IWST

wood *is* good

GROW MORE, USE MORE

ICFRE

Multifaceted Potential of Lantana camara

Vol.5 I Issue 2 I July-September 2024

ICFRE-INSTITUTE OF WOOD SCIENCE AND TECHNOLOGY (IWST), BENGALURU

Indian Council of Forestry and Education

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

FOREST DEVELOPMENT CORPORATION OF MAHARASHTRA LTD.

(A Government of Maharashtra Enterprise)

The Giant leap of FDCM Teak!!!

Started with the Sacred journey of FDCM Teak for Shri Ram Temple, Ayodhya to the comfort & dutiful chairs of the esteemed Parliamentarians and through (with) good hope now ready to explore the economic corridors of the Western World...

Teak: The Timeless Treasure

Choose the *Elegance in Each Grain* in the first ever FSC Certified Teak of India !!!

For Business Enquiry :

Address: FDCM Bhavan, 359/B Hingna Road, Ambazari, Nagpur -440036, Maharashtra

Contact No.: 7447279356, 9412996753, 8830911098

Email : gmplnfdcm@gmail.com, md@fdcm.nic.in | Website : www.fdcm.co.in

wood is good

GROW MORE, USE MORE

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.

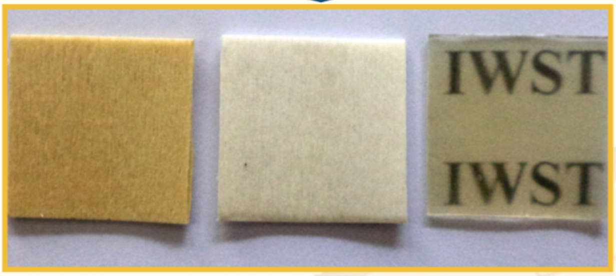
Wood Welding

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 colours, 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

For further details please contact :
Assistant Director General, Media & Extension Division,
Indian Council of Forestry Research and Education,
Dehradun - 248 006
Phone:- +91-135-222 4814, +91-135- 2755221,

Rajesh S. Kallaje, IFS

I/C DIRECTOR
ICFRE - INSTITUTE OF WOOD SCIENCE AND TECHNOLOGY,
P.O. MALLESHWARAM,
BENGALURU – 560 003

PREFACE

India's diverse forest ecosystems face increasing pressure from invasive species, posing challenges to biodiversity, forest management, and rural livelihoods. One such invasive species, *Lantana camara*, has proliferated across vast landscapes, altering native vegetation and reducing the productivity of forested areas. However, what is often perceived as a challenge also presents an opportunity—by exploring the utilisation potential of *Lantana camara*, we can transform this invasive plant into a valuable resource for sustainable development.

The theme of this edition of Wood is Good magazine focuses on the multifaceted potential of *Lantana camara* in the wood-based industry, handicrafts, and rural livelihoods. From its application in furniture-making, basketry, and bioenergy to its role in livelihood generation, *Lantana camara* presents a promising avenue for sustainable utilization. Research and innovation in processing techniques, treatment methods, and product diversification have shown that this invasive species can be converted into an eco-friendly alternative to conventional wood, thereby reducing dependency on timber resources.

At the Institute of Wood Science and Technology (IWST), Bengaluru, under the guidance of Indian Council of Forestry Research and Education (ICFRE), we strive to promote sustainable wood-based solutions. Our ongoing research aims to explore value-added applications of lesser-utilised plant resources, encouraging industries, artisans, and policymakers to adopt innovative approaches. By integrating *Lantana camara* into the circular economy, we can mitigate its adverse impact on forests while simultaneously fostering economic opportunities for forest-dependent communities.

This edition of Wood is Good brings together insights from researchers, policymakers, NGOs (Such as ATREE, The Shola Trust, Junglescapes, Green Yatra, etc.,) and industry experts on the potential of *Lantana camara* management and utilisation. We hope it serves as a platform to inspire further research, collaboration, and policy interventions for harnessing invasive species into productive and sustainable resources. As part of an extension activity under the project *Mapping, Monitoring, and Management of Lantana camara through Utilization for Improving Livelihoods of People in Forest Fringe Villages of India*, funded by CAMPA, MOEF & CC, Government of India, this edition sensitizes all stakeholders to the potential of *Lantana camara* management and utilization.

Contd..2

We extend our sincere gratitude to all contributors for their valuable insights and look forward to fostering meaningful discussions on this promising frontier of wood science and technology. Special thanks to the NGOs working alongside stakeholders to develop a holistic and adaptive approach to *Lantana camara* management.

Dated: 14th March 2025 (Rajesh S. Kallaje)

दूरभाष/Phones: कार्यालय /Office: 080-23341731 (निदेशक/Director), 22190100, 200 (सामान्य/Gen)
फैक्स/Fax: 080-23340529, ईमेल-/e-mail: dir_iwst@icfre.org,
वैबसाइट/Website:http://iwst.icfre.gov.in

CONTENT

Wood is Good
Vol. I. Issue I. April-June 2020

Wood is Good
Vol. II. Issue I. April-June 2021

Wood is Good
Vol. I, Issue II July-September 2020

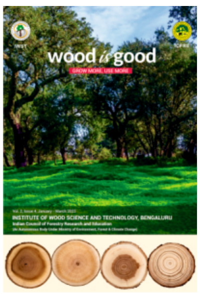
Wood is Good
Vol. II, Issue II July-September 2021

Wood is Good
Vol. I, Issue III October-December 2020

Wood is Good
Vol. II, Issue III October-December 2021

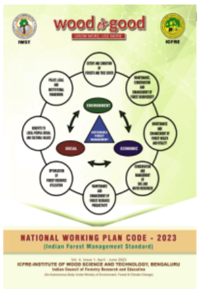
Wood is Good
Vol. I, Issue IV January-March 2021

Wood is Good
Vol. I, Issue III October-December 2020



Wood is Good
Vol. III. Issue I. April-June 2022

Wood is Good
Vol. VI. Issue I. April-June 2023



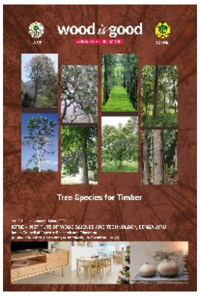
Wood is Good
Vol. III, Issue II July-September 2022

Wood is Good
Vol. VI, Issue II July-September 2023

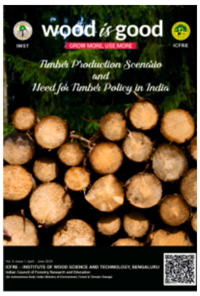
Wood is Good
Vol. III, Issue III October-December 2022

Wood is Good
Vol. VI, Issue III October-December 2023

Wood is Good
Vol. III, Issue IV January-March 2023



Wood is Good
Vol.IV, Issue IV January - March 2024



Activities of ICFRE-IWST during July – September 2024

Institute Industry Interactive Meet

ICFRE-IWST in collaboration with Federation of Indian Plywood and Panel Industry (FIPPI), Association of Furniture and Traders (AFMT) and Association of Indian Panel Board Manufacturers (AIPM) organized Plywood, Panel and Furniture industry Meet - Need for Forward and Backward Linkage through hybrid mode on 15th July 2024 in which Leading Industry Directors participated. Dr. M. P. Singh, IFS, Director, IWST delivered the inaugural address.

The meet addressed the challenges of wood based industries like changing raw material scenario, policy issues in panel industries and revision of Indian Standards for various categories of panel products. The Institute Industry Interactive Meet concluded with fruitful open house discussion and interaction with stakeholders, policy makers, furniture industries and others thus paving the way forward to create linkages between wood based panel industry and furniture sector to bridge the gap and develop healthy network.

Training for IFS officers on "Enhancing Productivity of Forest Corporations through Value Addition to Wood"

ICFRE-IWST organized the MoEF&CC sponsored one week compulsory training on "Enhancing Productivity of Forest Corporations through Value Addition to Wood" for serving IFS Officers. A total of 9 IFS officers nominated by MoEF&CC from different states attended the training from 22 - 26 July 2024.

The training covered various topics which are essential to enhance productivity of forest corporations like alternative timbers for commercial application; wood processing and value addition : current trends, sandalwood as commercial plantation; world trade in teak and opportunities for India; timber certification and its legality in India with respect to profitability of forest development corporations; role of FDCs in increasing timber productivity – case study from Maharashtra; activities of forest development corporation of Kerala; augmenting teak production through clonal teak; activities of forest development corporation of Karnataka and rubber wood value chain activities of forest development corporation of Tripura. Managing Directors from Forest Development Corporations of Karnataka, Kerala, Maharashtra and Tripura shared about the role and activities of the corporations and interacted with the participants. The training included field trip to plantation sites of Andhra Pradesh Forest Development Corporation at Tirupati. The officers also visited IWST laboratories, xylarium, wood museum and wood working centre to get an understanding of the research activities being carried out at the institute.

Training for IFS officers on "Sandalwood Cultivation and its Management"

Institute organized the MoEF& CC sponsored three days training workshop for serving IFS officers on "Sandalwood Cultivation and its Management". A total of 13 IFS officers nominated by MoEF& CC from different states attended the training from 07 - 09 August 2024 at Lalitha Mahal Palace Hotel, Mysuru. The training included aspects like introduction to sandalwood and its perspective; nursery and seed technology; plantation establishment and agroforestry models; Electrical Resistance Tomograph (ERT) for estimating heartwood in standing trees of Santalum album L.; sandalwood oil, uses & adulterants; management of plant diseases in sandalwood nursery & plantations; sandalwood products, prospects, protection and policy issues. Field visit to sandalwood plantations, sandalwood depot, sandalwood oil factory and sandalwood museum was arranged for the participants to give them onsite practical insights about sandalwood cultivation, management and oil extraction.

Independence Day Celebration 2024

ICFRE- IWST Bangalore celebrated 78th Independence Day on 15th August 2024. Shri. Rajesh S. Kallaje, IFS, I/C Director IWST unfurled the National Flag and addressed the gathering of officers, technical & administrative staff and students.

Training for IFS officers on "National Working Plan Code-2023 and Indian Forest Management Standard"

ICFRE-IWST, Bangalore organized the MoEF& CC sponsored one week training on "National Working Plan Code-2023 and Indian Forest Management Standard" for serving IFS Officers during 19 – 23 August 2024 at Lalitha Mahal Palace Hotel, Mysuru. A total of 19 IFS officers nominated by MOEF &CC from different states attended the training.

The training comprised of classroom sessions and field visit. The technical session covered important topics like Overview of National Working Plan Code 2023; Basics for the Preparation and Approval of Working Plan; Use of IT, GIS and Remote Sensing in Forest and Wildlife Management; Writing of Part I and Part II of Working Plan (Constitution of Working Circles); Importance of Maps in Working Plan Preparation; Use of VAN App for Field Data Collection; Forest Resource Assessment and Data Collection' Generation of Geospatial database of forest and land resources; Presentation on Working Plan of Kundapura Forest Division, Karnataka using the Geospatial data base; Forest Certification in Global Perspective and Indian Forest & Wood Certification Scheme. Field visit to working plan office, Mysore and Madikeri Forest Division for hands on exercise on laying sample plots and field data collection was the highlight of the training program.

Forestry Training and Capacity Building: Training of Other Stakeholders on Adhesives& Wood based Panel Products

ICFRE-IWST organized three days training on "Adhesives& Wood based Panel Products"under the MoEF&CC sponsored Forestry Training &Capacity Building –Training to other Stakeholders during 18 – 20 September 2024. The training was well received by 30 industry representative working in different sectors from Maharashtra, Bihar, Gujarat, Telangana, Andhra Pradesh and Karnataka.

The resource persons for the training program were scientists and officers from ICFRE-IWST and the visit to two industries was supported by Karnataka State Forest Industries Corporation (KSFIC), Bangalore and M/s. Raaj Wood Products, Nelamangala, Bangalore. Lectures from resource persons were scheduled over three days covering various aspects of professional knowledge with regard to processing technologies for efficient utilization of wood and its conversion into engineered wood and a variety of panel products viz. plywood, particleboard, fibre board, block board and flush door etc.; synthetic conventional resins adopted on commercial scale and bio adhesives synthesized using materials of natural origin with detailing on adhesive formulations used for panel product and their importance in terms of durability of product; raw materials for resin manufacturing; processing of plywood and other panel products; testing of plywood, block board and flush door; importance of preservation and techniques adopted for treatment of wood and panel products to enhance the service life. Hands on practise and demonstration of processing and products manufacturing were also made on pilot scale at chemical, mechanical, wood identification and protection laboratories. The participants were taken on one day trip to provide exposure on industrial production of plywood, block board and flush door.

Hindi Pakhwada Celebration 2024

ICFRE-IWST, Bangalore celebrated Hindi Pakhwada from 14-28 Sept 2024. Sri. Rajesh S. Kallaje, IFS, I/C Director of the Institute inaugurated the hindi fortnight. The Director addressed all the scientists, officers and staffs of the institute and encouraged them to use Hindi in day to day official correspondences. He also requested employees to work towards promoting Hindi as Rajbhasha in personal as well as organizational capacity. Competitions were conducted under different categories. Employees and students and showed keen interest and participated in competitions. The concluding program was held on 28th Sept 2024.and on this occasion prizes were distributed to the winners of various competitions.

Memorandum of Understanding Signed

Memorandum of Understanding was signed on 19th July 2024 between ICFRE- Institute of Wood Science and Technology, Bangalore and Maharani Lakshmi Ammanni College for Women, Bangalore towards academic and technical collaboration and sharing of facilities.

Memorandum of Understanding was signed on 29th Aug 2024 between ICFRE- Institute of Wood Science and Technology, Bangalore and Mount Carmel College, Bangalore towards academic and technical collaboration and sharing of facilities.

VVK – KVK trainings

Under VanaVigyan Kendra trainings funded by CAMPA, ICFRE-IWST, Bangalore conducted a one day training program on "Sandalwood based Agroforestry Models & its Health" (Pest management) for farmers through KVK, Kandali, Hassan on 30 July 2024. About 40 farmers benefitted from the program.Progressive farmers also shared their experience during the program.

Two trainings each on Wood Science and Technology and Bamboo primary processing and value addition was conducted on 4th and 5th September 2024 to enrich the practical knowledge of forestry students of College of Forestry, Ponnampet, Madikeri District.

Visit of trainees from CASFOS and Forest Academies

120 Range Forest Officer trainees from Karnataka Forest Academy, Dharwadand Kundal Forest Academy, Maharashtra visited the laboratories, workshops and other facilities at the institute. IWST also organized two days short term specialized training module on "Wood Technology" for42 State Forest Service Officer trainees of CASFOS, Coimbatore. Artisans trainees, instructors and officer from Madras Engineer Group & Centre, Bangalore visited Xylarium, Wood workshop, Advanced Wood working Training Centre and Technology Demonstration Centre .

Visit of students under Prakriti program of ICFRE

An overview of research activities carried out at ICFRE-IWST is given to visiting students of different age groups and disciplines from universities, colleges & schools as part of Prakriti program of ICFRE. According to their curriculum needs, interests and education level, students are taken to various facilities like Tissue Culture lab, Molecular Biology lab, Pathology lab, Chemistry lab, Plant Nursery, Xylarium, Wood workshop and Advance Woodworking Training Centre, Wood Museum and Technology Demonstration Centre. Few student batches visit the IWST-IPIRTI Campus to enhance their knowledge at Adhesive Technology lab, Plywood pilot plant, Particle Board pilot plant, Fire door testing facility, Bamboo Processing units and Coir Composite centre. Students and faculty arealso sentisized about Mission LiFE Activity and Pledge is also administered.

Few institutions that visited IWST are Mitra Academy, Ten Brooke Academy, National College, Presidency School, NIFD Global, New Baldwin International School, The Indian Public School, Thirumala Vidyaniketann and LISAA School of Design, Bangalore. Also 200 students from Government School Sira and Madhugiri, Tumkur District on Science industrial trip (organized from K.C. Reddy Sarojamma Welfare Foundation Bangalore) visited the institute and its facilities during this period.

Trainings under NTPS

National Transit Pass System cell of ICFRE-IWST conducted 7 trainings during July-September 2024 to Forest Department officials of 6 States/UTs (Uttarakhand, Uttar Pradesh, Maharashtra, Chhattisgarh, Andhra Pradesh, West Bengal) and 1 Training for Federation of All India Timber Merchants Saw Millers & Allied Industries for smooth roll out and implementation of National Transit Pass System.

Other events:

CFRE-IWST conducted two days customized training on 'Wood based packaging materials' for the executives of M/S SIGNODE India Pvt. Ltd from 8th - 9th July 2024. Ten officers participated in the training programme.

ICFRE-IWST in association with ICFRE-IFGTB, Coimbatore organized the ICFRE-Regional Research Conference on Forest Research So Far – Way Forward. 250 forest dept. officials, academicians and Wood Industry representatives participated through hydride mode on 28th Aug 2024.

