coffee plantations in the Kodagu district of Karnataka. In India, this is the only species which belongs to the genus Acrocarpus. It is considered as one of the tallest trees in India. It has a physical resemblance to ash and walnut wood trees (Anibal *et al.*1986) and is propagated as an ornamental tree (Whitmore and Otarola 1976). In tropical Africa and India, it is grown as a shade tree for coffee plantations (Rocas 2010).

Acrocarpus fraxinifolius

A. fraxinifolius Wight. & Arn. is a large deciduous, fast-growing species (Nath et al. 2012), annually grows up to 1.3–3 m and can reach a height of 50–60 m with a diameter 0.90–2.40 m (Whitemore and Otarola 1976). This species has originated from tropical Asia and is probably native to Asian tropics, with natural and biological distributions spanning India, China, Burma, Borneo, Sumatra, Indonesia, Vietnam, and Bangladesh. This exotic species is planted around the globe and is extensively known as Acrocarpo, Mundane and Clapboard tree (Lorenzi et al. 2003). It is called by different names in different countries, in India it called as Mundani or Balangi in Karnataka, in tropical Africa as pink cedar, and in Latin America as Cedro Rosado, Mundani and Lazcar. The other vernacular names for the tree include Australian ash, Indian ash, Shingle tree (Onyango et al. 2010), Arbolguijarra, Rojo Cedar, Pink Decro, Kenya treeand Lazcar Mundani (Rocas 2010).

Geographical distribution

A. fraxinifolius is distinguished as a part of tropical evergreen and subtropical evergreen forests. In India, it covers the evergreen forests on the hill slopes (up to 1200 m) of the Western Ghats (Troup 1921; Rai 1976), the tropical semi-evergreen forests of the eastern Himalayas, where it is one of the dominant tree species (Puri 1960). Annually, it grows up to 1.3–3 m and can reach up to a height of 50–60 m with a diameter of 0.90–2.40 m (Whitemore and Otarola 1976). Comprehensive Acrocarpus distribution is monitored in southern India in the Nilgiris, Coorg, north and south Kanara, Anaimalai, Tirunelveli and in the Western Ghats of Kerala state. The tree is also grown as a shade tree for coffee plantations in tropical Africa, in the Coorg and south Kanara districts of Karnataka. The lofty tree is also considered suitable for tea plantations. The species are also cultivated in the high rainfall zone of Himachal Pradesh between 600 and 1200 m elevations (Ghildyal 1989). The species also covers the eastern Himalayas, West Bengal, Bhutan, Sikkim, Assam and Meghalaya between 600 and 1200 m.

In India, this is the only species which belongs to the genus Acrocarpus. It is considered as one of the tallest trees in India. It has a physical resemblance to ash and walnut wood trees (Anibal et al.1986)

A. fraxinifolius with straight trunk, branching profusely at the top with a symmetric balance befitting the coffee plantation environment.

Soil type and pH

A. fraxinifolius grows best in deep, well-drained, clay–loam soils with a pH of 4–7 and also thrives in acid soils and limestone areas (Cheng 1985). In Mexico, Balagigrows in vertisol soil type with average drainage and a pH of 6.9–7.5.

Associate tree species

Balangi is associated with many dominant species found in the Western Ghats of Kerala and Karnataka such as *Acrocarpus hirsute, Vateria indica, Adina cordifolia, Sterculia guttata, Salmalia malabarica, Xylia xylocarpa, Hopea parviflora, Tetrameles nudiflora and Mesua ferrea* (Champion and Seth 1968). Other associated species in the tropical forests of the eastern Himalayas are *Shorea robusta, Albizia marginata and Cedrela toona* (Puri 1960).

Properties of Balangi

The heartwood is hard and strong, attributed to its pale, pinkish bright red to reddish brown colour having darker streaks which are well distinguished from the pale yellowish sapwood, adding to furniture and cellulose production (Lorenzi *et al.* 2003). The density of the wood varies from 0.44 to 0.68 g/cm^3 according to the age, site and origin (Simpson 1996; Carvalho 1998; Honorato et al. 2005). It has interlocked grain and the wood texture is coarse.

Pest

Stressed young trees are susceptible to biological invasion such as termites, grasshoppers, caterpillars, etc. Serious defoliation of young seedlings is contributed by grasshoppers and caterpillars. Damping-off is a prominent disease. It is also invaded by decay/rot organisms like Armillaria mellea. High rainfall and dry season lead to the mortality of these exotic trees. Nectria species have a paramount impact on the shoots attributing to the decay of the trees. In Mexico, trees are defoliated by leaf-cutter ants (Atta sp.). Trees are invaded by termites after being infected by unidentified fungi (Combe and Gewald 1979).

Advantages and uses of Acrocarpus plantation

The tree is a source of fodder, firewood for charcoal production, apiculture, timber, furniture, gum and resin. The wood is used to produce pulp for paper and also recommended for reinforcing river banks, stabilizing terraces and in agroforestry systems (Orwa *et al.* 2009). The lipoid content of leaves exhibits anti-inflammatory effect (Abou Zeid *et al.*, 2011). *A. fraxinifolius* can be termed as the tree for the future. The cultivation and plantation of this leguminous arboreal will contribute to the wood necessary and will attribute to preserving the forest and thousands of habitat and vegetal species.

A. fraxinifolius trunk characters: cylindrical, free of branches for up to 75% of its total height.

References: Contact author at muthukumar@icfre.org

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