Dr.M.P. Singh, IFS, Director, IWST got repatriated to his parent cadre of Jharkhand on 15th July 2024 and Sri. Rajesh S. Kallaje, IFS took charge as Director In-charge of IWST.

ICFRE- IWST participated in MATECIA 2024 Exhibition at Yashobhoomi, Dwarka, New Delhi by showcasing innovative wood, bamboo & lignocellulosic composite products and sharing cutting-edge technology with industry, academia and public.

ICFRE-IWST organized an awareness program on 'Dynamic Digital Presence' (Cyber Hygiene and Security) on 12th Sept 2024 as part of three-month campaign on Preventive Vigilance. Mr. A. C. Ashok Kumar, STO, IWST delivered the lecture.

Shri. Rajesh S. Kallaje, IFS In-Charge Director, ICFRE-IWST inaugurated 5 days training programme on 'Sandalwood Farming and Management of its Health' from 23rd to 27th September 2024. About 26 farmers from different states participated in the training.

Exploring the Utilization Potential of *Lantana camara*

The workshop focused on exploring the potential uses of Lantana camara commenced with a welcome address by Dr. Shakti Singh Chauhan, Scientist- G & Component Coordinator, who underscored both the promising applications and the significant challenges in managing and managing this invasive alien plant species. Dr. Chauhan emphasized the dual nature of Lantana camara, highlighting the need for strategic management in light of its widespread spread. Shri. Rajesh S. Kallaje, IFS, Director of the Institute of Wood Science and Technology (IWST) then took the stage to make his opening remarks, extending a warm welcome to the attendees and emphasizing the importance of recognizing Lantana camara as a sustainable resource. He called attention to the necessity for innovative marketing strategies and economic models to overcome the hurdles associated with its production and scalability, while also pointing out its detrimental impact on coffee plantations and sandalwood forests.

Dr. Rajasekaran, Scientist- F & National Project Coordinator, provided further insights on *Lantana camara*, revealing that nearly 40% of the invasion occurs in national forests, which underscores the urgent need for effective management. Shri Shivakumar IFS, Group Coordinator of Research, IWST also highlighted the species spread from Kashmir to Kanyakumari, even reaching the Himalayan ranges. He advocated for a cooperative approach and stressed that management, rather than eradication, is the most viable strategy for dealing with this widespread menace.

After the inaugural remarks, participants introduced themselves, and Dr. Rajasekaran presented an in-depth analysis of the factors influencing Lantana camara growth, noting that none of the current control measures—be it chemical, physical, biological, or fire-based—have proven effective in halting its spread. He pointed to the lack of awareness and minimal disruption in current control strategies, asserting that management is the only feasible option. Dr. Rajasekaran also suggested that creating value-added products from *Lantana camara* could provide economic and social benefits, and outlined a comprehensive management framework comprising three key components:

1. Mapping,
2. Removal and restoration of affected areas, and
3. Demonstration of value-added products.

The project currently involves five states—Gujarat, Madhya Pradesh, Uttar Pradesh, Kerala, and Jharkhand—with Odisha recently joining. Research institutions such as Council of Scientific and Industrial Research - Indian Institute of

Forest Management (IIFM), National Remote Sensing Centre - Indian Space Research Organisation (NRSC - ISRO), and regional institutes of Indian Council of Forestry Research and Education (ICFRE) are collaborating on various aspects of the project, including bioenergy research, business model development, and landscape restoration with stakeholder involvement. Effective strategies include seed ball distribution, sapling plantations, supporting native plants, and utilizing Lantana camara. Dr. Rajasekaran highlighted the promising outcomes of the project, including standardized mapping techniques, skill development, restoration protocols, and innovative uses like essential oils for insect repellents. For instance, ICFRE-IFGTB Coimbatore has developed "Tree Pal," a product effective against teak defoliators, and is also exploring Lantana camara as an insect repellent and compost. The meeting emphasized the need for comprehensive research, business models, and collaboration to transform Lantana camara from a harmful invader into a valuable resource.

Next, Dr. Subhash and Ms. Nikita Nayak from the Shola Trust presented their perspective on utilizing Lantana camara as a resource, describing it as a "weed turned into wealth." They emphasized the plant's coppicing ability and noted the vast invasion in the Nilgiri Hills, which covers roughly 2,000 square kilometers. The speakers introduced the concept of a circular economy that integrates habitat restoration, removal efforts, and livelihood generation to improve elephant habitats. They discussed potential products such as furniture, biomass pellets, and other items, and highlighted their efforts in Karnataka, Kerala, and Tamil Nadu, which have generated INR 4 crore in income through their Lantana camara removal and utilization initiatives. They also stressed the importance of developing logistical and institutional support for Lantana camara utilization, including potential products like biochar, gasifiers, and modular housing. The Shola Trust also faced challenges such as limited cooperation from forest departments, hindering large-scale implementation. During a discussion on biochar production, they shared insights on pyrolysis and its potential applications in sustainable practices.

Dr. Harisha RP from ATREE, Karnataka, then shared a case study on Lantana camara crafting and livelihood initiatives at MM Hills. He detailed how invasive species like Lantana camara affect ecosystem diversity, health, and productivity, and discussed ATREE's long-term monitoring of Lantana camara invasion since 2003. Dr. Harisha highlighted the role of the Soliga community in utilizing Lantana camara for their livelihood and presented the three essential components for success:

a. Technology and Product Development,

b. Artisan Training, And

c. Market Linkages.

He explained the stick-boiling process used to enhance the durability of materials for furniture production and showcased the three Lantana Livelihood Centers (LLCs) operating in the region, which have generated INR 3.97 crore over the past two decades. While these initiatives have proven successful in enhancing local livelihoods and restoring native biodiversity, Dr. Harisha pointed out key challenges, including the need for better marketing channels, reduced production costs, increased volumes, and localized skill and technology development.

Dr. Hanumanth C.R. and Dr. K. Anand then presented on the ecological uses of *Lantana camara*, suggesting that restoration should focus first on low-to-medium-density infestation sites, in line with international principles for managing invasive species. They recommended the cut root-stock method for removal, supplemented with natural regeneration efforts, and advocated for policy amendments to allow for a minimum three-year restoration period. They emphasized that ecological restoration, rather than purely commercial exploitation, offers a more sustainable and impactful solution to the challenges posed by Lantana camara. They also discussed the potential of using the plant as a fuel source and called for large-scale funding to support ecological restoration, which would contribute to carbon sequestration and biodiversity conservation.

Mr. B.G. Seetharaman from M/s Indic Initiatives, Karnataka, presented his innovative work on producing handmade paper using Lantana camara. He described the plant as an untapped resource among fibrous agricultural residues. However, he acknowledged that traditional methods of handmade paper production are neither scalable nor economically feasible. To overcome this challenge, his team is developing compact machines specifically designed for handmade paper manufacturing. The raw materials used in their process include jute fibers, banana fibers, leather scraps, recycled waste paper, and a variety of agro-fibers. Their efforts focus on recycling waste paper and making productive use of agricultural residues. They have explored manufacturing techniques at both lab and pilot scales, utilizing inputs from farms, industrial operations, and municipal solid waste plants. Mr. Seetharaman emphasized that approximately 40% of the raw material required for paper production currently comes from wood chips, presenting a significant opportunity to substitute these with alternatives like Lantana camara. He also detailed the development of specialized machines, including nano and mini pulp mills, designed to make paper production more sustainable and accessible. When asked about the cost of implementing these machines, he mentioned that a large-scale plant setup could cost as much as 90 lakhs.

Following this, Mr. Parameshwaran K. Iyer, Director of Bamboo Pecker Lifestyle Crafts showcased diverse applications of Lantana camara in their product designs, particularly highlighting its use in creating aesthetic and functional furniture. The session continued with Mr. Thanigai K, a senior scientist from IWST, who shared insights into the institute's initiatives for utilizing Lantana camara. He discussed the plant's anatomy, delved into its physical and mechanical properties, and provided details about its cellulose, hemicellulose, and lignin content. Mr. Thanigai also discussed ongoing product development efforts involving composite fibers and molding, particularly as sustainable alternatives to single-use polymers, which have been banned by the European Union. During the session, participants raised questions about the challenges of manufacturing products from Lantana camara, especially in the context of cement boards. In response, Mr. Ramkumar V R, Scientist- C, explained that water absorption is a significant obstacle in using Lantana camara for cement board production.

Mr. Ritesh Kumar, a senior scientist at IWST, presented on the potential of Lantana camara as biomass and its application in briquetting for thermal power plants. He detailed the briquette manufacturing process, outlined the National Thermal Power Corporation (NTPC) specifications for briquettes and pellets, and provided insights into the fuel properties and elemental analyses of Lantana camara. Further insights were provided by Mr. Jayadeep Uniyal, a project associate from the Council of Scientific and Industrial Research Indian Institute of Petroleum (CSIR-IIP), Dehradun, who elaborated on existing models for collecting and utilizing Lantana camara. This was followed by Mr. Rajkumar IFS, Conservator of Forests and Field Director from the Sathyamangalam Tiger Reserve in Tamil Nadu, who shared his perspective on the challenges posed by this invasive species. He highlighted that approximately 222,000 hectares of the reserve are covered by Lantana camara, adversely affecting habitat quality and complicating management efforts.

The session concluded with a vote of thanks by Mr. Ramkumar VR, Scientist- C, IWST. He expressed his gratitude to the participants, speakers, and organizers for their valuable contributions and insights into managing and utilizing Lantana camara. He underscored the importance of collaborative efforts to address the challenges posed by this invasive species and emphasized the need for continued research and innovation to transform Lantana camara from an ecological problem into a valuable resource that can benefit both ecosystems and livelihoods.

"Adaptive management" offers a dynamic and practical solution to address the challenges posed by Lantana camara. By integrating continuous learning, stakeholder collaboration, and innovative practices, it enables effective utilization of this invasive species while minimizing its ecological impact. This approach ensures sustainable outcomes that benefit both the environment and livelihoods.

Glimpses of the workshop

Current Status of *Lantana camara* Invasion in India

Rajasekaran, A., Dharani, B., Krishna Priya, J., and Rachana, P.M.
Institute of Forest Genetics and Tree Breeding,
Coimbatore -641002
E-mail :- rajashekarana@icfre.org

Lantana camara L., an invasive terrestrial weed of South and Central American origin has a huge impact on the native composition of terrestrial ecosystem. Lantana has spread rapidly across the country due to its fast growing nature and its ability to adapt to a variety of environmental conditions. Lantana poses a serious threat to biodiversity, soil health, and human livelihoods. This article explores the current status of Lantana invasion in Indian forests and non-forest areas, highlighting its ecological impact, spread, and management strategies being employed.

Lantana in India: A Brief Overview

Lantana camara was introduced to India in the early nineteenth century by the British as an ornamental plant (Figure 1). It was initially imported from Central and South America for use in gardens due to its vibrant flowers and ability to attract pollinators. Over centuries, hundreds of cultivars and hybrids have been developed and cultivated. Lantana species are primarily pollinated by bees, butterflies, and other insects, which transfer pollen between different varieties and species. This allows genes from different Lantana populations to mix, creating genetically diverse hybrids with enhanced survival traits. Further, birds, especially frugivorous (fruit-eating) species, consume Lantana berries and spread seeds across large distances. This dispersal promotes genetic mixing as seeds from different parent plants grow in new areas and interbreed. In addition, Lantana quickly escaped from cultivation and spread into forests, grasslands, and agricultural lands. Hybridized forms of Lantana camara have been observed with varied flower colors, differing growth habits, and increased invasiveness in different parts of the country (Figure 2). Its rapid growth, ability to produce a large number of seeds, and high adaptability to disturbed environments has allowed it to spread across India, especially in areas that have been altered by external disturbances. Lantana camara's phenotypic plasticity is a key reason for its global success as an invasive species. Its ability to modify growth patterns, physiological traits, and reproductive strategies enables it to thrive in various environments, making it difficult to manage. Today, it is regarded as one of India's most problematic invasive species spreading throughout tropical and subtropical areas.

Characteristics of *Lantana camara*

Lantana camara's success as an invader stems from a combination of biological, ecological, and reproductive characteristics that allow it to out compete native plants, alter ecosystems, and resist control efforts. Key invasive traits of Lantana camara included high phenotypic plasticity (ability to adapt to different environments), rapid growth and competitive advantage, effective reproductive strategies (high seed production &long seed viability), efficient seed dispersal mechanisms (birds, animals, water and human activities), allelopathy, regrowth after cutting or burning and minimal natural enemies. It thrives in diverse climates and soils, tolerates drought and shade, and releases allelopathic chemicals that suppress native plants. Lantana forms dense thickets, grows rapidly, and resists grazing due to toxic compounds. It modifies soil properties, reduces biodiversity, and disrupts ecosystems. Its ability to resprout after fire and thrive in disturbed habitats enhances its spread, often aided by human activities. Additionally, the absence of natural enemies in its introduced range allows it to grow unchecked, out competing native vegetation

Fig 1. A view of *Lantana camara*

Fig 2. Another view of Lantana camara in Nilgiris

Lantana camara is a highly allelopathic plant, meaning it releases biochemical compounds (allelochemicals) that inhibit the growth, germination, and survival of other plants in its surroundings. These chemicals give Lantana a competitive advantage, making it a dominant invasive species in many ecosystems. Major allelochemicals in Lantana include Phenolic Compounds (p-Coumaric acid, Caffeic acid, Vanillic acid, Ferulic acid, Syringic acid), Terpenoids and Essential Oils (Lantadene A & B, Camphor, Linalool, α-Pinene & β-Pinene), Flavonoids (Quercetin, Kaempferol, Rutin). These allelochemicals suppressnative vegetation by hindering seed germination and plant growth, changingsoil chemistry, making it unsuitable for other species, reducingmicrobial diversity, limiting nutrient availability for native plants and Inhibitingcrop productivity.

Lantana camara Distribution

Lantana camara is widely distributed across India, thriving in tropical, subtropical, and dry regions. It has spread across forests, agricultural lands, roadsides, grasslands, and wastelands, outcompeting native vegetation. It has spread across various forest ecosystems, including moist deciduous, dry deciduous, and scrub forests. Lantana is often found at the edges of forests, along roads, and in disturbed areas where human activities such as logging, grazing, and agriculture have occurred. It is also widely spotted in ecotone habitats across the ecosystem. However, in the recent past it has begun to spread into less disturbed areas as well, making it a growing threat to biodiversity.

In Northern India, Lantana is found in the lower Himalayan foothills and Shivalik ranges of Uttarakhand, Himachal Pradesh, Jammu & Kashmir and it grows along roadsides, abandoned fields, and open lands in Uttar Pradesh, Punjab, and Haryana states. In Central India, Lantana dominates forests, grasslands, and national parks (e.g., Kanha and Bandhavgarh National Park) of Madhya Pradesh, Chhattisgarh and in coastal areas and dry forests of Odisha. In Western India, Lantana is found in semi-arid and dry deciduous forests of Rajasthan, Gujarat, and Maharashtra states and in coastal zones and forested regions of Goa. In Southern India, it is found in both forested and non-forested areas of Karnataka, Kerala, Tamil Nadu, Andhra Pradesh and Telangana states. In Eastern India, it grows in terai grasslands, riverbanks, and degraded lands of West Bengal, Bihar, Jharkhand. In North-eastern India, it is found in hilly regions and tea plantations of Assam, Meghalaya, Arunachal Pradesh and Nagaland.

The states including Uttarakhand, Himachal Pradesh, Madhya Pradesh, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Odisha, West Bengal and Chhattisgarh havebeen reported to be highly invaded by Lantana. The plant also has a significant presence in India's protected areas, national parks, wildlife sanctuaries, and forest reserves. A study published in Global Ecology and Conservation reports that Lantana has occupied 154,000 sq.km of forests in India's tiger range. Among these forests, Shivalik Hills in the North, the fragmented deciduous forests of Central India, and the south Western Ghats are the worst hit by its invasion (Figure 3). Lantana is usually found up to altitudes not more than 2000 metres above sea level.

Fig 3. A view of Lantana camara spread in Himachal Pradesh

Lantana has spread significantly in non-forest areas in India, including urban areas. The plant thrives in disturbed environments, particularly where human activities such as grazing, agriculture, and urbanization have altered the landscape. It is commonly found along roadsides, railway tracks, abandoned agricultural fields, and degraded grasslands.

In agricultural landscapes, Lantana competes with crops and reduces their yield by forming dense thickets that block sunlight and access to soil nutrients. It is particularly problematic in grazing areas, where its spread reduces the availability of forage for livestock. The plant's aggressive growth also hampers the regeneration of native grasses and plants that are crucial for maintaining the ecological balance in non-forest areas.

Extent of Lantana spread

Despite the alarming effects of Lantana camara on the environment, the rate at which it is spreading into new areas has been poorly documented. Remote sensing technologies proved to be useful in mapping and monitoring invasive species over time. Various methods of mapping and modelling have been used by various researchers to study the extent of the Lantana invasion in India. Maxent (Maximum Entropy) Modelling is one of the widely used modelling techniques used to model Lantana invasion. Some studies used combined satellite data to map the spread of Lantana. For example, Indian Remote Sensing Linear Imaging Self-Scanning Sensor (IRS-LISS) III (multi-spectral, 23.5 m), IRS LISS IV (multi-spectral, 5.8 m), Cartosat-1 (Panchromatic, 2.5 m) and a merged image of LISS IV and Cartosat-1 using Brovey fusion techniques was used to map Lantana. However, Lantana being an understorey species, it is difficult to detect from satellite imagery. Hence, there is a need to standardise geospatial technology for mapping of Lantana spread.

A recent study predicted that Lantana invaded 86,806 km2 of forests (38.8%) in India. However, the actual extent of Lantana invasion in various biodiversity rich areas especially Protected Areas (PA) of the country is unavailable. Indian Council of Forestry Research and Education (ICFRE) in collaboration with National Remote Sensing Centre (NRSC) has initiated a study to develop a standardized technology for mapping of Lantana. Since the accurate mapping of Lantana is a challenge, various multi-temporal, multi-spectral, higher spatial resolution satellite images (Landsat/ Sentinel 2/ LISS-IV/Cartosat), would be used in this study depending on the need. Similarly, various algorithms such as maximum likelihood and machine learning will be used for accurate mapping of Lantana and other of IAPS. In addition, important indices like Normalized Difference Vegetation Indices (NDVI), Enhanced Vegetation Indices (EVI), distance from road and river will be used for mapping the species.

2. Ecological Impacts

The ecological impact of the Lantana invasion in Indian forests is profound. Lantana forms dense thickets that significantly reduce light availability, thereby inhibiting the germination and growth of native plant seedlings. Its aggressive competition for vital resources, including water, nutrients, and space, and allelopathic properties further suppresses the establishment of native seedlings and saplings, which are crucial for natural regeneration.

The loss of native plants impacts herbivores and small mammals that depend on these plants for food and habitat. It negatively impacts wildlife by altering habitat structure, food availability, and ecosystem dynamics. It replaces native vegetation, reducing habitat quality for native fauna that depend on diverse plant communities. Lantana invasion leads to the loss of forage plants for herbivores and alters food webs, often leaving certain species without adequate resources. The plant's toxicity can harm grazing animals, while its proliferation restricts movement for larger wildlife, affecting their natural behaviours and survival.

Lantana camara negatively affects soil quality by altering its physical, chemical, and biological properties. Lantana reduces soil moisture by forming dense thickets that compete for water, reducing availability for native plants. Lantana modifies soil properties by altering pH, reducing organic matter, and depleting nutrient availability, creating unfavourable conditions for native flora. Additionally, its dense root system interferes with soil structure and water infiltration. Lantana releasesallelochemicals into the soil that inhibit the growth of surrounding plants and further contribute to its dominance in invaded areas. This reduces the diversity of flora, affecting the entire food web in the ecosystem. The reduced plant diversity has cascading effects on the fauna, particularly pollinators, herbivores, and small mammals, which in turn affect the food chain.The loss of food and habitat for wild animals leadsto human-wildlife conflict.

Lantana camara is highly fire-prone and plays a crucial role in altering fire regimes in invaded ecosystems. It forms dense, flammable thickets, increasing the frequency and intensity of fires. Moreover, fire often favours Lantana's regrowth, making it even more difficult to eradicate. The Lantana-Fire Hypothesis suggests that Lantana camara alters fire regimes by increasing fire frequency, intensity, and severity, which in turn promotes its spread and dominance while suppressing native vegetation. This creates a self-reinforcing fire-invasion cycle, making it difficult to restore invaded ecosystems

The decrease in native species directly affects the forest-dependent communities who rely on non-timber forest products (NTFPs) for their livelihood. The dense growth of Lantana affects the lifestyle and livelihood of forest communities, making itexceedingly difficult for them to access the forest to forage for edible tubers and collect firewood.

The invasion of Lantana in non-forest areas in India has both ecological and economic consequences. Lantana's ability to form monocultures reduces biodiversity in grasslands and agricultural landscapes, as it outcompetes native plant species. The reduction in native vegetation impacts herbivores, including livestock, which rely on native grasses for food. Additionally, Lantana's spread in grazing areas increases the cost of livestock management for farmers, as they need to clear the plant from their lands or find alternative grazing grounds.

In agricultural areas, Lantana reduces crop yields and disrupts farming activities. Farmers often face challenges in controlling the spread of Lantana, which can result in significant economic losses. The plant also reduces the aesthetic and recreational value of landscapes, which can affect ecotourism, particularly in regions where Lantana infestations are prominent.Lantana competes with native grasses and alters the vegetation structure. This reduces the habitat for native herbivores and grazing animals, which affects the local economy, especially in rural areas that depend on livestock and dairy farming.

3. Management and Control

Efforts to manage Lantana invasion in Indian forests have been ongoing for several decades. Mechanical control methods are generally not efficient for managing invasive alien plants and can exacerbate existing problems. Additionally, these approaches may result in soil disturbance and nutrient leaching. Despite their limitations and associated costs, they are commonly employed for small infestations due to their simplicity and ease of implementation. The cost and labour involved in manually clearing large areas, especially in remote or inaccessible parts of forests, make this method unsustainable in the long term.

Chemical control of invasive plants in forests involves the application of herbicides to manage non-native species that threaten biodiversity and forest health. This method is often employed when mechanical removal is impractical or insufficient. Chemical management techniques present considerable risks to the forest environment. It is not advisable to carry out chemical methods of control in forest areas because they also severely impact other plant communities and the micro-fauna that depend on the said plant communities.

Biological control involves using natural enemies such as insects, fungi, and pathogens to suppress *Lantana camara* growth and spread. Since Lantana is highly invasive and difficult to manage using mechanical and chemical methods alone, biocontrol has been explored as a sustainable approach to reduce its dominance without harming native ecosystems. Insects such as Lantana Lace Bug (Teleonemiascrupulosa), Lantana Mealybug (Phenacoccus parvus), Seed-Feeding Fly (Ophiomyialantanae), Stem-Boring Beetle (Octotomascabripennis) and Gall-Mite (Acerialantanae) have been introduced to control Lantana in different countries, with varying success. Rust Fungus (Prospodiumtuberculatum) and Anthracnose Fungus (Colletotrichum gloeosporioides f. sp. lantanae) were also tried as biocontrol agents.However, biological control agents, while promising in managing Lantana, can pose significant risks to non-target species and ecosystem dynamics. Some agents may shift their focus to native plants, particularly those taxonomically similar to Lantana, leading to unintended ecological consequences. Over time, these agents may adapt genetically or behaviourally, broadening their diet and increasing risks to non-target species. Despite rigorous testing under quarantine, predicting long-term ecological impacts remains challenging, raising ethical and regulatory concerns about their use.

Another strategy being implemented is the use of fire as a management tool. Lantana is highly susceptible to fire, and controlled burns are sometimes used to reduce its spread. However, fire management is a delicate process and requires careful planning to prevent damage to the surrounding ecosystem. Burning of Lantana clumps is not advisable, since it may increase the risk of forest fire. Additionally, fire acts as a major factor in breaking the dormancy of Lantana subsoil seed banks. So, the burning will lead to re-emergence of Lantana from the dormant seed banks.

Though various control measures employed to curb Lantana camara infestations in India could not be able to completely curtail its invasion, Cut root stock method is gaining significant attention nowadays, as it has proven superiority over existing methods of Lantana removal. The Cut Rootstock Method is a manual control technique used to effectively remove Lantana camara by cutting the plant at the rootstock level, ensuring it does not regenerate. This method is widely used in forests, grasslands, and agricultural lands where Lantana invasion is severe. In India, few attempts have been made to remove the Lantana using the Cut root stock method from the forests. However,removal alone would not allow ecosystems to recover because some invaders alter the habitat conditions as a result it becomes unsuitable for native species. Several studies have concluded that Lantana removal is likely to be ineffective without post-removal monitoring and weeding. More efforts on the restoration of invaded landscapes to mitigatethe negative impacts of other invasive species need to be considered for implementation in India.

Lantana-invaded sites havebeen successfully restored in Corbett Tiger Reserve, India. This study involved the application of the Cut Rootstock method over an area of about 1600 hectares. The restoration of these areas to grassland communities has successfully prevented secondary invasions by Lantana and other weeds. It has also enhanced the habitat quality for herbivores whose populations are vital for the survival of top carnivores. After three years of continuous effort, the newly developed grasslands are visited by large herds of deer, along with wild boars and elephants. The frequency of wildlife sighting has also increased in these plots. Several grassland birds have been using these restored habitats for foraging and nesting.The re-colonisation of Lantana was quantified at sites that were either managed only once or for two consecutive years in Rajaji National Park, Uttarakhand. Rapid recolonization and recruitment was occurring from seed dispersal from surrounding Lantana populations, soil seed banks and vegetative regeneration. However, these restoration efforts have been conducted in smaller areas and are insignificant in comparison to the size of the affected area and the rate of invasion of this species. Furthermore, there is no information available about the impact of Lantana removal on ecosystem structure and function in the eradicated sites. As a result, combining removal with holistic assessment and subsequent site restoration will help protect native ecosystems from unintended negative effects.

Some forest departments have also implemented community-based management programs, where local communities are involved in the monitoring and management of Lantana. The Government has also considered implementing cut root stock method of Lantana invasion in selected forests of the country.

Managing Lantana in non-forest areas requires an integrated approach that combines mechanical, chemical, and biological control methods. Mechanical clearing, which involves manual removal or the use of machinery to clear Lantana from invaded areas, is one of the most commonly used techniques. However, this method can be labour-intensive and often ineffective in controlling large infestations.Herbicides are also used to manage Lantana in non-forest areas, but their use can have negative impacts. Farmers and landowners need to be cautious about the overuse of chemical herbicides, as they may harm soil health, water quality, and non-target species.

In addition to these control methods, the active involvement of local communities in Lantana management is crucial. Community-based programs that raise awareness and encourage landowners to adopt sustainable land management practices can help in the long-term control of Lantana invasions.

The various successful Lantana management approaches available in the country should be collated and disseminated to various frontline staffs for effective management of this Invasive Alien Plant Species (IAPS) of global importance.

The management of this weed species by utilization is gaining momentum in different parts of the world as Lantana could be used as a source for various products. Recent studies reported that small experiments with regard to utilization of Lantana for furniture making, charcoal production, fencing material, aromatic oil, wood polymer composites, particle boards, cement bonded particle board, polymer matrix composite, Lantana epoxy composite, have been attempted but none has been scaled up to economical utility till date.

Despite several management interventions our country is still not able to successfully control Lantana spread. Reasons for this may include lack of coordination and inadequate awareness and capacity among regional government and local communities, lack of human as well as logistics funds within the government system to execute the regulation and lack of coordination, and motivation among stakeholders. In order to control further spread of Lantana in Indian Forest lands and protected areas, an integrated approach covering development of technique for assessing the spatial extent of Lantana invasion, eradicating the Lantana and restoring the invaded area with the participation of various stakeholders and utilization of the eradicated biomass for improving the livelihood of the people.The Indian Council of Forestry Research and Education (ICFRE), in collaboration with state forest departments in Kerala, Madhya Pradesh, Gujarat and Uttar Pradesh has already launched suchan integrated study to effectively manage Lantana.

Conclusion

Lantana camara remains one of the most challenging invasive species in India, with its spread threatening both forest and non-forest areas. Its ecological and economic impacts are far-reaching, affecting biodiversity, agricultural productivity, and the livelihoods of local communities. While several management strategies are being employed, such as mechanical clearing, herbicide application, biological control, and livestock grazing, the effectiveness of these methods varies across regions and contexts.

A coordinated approach that integrates multiple control techniques, early detection, and community participation is crucial to managing the spread of Lantana. Ongoing research into biological control agents and the development of sustainable land management practices will play a vital role in mitigating the impacts of Lantana invasion in India. With continued efforts and a holistic management approach, there is hope for controlling this invasive species and protecting India's rich biodiversity for future generations.

References: Contact author at rajasekarana@icfre.org

Vol.5 I Issue 2 I July-September 2024

Mapping and Habitat Suitability Modelling for *Lantana camara*: A Geospatial Approach

C. Sudhakar Reddy
Forest Biodiversity and Ecology Division,
National Remote Sensing Centre, ISRO, Balanagar,
Hyderabad, Telangana - 500 037
Email : drsudhakarreddy@gmail.com

Lantana camara L. (Verbenaceae) is an aggressive colonizer and perennial shrub, native to the tropical regions of Mexico and Central America. It has become a major invasive species in various parts of the world, including Africa, Australia, India, and Southeast Asia. This species is often recognized for its vibrant flowers and invasive growth patterns by outcompeting native plant species and altering soil chemistry. Its adaptability to different soil types and climatic conditions contributes to its invasive status in many regions. Mapping the spatial distribution of *Lantana camara* is essential for effective management, mitigation and restoration of invaded ecosystems. Accurate spatial data can guide targeted removal efforts, policy decisions, and resource allocation. Remote sensing and geographic information systems (GIS) offer powerful tools for detecting, monitoring, and managing such invasive species. Remote sensing is the collection of information about an object or area from a distance using satellite and aerial imagery. Optical remote sensing uses spectral signatures to identify invasive species, enabling their detection and mapping. Hyperspectral imaging enhances this capability by providing detailed spectral resolution, allowing better discrimination of invasive plants. LiDAR technology contributes structural information to help determine the density and canopy characteristics of invasive plant species. Synthetic Aperture Radar (SAR) is particularly useful for detecting invasive species in areas of dense cloud cover and under forest canopies where other remote sensing methods may be limited. GIS, on the other hand, is a framework for managing and analysing spatial and non-spatial data. It enables visualization and interpretation of data through maps and models, facilitating informed decision-making.

Species detection and mapping:

The effectiveness of remote sensing and GIS is enhanced when combined with ground truth efforts. Field surveys provide input data as well as validation data that improve the accuracy of remote sensing-based analyses. This integration is necessary to develop management strategies that consider both remote sensing and ground truth (Rakgoale & Ngetar, 2024). A random sampling or systematic sampling or transect or species targeted sampling techniques provide ground truth points for mapping of distribution. In addition to sensors, the selection of classifiers is considered important for the discrimination and detection of invasive plants species. Parametric methods are generally simpler and faster but may not capture complex relationships as effectively as non-parametric methods. Various classifiers, including maximum likelihood, k-means, nearest-neighbour classification, fuzzy classification, neural networks, support vector machines, random forests, minimum distance have been used for invasion monitoring in different parts of the world.

Pixel-based classification method classifies each pixel in the remote sensing imagery based on its spectral signature. While effective, it may struggle with mixed pixels where different species coexist. Studies have demonstrated that high-resolution satellite images from Geo-Eye and World View can successfully differentiate *Lantana camara* from other vegetation types (Niphadkar et al. 2017). Object-based classification approach segments images into meaningful objects before classification, which has shown improved accuracy in distinguishing Lantana camara from surrounding vegetation.

Dube et al. (2020) used moderate-resolution data from Sentinel-2 (10 m) and Landsat (30 m) to characterize the *Lantana camara* in the rangeland ecosystems of South Africa and achieved 83% classification accuracy with a random forest (RF) classifier. The studies reported higher user and producer accuracies were obtained from the RF algorithm (Iqbal et al. 2023). Classified map showing distribution of *Lantana camara* using PlanetScope data and RF algorithm indicates its predominance over Bandipur tiger reserve (Figure 1). Hyperspectral imagery can be used to identify invasive plants based on their specific reflectance patterns in the near-infrared and shortwave infrared regions of the spectrum. Kishore et al. (2024) used AVIRIS-NG airborne imaging spectroscopy and Multiple Endmember Spectral Mixture Analysis to map the Lantana camara in Mudumalai Tiger Reserve (MTR). It achieved high accuracy for detecting Lantana camara (87%). Deep learning has gained prominence in species detection due to its ability to handle large datasets and extract complex features automatically. Convolutional Neural Networks (CNN) is effective for image classification tasks. CNNs can learn hierarchical features from raw pixel data, making them suitable for identifying individual species from aerial or satellite images.

Unmanned Aerial Vehicles (UAVs) serve as an efficient alternative for the mapping of invasive species, offering high-resolution spectral, spatial and temporal data at a relatively low cost. UAVs can operate in challenging terrains and provide flexibility in data acquisition, enabling the detection of invasive species in fine detail over localized areas. Time-series data can capture phenological changes, such as flowering and leaf senescence, which aid in distinguishing *Lantana camara* from native vegetation. Utilizing vegetation indices such as NDVI (Normalized Difference Vegetation Index) enhances the detection capabilities by highlighting differences in plant health and density. Studies indicate that combining multiple indices and high temporal remote sensing data can significantly improve classification accuracy for *Lantana camara* detection. GIS tools can analyse changes in *Lantana camara* distribution over time by comparing historical and current remote sensing datasets. GIS allows for risk assessment by overlaying Lantana camara distribution maps with Biodiversity hotspots and Protected areas.

Remote sensing and GIS facilitate monitoring the success of management interventions and evaluating the effectiveness of restoration programs. PlanetScope images showing sites of eradication of *Lantana camara* in Bandipur tiger reserve (https://www.planet.com/nicfi/) are presented in Figure 2. This information can be used to track the effectiveness of management interventions and adjust strategies as needed. Spatial decision support systems integrate information from multiple sources to assist resource managers in making informed decisions.

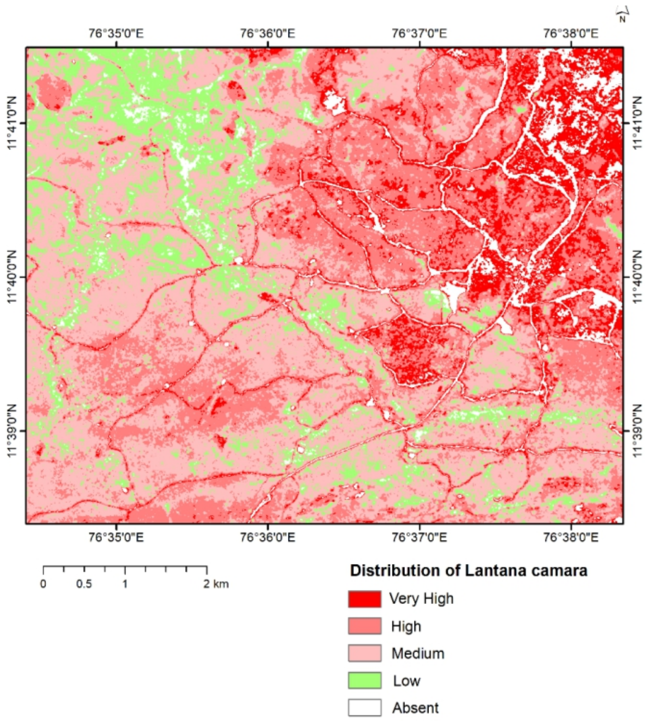


Fig 1. Map showing distribution of *Lantana camara* in part of Bandipur tiger reserve

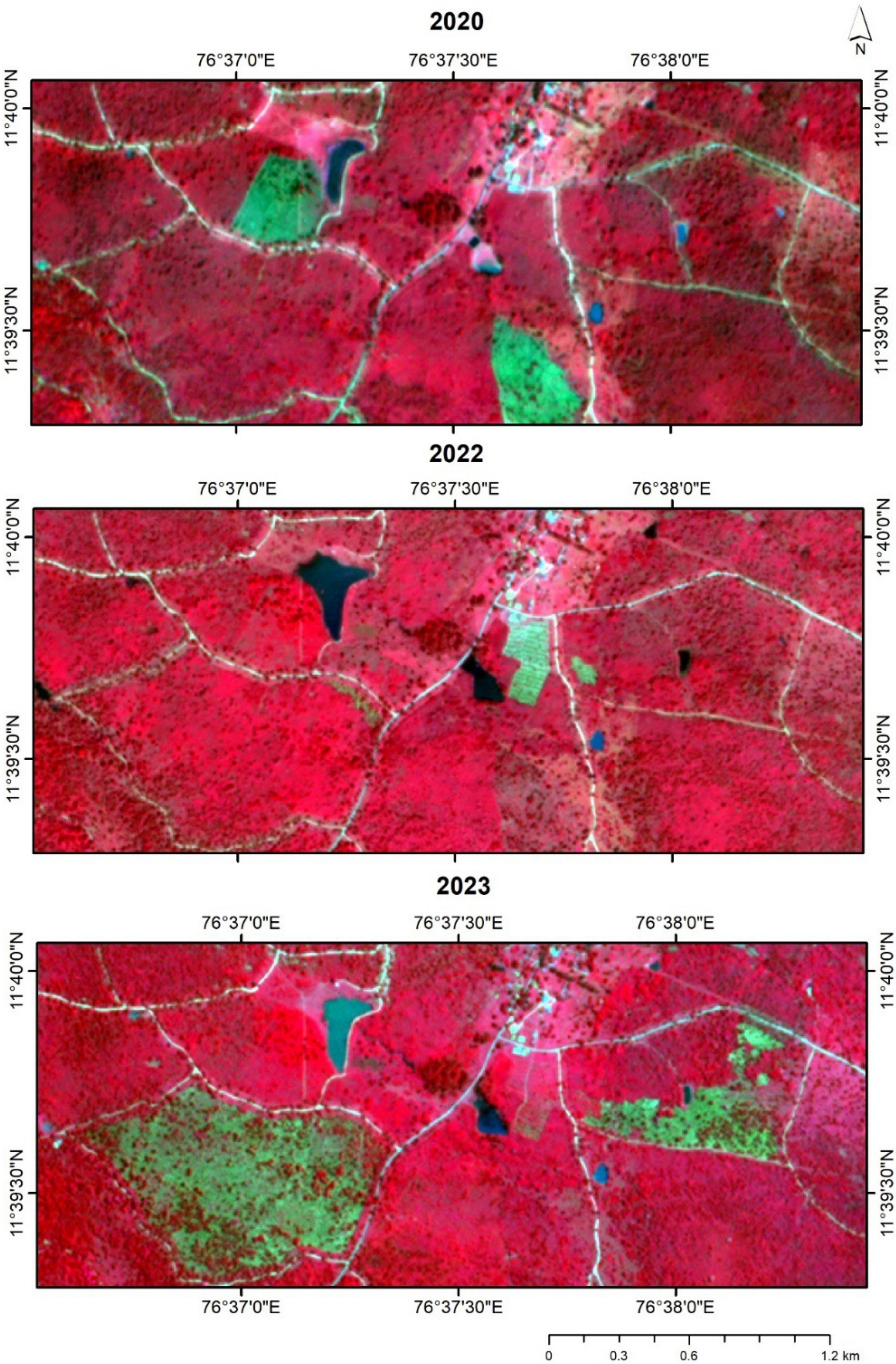


Fig 2. PlanetScope False colour composite images showing sites of *Lantana camara* eradication in part of Bandipur tiger reserve

Habitat suitability modelling:

Habitat suitability modelling is a statistical technique that predicts the likelihood of a species occurring in a particular area based on its environmental preferences. GIS can be used to model the potential distribution of invasive species based on environmental factors such as climate, topography, soil and land cover. Remote sensing and GIS facilitate ecological modelling by providing spatial data that can be analysed to understand species-habitat relationships. Models can predict how species distributions might change under different climate change scenarios helping conservationists prioritize areas for management. The predictive power of remote sensing indices has shown significant potential in modelling species distributions based on environmental variables. To model current potential habitat suitability for the species Maxent (Maximum Entropy), is the widely used machine-learning algorithm. The study used occurrence data for the species from reliable sources, including field surveys and GBIF (Roy et al. 2012; Neethu Visakh, 2021; GBIF, 2024). Duplicate and erroneous records were filtered to ensure data quality. A total of 19 bioclimatic variables representing temperature and precipitation patterns were retrieved from the WorldClim database at a spatial resolution of 30 arc seconds (~1 km) (https://www.worldclim.org). To reduce multicollinearity, a Pearson correlation analysis was performed, and highly correlated variables ($r > 0.7$) were excluded, ensuring only ecologically significant variables were retained. The Maxent model was configured with training data comprising 70% of the occurrence points, while the remaining 30% were used for validation. Default settings for feature types and regularization were employed to balance complexity and generality with five replicates. Model performance was assessed using the Area Under Curve (AUC) of the Receiver Operating Characteristic (ROC), with values above 0.8 indicating acceptable predictive performance. Jackknife tests were conducted to determine the relative importance of each variable. The output logistic maps were classified into suitability categories to identify habitat suitability areas. Global map shows potential distribution of *Lantana camara* throughout the tropical regions and parts of subtropical regions (Figure 3). Saranya et al. (2021) employed multiple ML models to predict the potential habitats of Chromolaena odorata and *Lantana camara* in the northern Eastern Ghats of Andhra Pradesh. Reddy et al. (2024) modelled the global and regional ecological niches of major invasive species, providing critical insights into their potential distribution and areas at risk. This spatial approach helps predicting and managing invasions effectively at both local and global scales by considering both the native and invaded ranges.

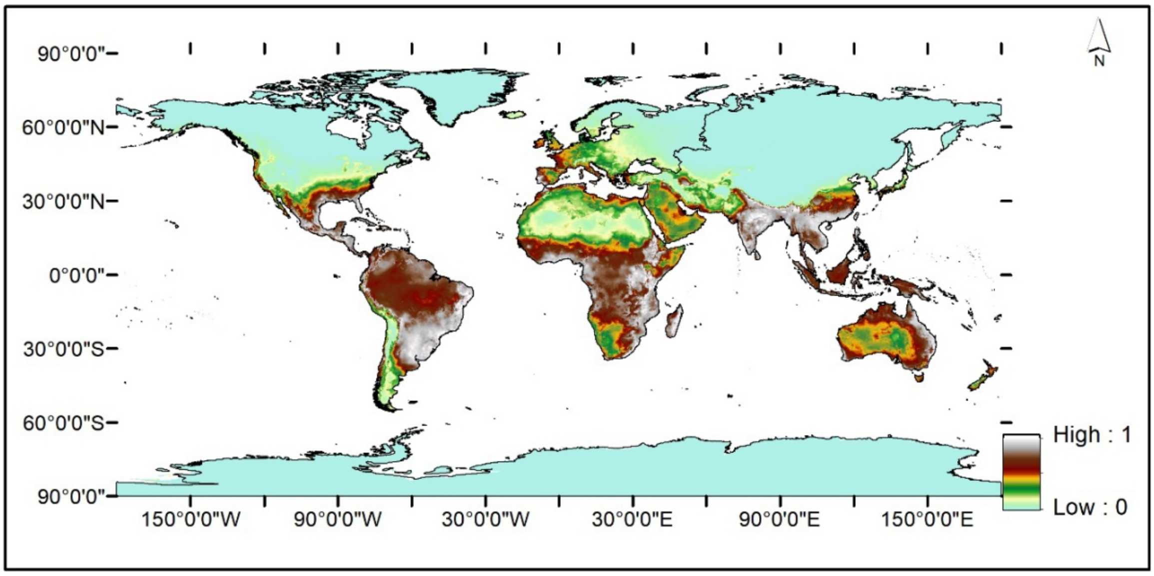


Fig 3. Global map showing potential distribution of *Lantana camara*

Conclusions

The spectral signatures of invasive plant species can vary depending on factors such as phenology, environmental conditions and species diversity. This can make it difficult to accurately detect and map these species using remote sensing. As an understory species, Lantana camara is often shaded by taller vegetation, making it difficult to detect from aerial or satellite imagery alone. Standardized methods for mapping of Lantana camara in different forest landscapes are lacking. In general, hyperspectral data more accurately identify and distinguish target species, but are not widely used in research due to lack of availability and high cost. Advances in the development of image processing and classification algorithms are poised to significantly improve the detection and spatial mapping of invasive species using remote sensing datasets. The accuracy of species distribution models can be influenced by various factors, including data quality, model selection, and the complexity of species-environment relationships. Incorporating both spectral and temporal characteristics into habitat suitability models enhances their predictive accuracy by accounting for the unique ecological requirements of target species. Integrating remote sensing technologies with advanced analytical frameworks enables a more comprehensive understanding of the spatial distribution and dynamic spread of Lantana camara, thereby facilitating the formulation of management strategies. Future research should prioritize the development of standardized methodologies for mapping invasive species across heterogeneous ecosystems to optimize management interventions.

References: Contact author at drsudhakarreddy@gmail.com

Winch-Based Removal of Lantana: A Scalable Solution

Nikita N., Subhash Gautam, Naveen M. and Tarsh Thekaekara
The Shola Trust, Mudumalai 643211, Tamil Nadu
E mail : nikita@thesholatrust.org

For over 15 years, the Shola Trust has been working to address the widespread invasion of Lantana camara across various landscapes in southern India. While working on removal we focused on three main concerns: -

- To ensure the inclusion of Indigenous communities in the process,
- To find an ecologically better method that reduces the disturbance to the soil,
- To develop a removal technique that is faster and more efficient than manual methods, allowing it to be scalable.

Addressing these priorities, we adopted a semi-mechanized approach involving a winch-pulling method, which has proven to be a balanced solution for both ecological and practical considerations. This method was particularly effective in areas with moderate to dense Lantana infestations. It has been successfully implemented in the Biligiri Rangaswamy Temple (BRT) Tiger Reserve, Mudumalai Tiger Reserve, and Wayanad Wildlife Sanctuary—three critical regions of the Western Ghats known for their rich biodiversity.

The Winch-Based Removal Method

The winch-based method integrates manual effort with mechanical power, making it a versatile and efficient solution. This approach involves bundling several Lantana bushes together to belts and attaching them to a mechanical winch mounted on a tractor. The winch then pulls the tied plants, uprooting them along with their root systems. By combining the precision of manual labour with the strength of machinery, this method ensures the thorough removal of Lantana with minimal disturbance to the soil and minimizes the physical strain on workers.

This technique is particularly effective in areas with moderate to dense Lantana infestations, where fully mechanized equipment might be excessive, and manual labour alone may prove inadequate. The winch-based method strikes a balance between efficiency and adaptability, making it suitable for varying terrains and densities. Why Focus on Semi-Mechanized Removal.

One of the significant advantages of the winch-based method is its scalability. Unlike manual removal, which is labour-intensive and time-consuming, or fully mechanized removal, which can cause considerable soil disturbance, the semi-mechanized approach offers a middle ground. It allows for the removal of large quantities of Lantana in a relatively short period while maintaining ecological sensitivity. In regions like BRT Tiger Reserve, Mudumalai Tiger Reserve, and Wayanad Wildlife Sanctuary, where Lantana covers significant portions of the forest floor, the winch-based method has proven invaluable. These areas often feature challenging terrains, including slopes and dense thickets, which are more manageable with the semi-mechanized approach.

Addressing these priorities, we adopted a semi-mechanized approach involving a winch-pulling method, which has proven to be a balanced solution for both ecological and practical considerations. This method was particularly effective in areas with moderate to dense Lantana infestations. It has been successfully implemented in the Biligiri Rangaswamy Temple (BRT) Tiger Reserve, Mudumalai Tiger Reserve, and Wayanad Wildlife Sanctuary-three critical regions of the Western Ghats known for their rich biodiversity.

The Winch-Based Removal Method

The winch-based method integrates manual effort with mechanical power, making it a versatile and efficient solution. This approach involves bundling several Lantana bushes together to belts and attaching them to a mechanical winch mounted on a tractor. The winch then pulls the tied plants, uprooting them along with their root systems. By combining the precision of manual labour with the strength of machinery, this method ensures the thorough removal of Lantana with minimal disturbance to the soil and minimizes the physical strain on workers.

This technique is particularly effective in areas with moderate to dense Lantana infestations, where fully mechanized equipment might be excessive, and manual labour alone may prove inadequate. The winch-based method strikes a balance between efficiency and adaptability, making it suitable for varying terrains and densities. Why Focus on Semi-Mechanized Removal?

Removal site	Labour cost per hectare (in Rs.)	Operational cost per hectare (in Rs.)	Total cost per hectare (in Rs.)
MTR (Mandradiar)	54,000	8,000	62,000
MTR (Gavihalla)	23,500	26,000	49,300
Wayanad WS	10,100	8,000	18,100
BR Hills TR	58,700	27,100	85,800

One of the significant advantages of the winch-based method is its scalability. Unlike manual removal, which is labour-intensive and time-consuming, or fully mechanized removal, which can cause considerable soil disturbance, the semi-mechanized approach offers a middle ground. It allows for the removal of large quantities of Lantana in a relatively short period while maintaining ecological sensitivity. In regions like BRT Tiger Reserve, Mudumalai Tiger Reserve, and Wayanad Wildlife Sanctuary, where Lantana covers significant portions of the forest floor, the winch-based method has proven invaluable. These areas often feature challenging terrains, including slopes and dense thickets, which are more manageable with the semi-mechanized approach.

Why Focus on Semi-Mechanized Removal?

One of the significant advantages of the winch-based method is its scalability. Unlike manual removal, which is labour-intensive and time-consuming, or fully mechanized removal, which can cause considerable soil disturbance, the semi-mechanized approach offers a middle ground. It allows for the removal of large quantities of Lantana in a relatively short period while maintaining ecological sensitivity. In regions like BRT Tiger Reserve, Mudumalai Tiger Reserve, and Wayanad Wildlife Sanctuary, where Lantana covers significant

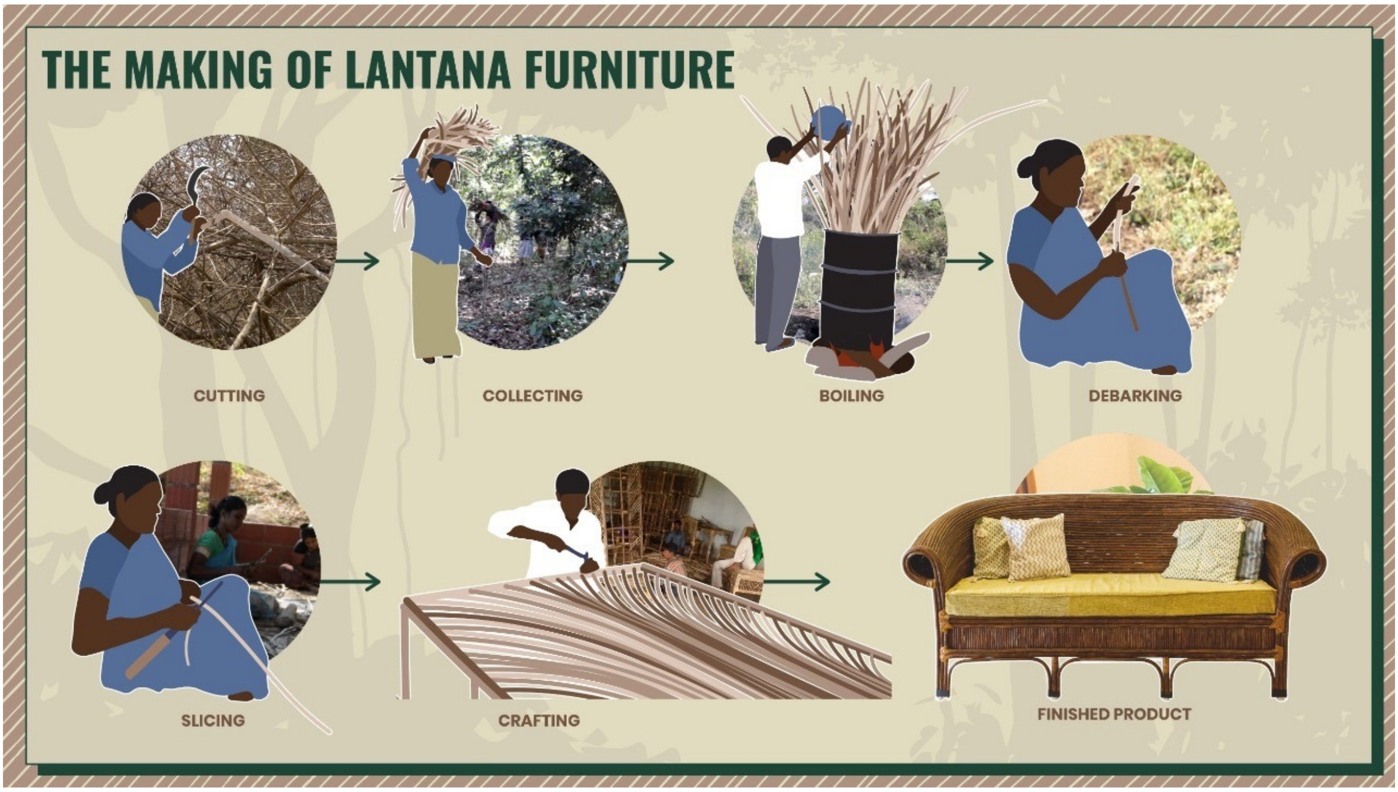
References: Contact author at nikita@thesholatrust.org

Joy of Building the Lantana Collective

Sandeep Hanchanale
Senior Director | Startups - Innovation, Incubation |
Email : sandeep.hanchanale@atree.org

I had no clue how many options this journey would open up for developing a circular economy around an invasive plant species when I started working with Lantana camara as an input material. Lantana is an invasive plant species that now covers over 40% of the forests of the Western Ghats. It's causing problems not just in India but also worldwide. ATREE introduced Lantana craft as a way of providing livelihoods to these communities. Since the launch of its lantana Craft Centre in 2004, ATREE has trained over 650 artisans in Lantana craft of whom 40% are women. Trained artisans derive nearly 80% of their cash income from Lantana crafts. As the next phase of development, with a grant from Social Venture Partners , we embarked on a path to figure out what more can we do with *Lantana camara* and build livelihoods at scale.

1) Idea Generation

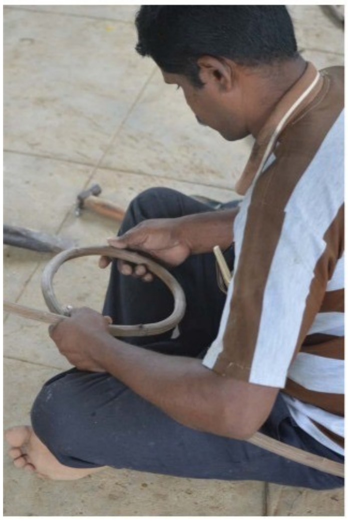


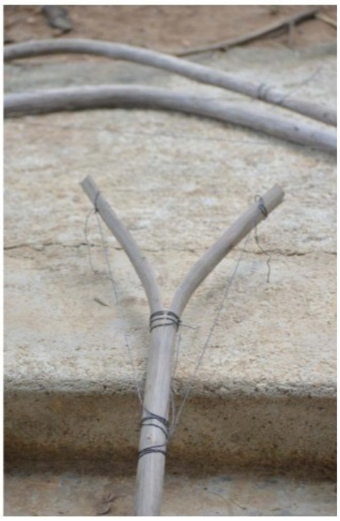
Weeds to wealth is the foundation for this. Tribal communities were trained to make small handicrafts and furniture using Lantana. The growth of Lantana was already creating challenges for wildlife, tribals, and other native trees. Artisans were using bamboo to make some of these products. With Lantana, there was an opportunity to switch from bamboo and make viable products. This would put that weed to meaningful use.

2) Research

a. Market Research

At the very outset, owing to the nature and look of the sticks, it was easily getting compared to cane furniture. To get premium pricing, better innovations around material, finish, and design had to be done. Durability and requirement of paint were other questions that were coming up. Customers were willing to pay a little over-market alternative, provided basic hygiene factors were met. The premium was not for profits; it was more to bring these products to an even playing field. The underlying message of using something that was causing harm to the environment was at the center of our product.

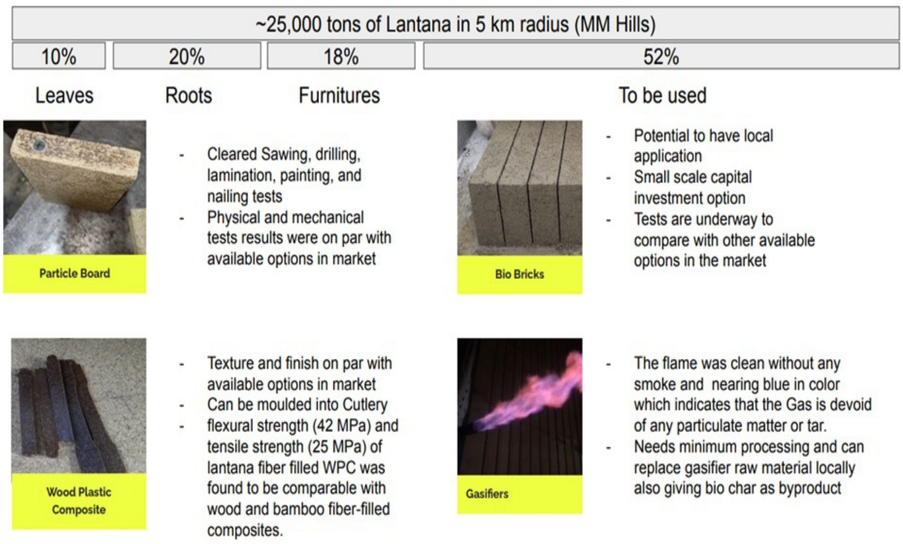




b. Competitor Analysis

Cane, Jungle sticks, Bamboo, etc. were some alternatives. Cane is an established market. We had to go beyond positioning and pricing to make this product accepted by the customers. Many design houses were eager to try Lantana as a standalone material and mixed material as part of their offerings. Reliable supply was a major concern for large design houses and that had to be addressed.

3) Planning



3) Planning
a. Raw material supply

Planning the raw material supply was essential. The process involved removing the raw material, grading and sorting it, boiling the sticks, and then assorting them by size—each step crucial for maintaining an efficient supply chain.

b. Production

Setting up production units was a crucial step, particularly within the gig economy. This involved training groups of artisans and providing them with access to the right tools, ensuring they could establish and operate active production centers within their hamlets.

c. Indicative Product Pricing

Value-based pricing or cost-based pricing? We had to innovate in our approach to pricing these products. The goal was to create an aspirational product that not only appealed to customers but also fostered a sense of engagement with sustainability.

4. Prototyping

Since we were moving a little beyond our traditional product mix, testing strength, and breakpoint was important. A lot of customers had ideas in their minds, but the material should also support such ideas. In many cases, the material didn't support the design beyond a certain threshold. We tried 2 types of products.

a) Innovate on existing furniture lines with single input material
- New Designs
- Other product lines

b) Commodity products
- Gypsum board
- Bio Bricks
- Particle Boards
- Feedstock for Gasification

c) Mixed Material products

Mixing Lantana camara and Senna spectabilis to make some products

5) Testing

While we did some basic strength and material tests with IPIRTI, the real test was when the community members themselves decided to stretch their imaginations on these products.

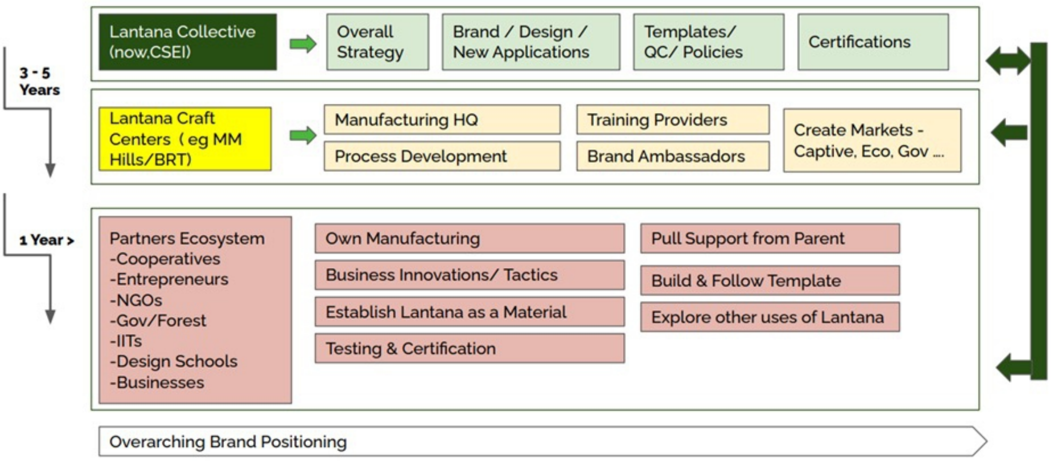
6) Product Development

Minimum value products (MVP)
Be it be designer in residence or apprenticeships, each model threw up wonderful product opportunities. After trying different combinations, the artisans developed minimum viable products which were later sent to production.

7) Commercialisation

- Channel/Partnerships
- Warehouse
- Messaging
- Go to Market
- Delivery Experience

We always believe that we would scale through partnerships. We built robust partnerships with our ecosystem players who would take this work ahead.



Highlights
How apprenticeships evolved to long-term projects- Lantana Elephants

Community and elephants coexist; these elephants made from *Lantana camara* bring that essence to life.

Lampshades

Collaboration with Oorja is creating a new dimension to how the *Lantana camara* can be used in the design.

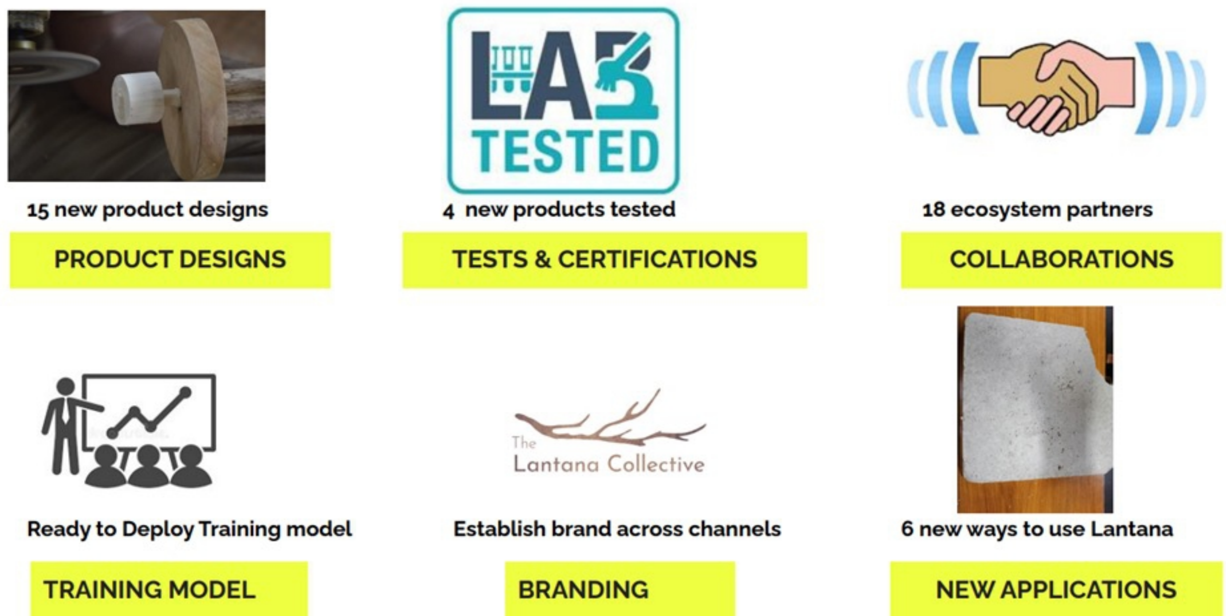
Designer in Residence programme

Young designers like Prashanth, Rohan and Kausthuba innovated on products

Bamboo Peckers

Lantana as a decorative building material is a growing segment. Kaiyare Women artisans at Kaiyare were already making baskets from Banana fibre. Training on Lantana-based products gave them additional opportunities to increase their product portfolio and keep their surrounding forests clear of Lantana.

Milestones



Conclusion

The idea of "weeds to wealth" is becoming more and more popular worldwide. The circular economy is changing. Taking a forest weed and making some valuable products from it not only gives livelihood options but also the ability to kick-start a bioenergy cluster keeping such invasive plants in focus. There is enough opportunity to innovate on efficient ways of removal of lantana from invaded spaces. Lantana camara-based biochar can be a wonderful opportunity to generate carbon credits along with afforestation.

References: Contact author at sandeep.hanchanale@atree.org

'Weeds to wealth'- A Community-led Livelihood Initiative to Control and Manage the Invasive Species *Lantana camara* in MM Hills, Karnataka

Harisha R.P., Siddappa Setty R., and Narayana B.
Ashoka Trust for Research on Ecology and the Environment (ATREE), Bangalore, India
E mail : hari@atree.org

Soligas, the tribal artisans of South India in Male Madeshwara Hills (Karnataka) are ingeniously utilizing the invasive weed Lantana. The community involvement in conservation practices with place-based control and management tools is used effectively in making 43 different furniture products, 46 utility products, lampshades, and a life-size elephant sculpture cheaper than cane and equally strong. Bangalore-based institution Ashoka Trust for Research in Ecology and the Environment (ATREE) has facilitated the tribal and village communities on logistic, certification, and marketing support for Lantana products under the weeds to wealth approach from 20 years (2004 to 2024). This initiative reduced Lantana density from 70% to 40% in 2800-hectare forests by removing 500 tons of Lantana sticks (earned Rs. 65 lakhs) with zero cost. Moreover, harvested Lantana used in crafting and value addition (with localized innovation) generated livelihoods for 250 people in six villages (income generated Rs. 3.97 crores).

This long-term study revealed that the use of the invasive Lantana as an opportunity to control invasive and generate income. Research monitoring showed that reduced density of Lantana (from 70% to 40%) and increased regeneration of native plant species (143 seedlings per hectare to 318 seedlings per hectare) in harvested sites. Lantana stick harvesters perceived that forest fire reduced significantly in harvested areas. The bush thinning technique is a better, time-tested strategy to control and manage established invasive species by limiting its distribution and by limiting its density with no cost. Better collaboration, and coordination among different stakeholders in formulating strategies and using an integrated management approach were the best management practices recommended by various review studies. More inclusive policy and regulatory roles to ease accessibility and ownership to the local community in control and management of invasive is an urgent need for solving the Lantana problem.

Introduction

A problem that modern ecologists and natural environments have to deal with is that of alien invasive species. These are species that were introduced into a landscape by anthropogenic means and often overtake and subvert the biodiversity of the region by successfully competing with the native flora and fauna over resources. Lantana camara is one such invasive species that originated from South America and was transported to various parts across the world like South Asia, Africa, Australia, and Hawaii. The Lantana is distributed in more than 12 bioregions and 60 countries globally. The invasive nature of Lantana has been widely observed and acknowledged in the Indian regions, however, regional studies assessing the impact of Lantana from these diverse areas are highly limited. The establishment of invasive alien species in a habitat is often correlated with lower biodiversity in the area in question. While this may be due to increased competitiveness by the invasive species or by increased adaptability in the face of human activity, the result is a loss in biodiversity, which can negatively impact habitats.

In India, 30 million hectares of forest are invaded by Lantana and pose serious threats to biodiversity, the livelihoods of local communities, and the economics of forest management (Negi et al., 2019). The Lantana contends with local flora for space, and resources and also modifies the soil nutrient cycle. Moreover, Lantana-density areas are prone to high-intensity forest fires in the protected areas which leads to loss of biodiversity and increase the management cost. Also, many studies predicted that further expansion of Lantana in open land was created due to forest fire and local climatic variations. Despite increased recognition of the environment and economic impacts of biological invasion, we failed to develop successful management tools and policies to control and restore 40% of Lantana-invaded protected areas in India.

Several studies attempted to develop methods/strategies to control and management of invasive species in the forests however, attempts failed to develop the best methods/strategies (Bhagwat et al 2012). Many studies also suggested that an integrated approach would give better results in controlling and managing invasive species in India (Kannan et al 2014). An integrated approach would accommodate three indicative evaluation strategies such as economic viability, environmental security, and sustainability. These indicative tools measure the effectiveness of the method/model and replicability on the ground.

Study area

The Male Mahadeshwara Hills (MM Hills) Wildlife Sanctuary (Figure 1) is located in the Chamarajanagar district of Karnataka, Southern India. This mountainous hills range is located between latitude 12° 13' and 11° 55' N and longitude 77° 30' and 77° 47' E in the confluence of Eastern Ghats and Western Ghats. The sanctuary covers an area of 906.2 km² and has been declared as a wildlife sanctuary in 2013. The MM Hills possess a chain of mountains with undulated terrain has altitude ranging from 400 to 1200 meters and shares boundaries with Cauvery Wildlife Sanctuary in the north, Sathyamangalam Tiger Reserve south, and Biligiri Rangaswamy Temple Tiger Reserve in the west. The sanctuary is a vital part of the landscape as it serves as a corridor that helps in animal movements between Eastern Ghats and Western Ghats.

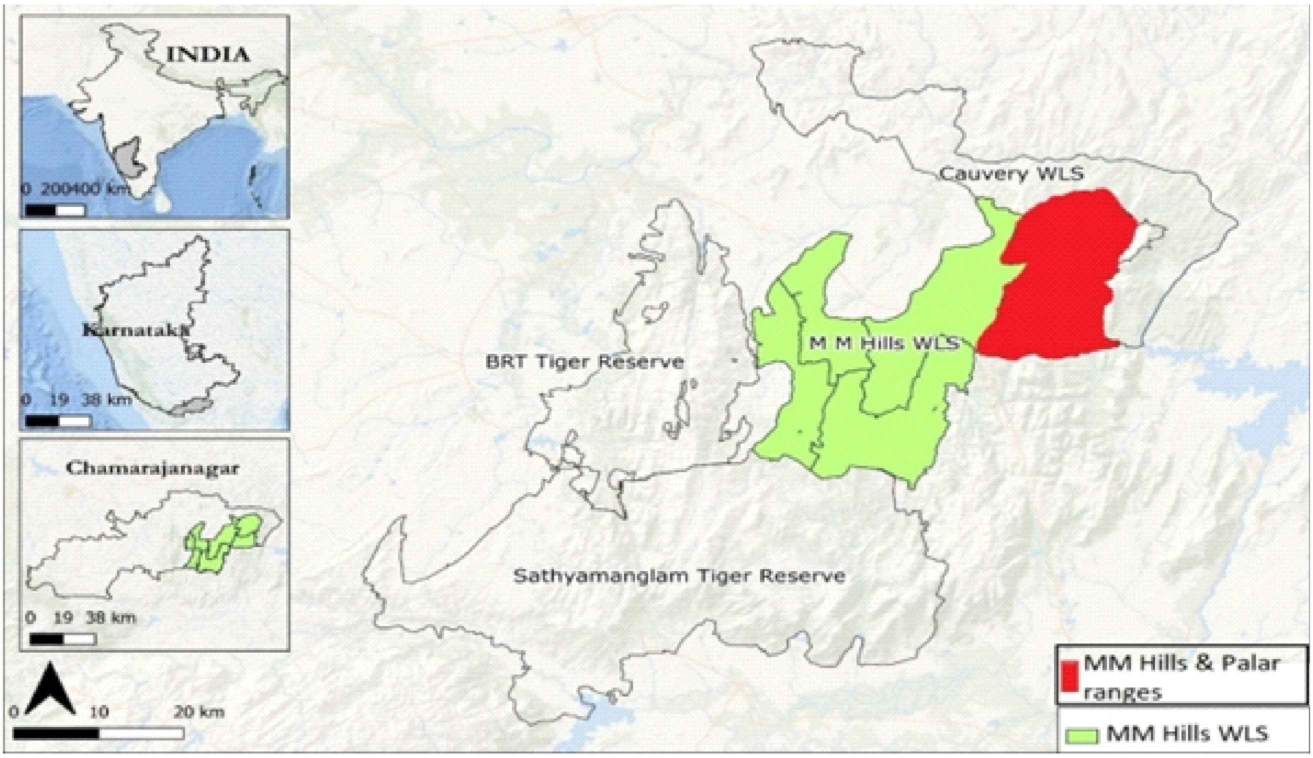


Fig 1. Male Mahadeshwara Hills (MM Hills) Wildlife Sanctuary

Weeds wealth initiatives have been focusing on two forest ranges (MM Hills range with an area of 19255 ha. and Palar range with an area of 8889 ha.) for the past 20 years due to high Lantana invasion, and logistical and accessibility issues. These two ranges had more than 73% Lantana density and 16 villages located within and periphery of the forest (Aravind et al., 2010). Also facing development pressure along with grazing and tourism activities.

Lantana invasion in MM Hills WLS

One of the major environmental issues in MM Hills is the invasion of Lantana, which has affected large areas of the sanctuary. In MM Hills Lantana has been estimated to have occupied about 70% of the forest area and 58% of the fallow land (Shaanker et al., 2004; Aravind et al., 2010). It is considered a major threat to forest structure and species composition in the sanctuary apart from forest fragmentation and developmental activities (Aravind et al., 2010). Increasing Lantana has contributed to the change in the native plant communities, and a decline in species richness (Sundaram & Hiremath, 2011). Significantly affected the bird species richness, diversity, and abundance (Aravind et al., 2010). Lantana invasions also forced a change in local peoples' livelihood activities like grazing, farming, and Non-timber forest products (NTFP) collection in the sanctuary (Kent & Dorward, 2015). Additionally, human-wildlife conflict is a concern, as local communities depend on forest resources for their livelihoods, habitat fragmentation, and wildlife protection, especially tigers in the landscape.

'Weeds to wealth' initiative

To manage invasive Lantana in the forests, a comprehensive, scalable, time-tested, and effective Lantana control and management model has been developed by ATREE. It started a novel and innovative "weeds-to-wealth" approach that encourages the use of Lantana camara, initially at MM Hills WLS in 2004. The Weeds to Wealth initiative is an economically viable, ecologically sensible, and sustainability-assured model, empowering hundreds of Soliga and Beda Gamapana communities in MM Hills wildlife sanctuary over the past 20 years that created thousands of livelihood opportunities has been created increased their income six times. Later it was replicated across five Southern states of India successfully. Artisans succeeded in designing 115 innovative products from furniture to toys and utility products. More than 300 were trained in Lantana crafting and were recognized by the Department of Handicraft and Marketing Extension, Mysore. As our previous experience has shown, encouraging the use of Lantana can significantly enhance the income of poor tribal communities six fold. ATREE has established four Lantana craft centers (LCCs) at villages in MM Hills WLS, which directly market their products and assist artisans connect with mainstream markets. There is a significant reduction of Lantana density in the forest (decreased Lantana density from 70% to 40%) as indicated in our recent post-harvest impact studies and increased travel distance for artisans to collect Lantana sticks in the forest from 2 km (in 2004) to 6 km (in 2022). In turn, increased native plant diversity, and significantly reduced the frequency of high-intensity forest fires in Lantana-harvested areas.

Economic viability

Weeds Wealth Initiatives trained 300 people in the MM Hills forest area and employed them in harvesting sticks, crafting, marketing the products, and monitoring the harvested area for the past 20 years. Twenty years of continuous stick harvest (525 tons) created 2.92 lakhs man-days of work for local people and generated 3.97 crore income by producing crafts/furniture/utility products, elephant sculpture, lampshades, etc. Lantana controlling effort does not cost as it is embedded with incentives (Rs.250 to 300 per bundle) by purchasing for producing craft products in Lantana craft center (LCC).

This initiative focused on two forest ranges in MM Hills Wildlife Sanctuary which covers an area of 28144 hectares (MM Hills range-19255 ha. and Palar range-8889ha.). These two ranges had 70% of Lantana invasion with 515 per hectare density recorded in 2003 before the initiative. Now, Lantana harvesters travel an average of 4.5 kilometers away from the village to get the Lantana sticks for crafting, it was just a few meters away from their village in 2004. The Lantana density has significantly declined from 70% to 40% and density declined from 515 /ha. to 128/ha. in these two forest ranges.

Ecological security (through 'Bush thinning technique (BTT)'

The BTT is an indigenous agroforestry practice to raise tree species on farmland by the Soliga and Beda Gampana communities. It also protects seedlings from grazing, provides enough light, protects soil erosion, and enhances soil fertility. Similarly, in the forest, they adapted the same technique to thinning the Lantana bushes by harvesting sticks which are required for producing crafts. After harvesting large stems (old stem/primary stem with a minimum of three years old) which most preferable sticks for producing crafts that significantly lower the density, the bush became thin and allowed sunlight to reach the seedling growing inside the bush. The rest of the Lantana bush protects the native plant seedlings from grazing. After a few years, the Lantana bush disappears due to shade created by the native tree or shrub over it. This has been scientifically monitored for the past 15 years, and the data has been analyzed. The result revealed that native plant species density increased from 143 to 318 density per hectare in Lantana-harvested areas. Similarly, local plant species (shrubs and trees) diversity increased from 1.3 to 2.8 in deciduous forests and from 18 to 3.2 in moist deciduous forests.

BTT of the Lantana sticks harvesting method reduces Lantana spread, and creates a favorite microhabitat for local plant species regeneration. Lantana stick harvesters from local communities significantly control spread of Lantana effectively in the forests by decreasing Lantana density 1102 density per hectare in 2003-04 to 319 density per hectare in 2023-24 from moist deciduous forest, whereas 918 densities per hectare in 2003-04 to 414 density per hectare in 2023-24 from dry deciduous forest and 629 densities per hectare in 2003-04 to 328 density per hectare in 2023-24 from scrub forest. Further, utilizing Lantana in useful products (115 different products) like furniture, utility products, lampshades, and elephant sculptures helped create jobs and generate income for the forest-dependent communities. Co-opting of monitoring Lantana density and managing spread by the stick harvesters as part of their livelihood activity proved to be a better strategy with net zero cost.

The BTT method ensures ecological security by having negligible damage to the habitat during stick harvest. The BTT methods had zero percent change in soil structure and fertility. However, during the main stem cut 20-30% of the microhabitat around the Lantana bush. It has been monitored over the years and overall physical change has negligible impact on interspecies interaction and habitat. The BTT has increased 50% sunlight penetration into the Lantana bush which in turn enhances native seedling growth rate by 60% and 46% seedling survival rate.

More interestingly, across forest types, Lantana plant mortality significantly increased after cutting the main/primary stem for craft making. Our sampling plots in three forest types revealed that harvesting older/larger stems had significantly increased Lantana plant mortality. There is a significant decline in frequency (from once in three years to once in eight years) and intensity of forest fires in Lantana harvested areas due to the presence of low fuel load.

The Weeds to Wealth initiatives followed place-based/localized control methods which are continuous, easily adaptable, and can enhance effectiveness and reduce economic cost and ecological damage. Adapted long-term monitoring and adaptive management strategy to assess the effectiveness of control measures and make necessary adjustments. This includes tracking changes in Lantana populations and ecosystem health. Restored native plant diversity after removing Lantana and restored ecosystem balance with minimal ecological damage. In turn, it supports biodiversity and ecosystem services. Economic Incentives for sustainable management practices were achieved and empowered communities to participate in control efforts. The above indicative factors, set an example for sustainable management of Lantana in tropical forests and benefiting both the environment and local communities.

Recommendations

Recommended a clear policy on allowing communities to remove and sell Lantana camara, without obstruction from forest department staff, and with the full support of FD as partners in the exercise.Utilising other government funds such as MNREGA in low Lantana density areas, so that more area can be managed and restored.

Routing the governmental funds through community/local institutions such as Gram Sabhas, Forest Rights Committees, etc., to empower them and enable them to exercise their recognized rights under the Forest Rights Act. For instance, give the Lantana removal contracts to the Gram Sabhas instead of private contractors.

Grant permissions and access to the Soliga community to restore native habitats and livelihoods through the use of traditional knowledge for the restoration of Lantana harvested areas. This will allow communities to have continued access to non-timber forest products (NTFPs) such as Amla, Honey, Wild greens for food, Tubers, etc.

facilitating local communities for marketing Lantana craft products - maybe the Tribal Co-operative Marketing Development Federation (TRIFED) and other groups in cities would strengthen the localized community-led initiatives to achieve long-term sustainability.

References: Contact author at hari@atree.org

Utilisation of Lantana Biomass – Alternate Perspectives

Hanumanth C.R., Ramesh Venkataraman and Anand Krishnamurthy
Junglescapes Charitable Trust, Bengaluru
E mail : crhanumanth@gmail.com

Invasive Alien Species such as *Lantana camara, Prosopis juliflora* and *Senna spectabalis* have invaded large tracts of forest land across several parts of India. Lantana camara has had the longest presence in India of these invasive species. Therefore, it has occupied the largest extent of forest lands across multiple ecosystem types. Estimates of Lantana presence done using satellite imaging indicate invasion levels of over 40% in many forest areas. This reduces fodder availability for herbivores, impacts native biodiversity, and leads to increased ingress of wildlife into human-dominated landscapes in search of fodder. This, in turn, increases the risk of human-wildlife conflicts. As a result, this issue has recently gained considerable attention from government agencies, NGOs, and academics.

Until now, efforts to manage Lantana camara have largely been sporadic and at a small site or plot level which is significantly smaller in scale compared to the magnitude of the problem. One of the challenges cited for the absence of a larger-scale and landscape-level approach is the lack of adequate financial resources. An approach suggested in some forums to address this challenge is the commercial utilization of the removed Lantana biomass to make value-added products like briquettes and generate revenues therefrom, which can be ploughed back into the management of Lantana in more areas.

Junglescapes is a non-profit organization established in 2008 and has been actively working since 2013 on the ecological restoration of forests impacted by Lantana camara. Working closely with the forest department, Junglescapes has restored around 1200 hectares of Lantana-invaded forests in Bandipur Tiger Reserve, with good revival of biodiversity and rewilding by representative fauna. Junglescapes works closely with scientific research organizations like CEMDE, New Delhi and the Society for Ecological Restoration (SER). The Managing Trustee of Junglescapes, Mr Ramesh Venkataraman, is a member of the Expert Committee on Invasive Species appointed by the Hon'ble High Court of Madras, and is also a member of the Task Force on Best Practices for the UN Decade on Ecosystem Restoration formed by the UN-FAO.

This paper summarizes the experiences and learnings gained by Junglescapes in managing Lantana camara for over a decade. It highlights the risks involved in the approaches aimed at the commercial exploitation of invasive alien species and offers insights into an alternate approach for generating funds for the management of Lantana camara based on the activity of ecological restoration. Our experience shows that this approach can be more holistic, inclusive and ecologically sound.

Risks attached to commercial utilization of Lantana biomass

Can the removed bushes be used to create an economic activity that can fund more removal is a question that has been posed many a time. The approach of generating funds through the commercial utilization of *Lantana camara* has a number of inherent risks as discussed below.

a. Attaching high value to invasive species can lead to people preserving and propagating them. This has happened in the case of species like *Prosopis juliflora*, where the economic benefits from charcoal made from this species had led to obstacles in the way of eradicating them, including communities moving the Courts in the past and obtaining stay orders on the removal of these plants. In such situations, livelihood priorities gain preference over biodiversity priorities in the social context of India.

b. In the case of collecting Lantana biomass for commercial activities, the focus is on collecting the maximum biomass at the least cost and effort. Hence, the focus is commonly on harvesting mature adult plants. In many cases, only the branches of the mature Lantana bushes are slashed during harvesting. Juvenile plants and seedlings are not harvested. As a result, the Lantana invasion persists or increases within a short time.

c. The removal of Lantana on a large scale required for commercial purposes requires significant movement of men and materials (tractors, etc.) inside the forest areas. This has two major impacts. One is collateral damage to native vegetation. The second is the high risk of the spread of invasive species like Senna spectabilis, Chromolaena odorata, etc., seeds of which are spread by vehicles. We observe that such areas with high intrusions face significant invasion by multiple invasive plant species.

d. The removal of Lantana constitutes around 30% of the restoration efforts, with the remaining 70% focused on interventions to facilitate the recovery of native vegetation. These restoration activities take 5-7 years of continuous efforts. Commercial activities focused on harvesting Lantana may not be able to focus adequately on the critical long-term restoration components, resulting in the re-emergence of Lantana as well as sub-optimal restoration outcomes.

e. The internationally recognized principle in ecological restoration is to tackle invasive species in areas where the invasion is new and not fully established. This is primarily to arrest the invasion before it progresses further. These areas have good remnant native plants, helping in the quick recovery of native biodiversity over a large area in a short time. In turn, these restored areas act as nuclei of native plant propagules. In commercial harvesting, since the focus is on obtaining the maximum biomass in the shortest time possible, areas with high invasion are targeted. We have witnessed instances of removal of Lantana for briquetting from high-invasion areas that had no remnant native vegetation. Many of these areas have ended up with high invasions by secondary invasives in a very short period.

f. The removal of each invasive species has to be carried out using species-specific and scientifically sound removal methods. Commercial harvesting projects may not be in a position to adopt sound removal practices as the focus is on profit maximization.

g. For a livelihood-based approach to be viable, the price realized from Lantana-based products should offset the costs, which include labour and transportation, and leave a surplus. Lantana Camara exists in remote forest areas, which are accessible only through mud tracks. Tractor trailers are the only practical ways to move the removed biomass. Lantana is light and voluminous and hence, involves a high cost of transportation. Therefore, commercially oriented approaches could result in community stakeholders getting a relatively small share of the value chain, leading to socio-ecological issues in the local areas.

h. The usage of removed Lantana for handicrafts and furniture does not generally help in its eradication. Not all parts of the Lantana bush are useful for craft-making since only branches above a particular diameter are used. Initially, such biomass would be available for harvesting from nearby areas. Gradually, the distance from which the preferred Lantana sticks can be harvested increases, meaning more effort. As a result, many craftsperson generally cut only the required branches and allow the Lantana bushes to regrow for future harvesting. While this activity does generate livelihoods for small groups of people, the quantity of Lantana consumed is minimal.

I. Last but not least, the removal of Lantana biomass from forest areas requires a high degree of surveillance in order to ensure that native plants are not harvested either inadvertently or intentionally. Such surveillance becomes difficult in the case of large-scale removal for commercial purposes.

Livelihood creation through ecological restoration

It is well known that the Cut Rootstock method remains one of the soundest methods to remove Lantana. This method involves cutting the root of the Lantana bush about 3 inches below the soil, just below its coppicing zone. Re-emergence of Lantana under this method is very low. Also, there is almost no disturbance of the soil, ensuring minimal germination of Lantana camara from the dormant seed banks. With successive removal over 2-3 years, both the primary Lantana invasion and successive recruitment from the seed bank or seed dispersal by birds can be managed effectively.

The removal of Lantana and the concurrent ecological restoration activities are human-resource intensive. Apart from removal, manpower is required to bring back grass cover and other native shrubs and trees. This involves several allied activities like improving the hydrology of the site, seed collection, growing and planting of saplings, etc. Restoration of a 100-acre plot has the potential to generate almost 15,000 person-days of employment over 4-5 years. Hence, the activity of restoration promises to generate far higher levels of livelihood for local communities as compared to commercial activities that involve making products from Lantana.

Junglescapes has been working with local communities for ecological restoration since 2009. A total of Six Self-help Groups (SHG) have been formed exclusively for restoration activities, consisting of indigenous community members. A year-round restoration calendar has been planned, which enables around 70 SHG members to get a livelihood for almost 300 days a year each. Capacity building is done to train the SHG members in various restoration-related interventions, as well as in self-governance. This has helped create a restoration-based livelihood model that can be easily scaled up across the country to generate very high levels of employment. Around 80% of restoration spending under this approach accrues to community members, thus making sure that the local stakeholders are the main beneficiaries.

Ecological restoration also has added benefits for local communities through improved water tables, stabler micro-climate, reduced human-wildlife conflict, etc. In addition, this helps reconnect the indigenous communities with their ecological roots and preserve their rich traditional ecological knowledge, which sadly is fast disappearing in many regions of India. Apart from livelihoods, there are significant intangible benefits that accrue, like voluntary stewardship and protection of the restored forests by the local communities engaged in the restoration activities.

Meeting the household biomass needs of local communities

Our surveys in forest-abutting villages of Bandipur Tiger Reserve show that over 80% of households depend on firewood for their cooking needs. While LPG connections have been given by the Government to many rural homes, the usage remains low due to reasons of cost and adherence to traditional cooking methods. In addition to cooking, heating of bath water is also observed to be a major consumer of firewood. Most of the fuelwood is collected from the forests by lopping off branches of healthy native trees, leading to degradation.

Over the last 12 years, Junglescapes has been promoting the use of fuel-efficient cookstoves and water boilers to address this issue. The fuel-efficient water heating boilers use around 70% less fuelwood as compared to traditional methods used for boiling water. They also work extremely well with Lantana camara as fuel. This has the potential to reduce the use of native plant-based fuelwood by around 2 tonnes per household per annum.

The fuel-efficient cookstoves use around 50% less fuel than the traditional cooking with vessels placed on stones. These cookstoves are able to utilize a 50:50 mix of Lantana sticks and other biomass. There is a reduction in the use of native plant-based fuelwood by around 1.5 tonnes per household per annum. Both these interventions help achieve a significant reduction in carbon emissions due to lower fuelwood usage.

As can be observed above, a combination of fuel-efficient apparatus and replacement of native plant-based biomass with Lantana-biomass in forest-fringe villages can significantly reduce the pressure on forests from firewood collection. We observe that with lower firewood collection pressure, the native vegetation is able to recover quickly with minimum need for intervention. This could, therefore, be a win-win for both forests and local communities.

The fuel-efficient cookstoves can also serve as a transitional phase between traditional cooking methods and LPG-based cooking, helping the women recognize the advantages of reduced reliance on fuelwood like time saved, lower smoke, etc. This can, in the course of time, lead to better adoption of LPG.

Utilization of removed Lantana for ecological restoration

Removed Lantana can be used for ecological restoration in several ways:

a. The removed Lantana can be utilized as bio-fences for planted saplings or naturally recruited seedlings, to protect them from herbivory in their establishment phase. Lantana bio-fences allow sunlight and rainfall to reach the seedlings and at the same time protect them from herbivory.

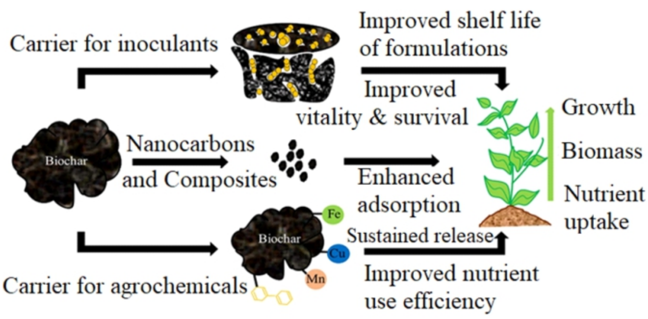
b. The Lantana biomass can be used to make biomass check dams across small streams. These check dams help improve soil moisture in surrounding areas by slowing down the flow of water. They also help in filtering the seeds of invasive plant species and preventing their further spread. The moisture in the check dams serves as a habitat for small fauna like butterflies, amphibians, etc. These check dams do not affect the hydrology of the area as they allow the water to pass through and only marginally slow down the water flow.

c. Removed Lantana can be collected in heaps which can serve as hiding places for small animals. Many of these small animals serve as seed dispersal agents for native plant species.

d. The removed and dried Lantana can be converted into biochar, which can be used in the restoration sites for improving soil health. Biochar helps in improving soil moisture retention and increases soil microbial activity. Soil enriched with biochar is proven to help better establishment of plants. The ability to retain moisture can be of significant use in reducing plant species attrition during periods of erratic rainfall and longer dry spells which are becoming common due to climate change.

Source: Bamboo pecker

Source: Tardio et al (2017) Use of local raw material for check dam construction



Source: Sashidhar et al 2020 and Wikipedia

Tapping alternate funding avenues

The declaration of 2021-30 as the Decade on Ecosystem Restoration by the United Nations has created a high level of interest in ecological restoration amongst multiple stakeholders in India. This is opening up newer avenues for fundraising for the management of invasive species. Many of these avenues are more reliable, sustainable and environmentally responsible as compared to the commercial exploitation of Lantana biomass. Some of these avenues are discussed below:

a. There is increased interest in ecological restoration amongst corporate CSR agencies. The amendments to CSR rules that allow corporates to fund multi-year CSR projects facilitate the undertaking of long-term restoration initiatives by the implementation agencies.

b. Research studies indicate clearly that biodiverse habitats sequester more carbon than monocultural habitats like those invaded by Lantana. Therefore, there is high potential for harnessing carbon funding for the restoration of Lantana-invaded sites back to biodiverse wildlife habitats.

c. Large international funding agencies are supporting landscape-level ecological restoration projects around the world. Many of these funding agencies, as well as CSR agencies, seek to fund projects that have a significant livelihood creation component.

d. Biodiversity offsets are a new funding mechanism that is gaining momentum and may be available soon.

Conclusion

As stakeholders in managing invasive species, we need to build on the experiences gained on the ground and focus more on restoration-based approaches that help build our natural capital, generate large-scale rural livelihoods and provide a wide array of ecosystem services. The commercial exploitation of Lantana, in our opinion, is neither viable nor sustainable and has several inherent ecological risks, as discussed above. We need next-generation thinking to raise the large amount of funds needed for managing Lantana at scale. With the increased interest in ecological restoration, this is more feasible now. To conclude, it is imperative in the interest of biodiversity that the focus is on restoration rather than on removal for commercial use.

References: Contact author at crhanumanth@gmail.com

Lantana (Caturang) : The Silent Invader Threatening our Ecosystems - Is There a Way Out?

Pradeep Tripathi and Swarup Datta
Founder of Green Yatra and Senior Project Coordinator
Green Yatra
E mail : pradeep@greenyatra.org

Imagine a plant so resilient that it thrives where others cannot, spreading its vibrant flowers across landscapes far from its native home. Lantana camara is this remarkable yet problematic plant. Despite its visual appeal, it's a silent invader with profound ecological repercussions. Originally from Central and South America, Lantana camara was introduced into India as a garden ornamental or bio-hedge plant in the early part of the 19th century (Love et al., 2009). Over time, it has rapidly colonized tropical and subtropical regions worldwide, displacing native flora, degrading wildlife habitats, and disrupting the delicate balance of ecosystems.

Global Status of *Lantana camara* Invasion

Lantana camara is ranked among the world's most invasive species, found in over 60 countries across tropical and subtropical zones. Its remarkable adaptability to diverse climates and soil types has enabled it to flourish in ecosystems ranging from forests to grasslands and agricultural lands. Dense thickets of Lantana outcompete native vegetation, reduce biodiversity, and disrupt ecological harmony. The economic and ecological impacts of this invasion are particularly severe in regions like Africa, Asia, and Oceania. In Australia, for instance, Lantana camara is classified as a Weed of National Significance (WoNS), with annual management costs reaching millions (Day et al., 2003). Similarly, its spread in Africa threatens savanna ecosystems, while in Southeast Asia, it dominates disturbed landscapes.

Fig 1: Lantana camara

The plant's allelopathic properties—chemicals that inhibit the growth of neighbouring plants—further enhance its invasive potential (Sharma et al., 2005).

Lantana is locally known as Caturang or Raimuniya in Central India, Gubon Gu-Phul in Assam. In the Nilgiri region, it is known as Nandhana chedi/Paralai chedi/Unni chedi.

Status of *Lantana camara* Invasion in India

In India, Lantana camara is one of the most aggressive invaders, spreading across 13 million hectares and affecting both forested and non-forested regions (Hiremath & Sundaram, 2005). Severe infestations are reported in the Western Ghats, Central India, parts of the Himalayas, and even in the Northeastern states like Arunachal Pradesh and Mizoram where it is invading the rich biodiverse regions of the state. In forested areas, it replaces native undergrowth, degrades habitats crucial for wildlife, and hinders the regeneration of native tree species, this invasion has resulted in the scarcity of native forage plants for wild herbivores; it has invaded more than 40 % of India's tiger range (Mongabay, Sahana Ghosh, 2023). In agricultural lands and pastures, Lantana reduces crop productivity, creates fire hazards during dry seasons, and imposes economic burdens on local communities reliant on forest resources for fodder and fuelwood.

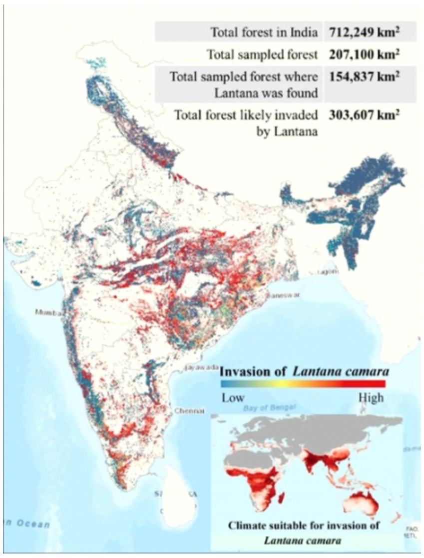


Fig 2: Lantana **invasion in India.** Red dots signify the highest density of lantana and blue signifies the least density. The world map on the bottom right shows the suitable area for lantana invasion, based on Mungi et al 2020. Image courtesy Ninad Mungi. (Mongabay, Rajat Rastogi, 2020)

Ecosystem Interactions of Lantana: A blessing and a curse

While Lantana's impact on ecosystems is overwhelmingly negative, some species have adapted to its presence. For example, sloth bears use dense Lantana thickets for nesting and consume its sweet, ripe berries. Many bird species include Lantana berries in their diet, and its flowers attract numerous butterfly species. However, this seemingly positive interaction underscores Lantana's evolutionary sophistication—it uses these animals to spread its seeds, ensuring its dominance. Lantana's asexual reproduction capabilities andallelopathic effects further enable it to outcompete native species, gradually diminishing species diversity and monopolizing landscapes.

Interestingly, the presence of Lantana in some ecosystems raises questions about whether its role can ever be justified. While it provides temporary shelter and food for certain wildlife, these benefits are outweighed by the long-term damage it causes. The plant's ability to transform landscapes into monocultures significantly diminishes the ecosystem services provided by native flora, including soil stabilization, water retention, and habitat support for a wider range of species. This duality complicates the perception of Lantana as an invader but ultimately reinforces the need for its management.

The Battle Against Lantana camara: Why Control Efforts Keep Failing

Efforts to control Lantana camara have spanned over 100 years, yet its spread remains unchecked. Here's some of the points which needs to be highlighted:

Mechanical Removal Challenges: The plant regenerates from its rootstock, making mechanical removal largely ineffective, and its seeds disperse easily during the process (Sundaram et al., 2015). Studies show that 70% of mechanically removed Lantana camara can regrow from rootstock within a year.

Limited Control Options: Chemical and biological methods, while promising, are fraught with challenges, particularly in forest ecosystems where non-target species are at risk.

The adaptability and resilience of Lantana: One of the key reasons for Lantana's persistence is its adaptability. This plant thrives in disturbed environments, which are often created by human activities like agriculture, logging, and urbanization. A single Lantana camara plant can produce up to 12,000 seeds annually, dispersed effectively by birds and animals.

Exploiting Fragmentation: The fragmented nature of forested landscapes provides ideal entry points for Lantana to infiltrate edges and gradually

Fig 3: Forest floor covered by Lantana, BRT Tiger Reserve. Source: Lantana, people, and wildlife in southern India (field trip report) https://christiankull.net/2014/10 /06/lantana-in-india/

spread deeper into ecosystems, displacing native flora and fauna. Without a unified and sustained approach to management, Lantana's invasion will continue to intensify, compounding ecological damage and economic losses.

Lantana Management: Smart Strategies for a Healthier Ecosystem

Lantana camara may be a persistent invader, but with the right strategy, we can manage its spread. Here's how a more holistic approach can help us in controlling the spread:

Complete Rootstock Removal is Key: Simply clearing Lantana is not enough—if the rootstock remains, the plant will come back stronger. Complete eradication requires removing the rootstock to prevent regrowth. (Sundaram et al., 2015)

Don't Let the Seeds Spread: Seeds dispersed during mechanical removal can quickly lead to fresh infestations. Managing the spread means containing the seeds as well as the plants. (National Invasive Species Council)

Act Fast with Native Plants: After removal, native plants must be introduced immediately in cleared areas to prevent Lantana from re-establishing. Research shows that native species like Justicia adhatoda, Broussonetia papyrifera, and certain grasses can successfully compete with Lantana. (Kumar et al, 2024)

Exotic Species are not the Answer: While plants like Eucalyptus may suppress Lantana, they don't contribute to true ecosystem restoration. Native plants are essential for rebuilding healthy landscapes. (Australian National Botanic Gardens)

Efficiency Through Technology: Using specialized machinery for rootstock removal makes large-scale operations more efficient, ensuring that restoration efforts reach their full potential. (Prasad et al., 2018)

Fig 4: Cut-rootstock method of Lantana camara
Source:https://indiabiodiversity.org/biodiv/content/projects/pr oject-fc210795-5976-42f6-ad1b-7f96a02dd819/826.pdf

Fig 5: Uprooted Lantana Plant
Source: https://repository.ias.ac.in/904/1/315.pdf

Restoring Ecosystems: Boosting Biodiversity and Resilience for a Healthier Future

Restoring areas previously dominated by Lantana can lead to significant improvements in ecosystem services. Native plants contribute to soil stabilization, enhance water retention, and provide habitat for a diverse range of species. For example, reintroducing native grasses and shrubs can prevent soil erosion and improve the microclimate, making the environment more hospitable for other flora and fauna. Furthermore, a restored ecosystem is more resilient to future invasions, as a diverse plant community creates natural barriers to the establishment of invasive species.

One innovative approach involves using community-led restoration programs. Local communities, especially those dependent on forests for their livelihoods, can play a crucial role in managing Lantana. Training and employing community members to remove Lantana and plant native species not only helps in controlling the invasion but also provides economic benefits. Such programs can foster a sense of ownership and stewardship, ensuring the long- term success of restoration efforts.

Sustainable Utilization of Removed Lantana

Once Lantana camara is removed, it doesn't need to go to waste. The plant can be repurposed in a variety of ways that contribute to sustainability goals while benefiting local communities. Here are some exciting opportunities:

Turning Lantana into Valuable Products: Lantana can be transformed into compost, biochar, and biogas, supporting environmental sustainability, and reducing waste. Studies show that converting Lantana into biochar, for example, helps sequester carbon and improve soil fertility. (Sharma et. al, 2005)

Handicrafts and Eco-Friendly Products: The stems of Lantana can be crafted into eco-friendly products such as baskets, ornaments, sculptures, and other handicrafts. This provides economic opportunities for local artisans and fosters community involvement in conservation.

Innovative Uses in Construction and Furniture: The woody stems of Lantana can be used as raw materials for furniture and construction, which helps reduce pressure on native forests and promotes sustainable materials for building.

Economic Benefits for Communities: Engaging local communities in Lantana removal and product creation can generate additional income and encourage participation in long-term conservation efforts. This not only supports the local economy but also builds awareness about the importance of managing invasive species sustainably.

These applications not only create economic opportunities but also contribute to sustainability by minimizing waste and promoting circular economy principles.

Fig 6: Dried stem of Lantana used as fencing Photo by Pradeep Tripathi, Green Yatra

Fig 7: Artisan making furniture from Lantana stem Source: https://medium.com/centre-for-social-and-environmental-innovation/part-1-connecting-lantana-crafts-to- the-furniture-market-9f4aeb7734ff

Fig 8: Artists making elephant displays from Lantana
Source: https://www.thehindu.com/sci-tech/energy-and-environment/lantana-elephants-to-the-rescue/article26094116.ece

The Role of Policy and Research

Effective management of Lantana camara requires robust policies and research-driven strategies. Policymakers must prioritize the control of invasive species and allocate resources for large-scale removal and restoration projects. Research institutions can contribute by developing innovative techniques for Lantana management and identifying native species that can outcompete the invader. Additionally, international collaboration is essential, as the invasive nature of Lantana transcends national boundaries.

Public awareness campaigns can also play a vital role in controlling Lantana. Educating communities about the ecological and economic impacts of this invasive species can motivate them to participate in management efforts. Schools, local governments, and non-governmental organizations can work together to spread knowledge and foster a culture of environmental responsibility.

The Path Forward

Managing *Lantana camara* requires more than eradication-it calls for a holistic approach that integrates mechanical removal, habitat restoration, and sustainable utilization of plant materials. By planting native species in cleared areas and promoting sustainable uses of Lantana biomass, we can restore ecosystems, support biodiversity, and empower local communities. This strategy not only curbs the spread of Lantana but also aligns with broader environmental and socioeconomic goals, paving the way for a more balanced coexistence between humans and nature.

The journey to control Lantana camara is challenging but not impossible. With coordinated efforts, innovative solutions, and the active involvement of local communities, we can mitigate theimpact of this invasive species and work toward a future where ecosystems thrive in their natural balance. By turning the challenge of Lantana into an opportunity for restoration and sustainability, we can ensure the health of our planet for generations to come.

References: Contact author at pradeep@greenyatra.org

Converting Lantana from a Liability to Asset: Case Studies from Three States in India

Maya Mahajan and Sampriti Kataki
Environmental Information Awareness Capacity Building and Livelihood Programme (EIACP),
Amrita Vishwa Vidyapeetham, Coimbatore
E-mail : forestlady31@gmail.com

In the year 2000, Maya Mahajan (author), then a PhD scholar at Salim Ali Centre for Ornithology and Natural History (SACON) Coimbatore, was researching the impact of invasive alien weeds on native flora and ecosystems across various forest types in the Nilgiri Biosphere Reserve, including the Siruvani Hills, Mudumalai, Silent Valley, and Upper Bhavani. Her study revealed a severe infestation of Lantana camara in the dry and moist deciduous forests of Siruvani Hills and Mudumalai Wildlife Sanctuary.
Through discussions with forest officials in these regions, she realized that mechanically controlling Lantana camara was labour-intensive, costly, and time-consuming. Later after secured funding she initiated an innovative project focused on managing Lantana through community participation. The initiative involved training local tribal communities to craft furniture and other utility articles from uprooted Lantana, turning it into a source of sustainable livelihood. This project was conducted in various tribal villages located in three states, ie Tamil Nadu, Kerala and Maharashtra through Green Skill development program funded by Ministry of Environment and Forest and Climate Change.

Invasion of *Lantana camara* poses a serious threat to various ecosystems and biodiversity in India. This plant was introduced in India for horticultural purposes. It has escaped from gardens and this highly invasive weed has taken over the landscapes of India, growing in thickets and encroaching wastelands, forests, wetlands, and agricultural fields. Lantana can thrive in the most adverse climatic conditions of tropical and subtropical regions. This profusely grown weed poses serious ecological and economic concerns severely impacting the native ecosystems. Due to its allelopathic behaviour, the plant restricts the growth of other plants and eventually outcompetes them all, leading to a decline in natural biodiversity. In India, parts of the Deccan, the lower hills of the Western Ghats, the Waynad, and the Nilgiris are among the places where L. camara has the most devastating impact. Lantana has invaded almost 40% of the environment of Nilgiris.

We felt a pressing need to control the spread of Lantana in forest ecosystems in Nilgiri Biosphere Reserve where author had conducted her doctoral research. As mentioned earlier since the mechanical control of this weed is very expensive and time consuming, we decided to take support of local community residing in the area to cut or uproot the Lantana and repurpose the same to craft furniture. The primary challenge in launching the project was persuading the tribal community to collect Lantana from the forest, as the area was prone to frequent elephant attacks. It was only when V. Vellachi, a resident of Singampathy, along with fourteen other women, stepped forward for training that other gradually joined in. Another hurdle was obtaining permission from the Forest department to cut and transport the Lantana to the villages. However, once the department recognized this initiative as an effective solution for removing the invasive species-an otherwise difficult task-they readily granted us the necessary approval.

Tribal Rural Techo Park in Siruvani, Tamil Nadu

Between 2014 and 2021, as part of the project "Developing a Rural Technology Park in Siruvani Forest," funded by Science for Equity, Empowerment and Development (SEED), Department of Science and Technology, Government of India, the tribal community in six villages in the Siruvani Forest, Coimbatore Division, actively participated in the mechanical control of Lantana by manually cutting. At the same time, they were trained in making low-cost furniture, handicraft, toys and other utility articles using harvested Lantana wood. Thus, a

Invasion of *Lantana camara* poses a serious threat to various ecosystems and biodiversity in India. This plant was introduced in India for horticultural purposes. It has escaped from gardens and this highly invasive weed has taken over the landscapes of India, growing in thickets and encroaching wastelands, forests, wetlands, and agricultural fields. Lantana can thrive in the most adverse climatic conditions of tropical and subtropical regions. This profusely grown weed poses serious ecological and economic concerns severely impacting the native ecosystems. Due to its allelopathic behaviour, the plant restricts the growth of other plants and eventually outcompetes them all, leading to a decline in natural biodiversity. In India, parts of the Deccan, the lower hills of the Western Ghats, the Waynad, and the Nilgiris are among the places where L. camara has the most devastating impact. Lantana has invaded almost 40% of the environment of Nilgiris.

We felt a pressing need to control the spread of Lantana in forest ecosystems in Nilgiri Biosphere Reserve where author had conducted her doctoral research. As mentioned earlier since the mechanical control of this weed is very expensive and time consuming, we decided to take support of local community residing in the area to cut or uproot the Lantana and repurpose the same to craft furniture. The primary challenge in launching the project was persuading the tribal community to collect Lantana from the forest, as the area was prone to frequent

This initiative not only provided a sustainable livelihood for the Irula tribal community but also contributed to forest conservation and biodiversity protection by eradicating Lantana. Over seven years, 150 Irula artisans were trained in making utility articles, crafts, and furniture from Lantana wood for 5 years. Master trainers emerged out of these programs, who acted as resource persons for all our further trainings and certification programs

Building on this success, a structured and certifiable course on Lantana craft and furniture making was developed. A dedicated training module was offered as part of the Green Skill Development Program (GSDP), funded by ENVIS-MOEFCC, at multiple locations. This program aims to empower local communities in and around Siruvani Hills, Senguttaiyur (Coimbatore Forest Division, Tamil Nadu), Wayanad Wildlife Sanctuary (Kerala), and Dahanu (Palghar district, Maharashtra) by equipping them with sustainable livelihood skills.

Module for GSDP

A special course/module on Lantana craft and furniture making and marketing was designed by Environmental Information Awareness Capacity Building and Livelihood Programme (EIACP) team with the help of technical experts, for the tribals in various villages located in remote forests in three states. The program comprehensively covers all parts of the craft making, including gathering of Lantana sticks, its processing and making the final products. The process of Lantana crafting is unique and involves heat treatment of the suitable stems by boiling for specific period of time, after which these can be bent at desired shape. After the shrub is chopped off, its wood is treated in boiling water to make it flexible. The bark is removed, and the log is sliced into sticks before it is assembled into furniture pieces by following various designs developed by our team. Later products are given finished look by applying varnish and organic colour. The participants were given comprehensive training to make a range of furniture, small craft and utility articles such as baskets, boxes, trays, toys, hangers, pen stands, mobile stands, glass holders, etc using Lantana woody stem in three phases during 60 days of certificate course. The recipients also were given hands-on experience for making large furniture such as chairs, stools, tables, bookshelfs, racks, sofa, tea-poy, Pet-cages, computer table, laptop stand, different types of idol cases etc in advanced course which was conducted subsequently. Advanced course included learning of innovative product designs developed with the help of research student's team from design school of TU Delft Netherlands.

Green skill development program and Project areas

The areas selected for the program are places where Lantana invasion has emerged as a serious nuisance posing significant threat to both ecosystems and livelihoods of local communities. The program was initiated at Siruvani reserve forest, in the foothills of Siruvani Hills, located inside the Western Ghats, which is inhabited by Irula tribe. Tribal inhabitants in these regions rely on non-wood forest items with very limited agricultural productivity. Total Over a span of four years, four GSDP programs were organized for the Irula tribes residing in five isolated tribal hamlets within the Siruvani reserve forest, engaging 80 participants. The second program took place in tribal hamlets in the eco-fragile Dahanu Taluka of Maharashtra, with 40 young tribal participants, predominantly female, participating in two phases. Following the training and exams, the innovative small crafts and utility items created by the participants were showcased by our partner NGO, Nareshwadi Training Center (Somayya Trust), in Dahanu Taluka and Mumbai. The third program was held in Mutanga, a village in the Wayanad Wildlife Sanctuary in Kerala, where 25 Kattunayakar tribe members took part. The fourth program took place in the remote and scenic Sengeuttaiyur Tribal hamlet, near the Anaikatti hill region in Coimbatore. The fifth round of the GSDP course was conducted in Duldhanwadi Village, Maharashtra, with 20 tribal participants focusing on small crafts and utility items. After each GSDP course, participants underwent a five-day practical exam, where they were required to independently craft products. Upon successful completion of the exam, certificates from the Ministry of Environment, Forest, and Climate Change were awarded to the participants.

Local tribals were enthralled by the idea of using easily available Lantana as a raw material for furniture production, which led them to actively participate in cutting and removing this plant from forest. Daily hands-on lessons helped the trainees to transform Lantana into artistic objects with great market value. Opportunities for participants' long-term economic well-being are created upon completion of training, by forming Self Help Groups (SHGs) involving indigenous communities. The furniture looks similar to the cane furniture in design and performance but is more durable and it is termite resistant. At the same time the cost of Lantana furniture is much lesser than cane or bamboo furniture as the raw material is available for free. The programs received support from local forest departments and other national organizations such as TRIFED and the Tamil Nadu Handicraft Development Corporation Center (TNHDCC), through which market linkages are being set up in these regions to ensure the long-term promotion of these products. The primary accomplishments of the programs included the capacity building of tribal population, the generation of alternative livelihoods for tribal members, and the eradication of Lantana from the adjacent forest regions. These communities,

Green skill development program and Project areas

The areas selected for the program are places where Lantana invasion has emerged as a serious nuisance posing significant threat to both ecosystems and livelihoods of local communities. The program was initiated at Siruvani reserve forest, in the foothills of Siruvani Hills, located inside the Western Ghats, which is inhabited by Irula tribe. Tribal inhabitants in these regions rely on non-wood forest items with very limited agricultural productivity. Total Over a span of four years, four GSDP programs were organized for the Irula tribes residing in five isolated tribal hamlets within the Siruvani reserve forest, engaging 80 participants. The second program took place in tribal hamlets in the eco-fragile Dahanu Taluka of Maharashtra, with 40 young tribal participants, predominantly female, participating in two phases. Following the training and exams, the innovative small crafts and utility items created by the participants were showcased by our partner NGO, Nareshwadi Training Center (Somayya Trust), in Dahanu Taluka and Mumbai. The third program was held in Mutanga, a village in the Wayanad Wildlife Sanctuary in Kerala, where 25 Kattunayakar tribe members took part. The fourth program took place in the remote and scenic Sengeuttaiyur Tribal hamlet, near the Anaikatti hill region in Coimbatore. The fifth round of the GSDP course was conducted in Duldhanwadi Village, Maharashtra, with 20 tribal participants focusing on small crafts and utility items. After each GSDP course, participants underwent a five-day practical exam, where they were required to independently craft products. Upon successful completion of the exam, certificates from the Ministry of Environment, Forest, and Climate Change were awarded to the participants.

Local tribals were enthralled by the idea of using easily available Lantana as a raw material for furniture production, which led them to actively participate in cutting and removing this plant from forest. Daily hands-on lessons helped the trainees to transform Lantana into artistic objects with great market value. Opportunities for participants' long-term economic well-being are created upon completion of training, by forming Self Help Groups (SHGs) involving indigenous communities. The furniture looks similar to the cane furniture in design and performance but is more durable and it is termite resistant. At the same time the cost of Lantana furniture is much lesser than cane or bamboo furniture as the raw material is available for free. The programs received support from local forest departments and other national organizations such as TRIFED and the Tamil Nadu Handicraft Development Corporation Center (TNHDCC), through which market linkages are being set up in these regions to ensure the long-term promotion of these products. The primary accomplishments of the programs included the capacity building of tribal population, the generation of alternative livelihoods for tribal members, and the eradication of Lantana from the adjacent forest regions. These communities, which are frequently overlooked and rely on forest resources for their survival, obtained a reliable source of alternative income through exhibitions and orders from individuals and institutions including Ministry of Environment, which greatly boosted their moral. Local ecosystems profit from reduced Lantana infestation and tribal populations reports improved earnings and quality of life in areas like Siruvani, Wayanad, Dahanu, and Coimbatore, demonstrating the transformative influence of the program. The transformation of Lantana wood into furniture and other value-added products has emerged as an innovative, eco-friendly alternative to traditional wood, marking a significant achievement in India's ongoing battle against Lantana invasion. This initiative highlights the effectiveness of community-driven ecosystem solutions in tackling environmental challenges. Our GSDP programs received wide appreciation from, community, forest officials, researchers, media, minister of Environment and we were invited to present the success stories in G20 working committee meeting in Amritsar.

Beyond promoting sustainable livelihoods, the program has contributed to the restoration of degraded habitats by equipping indigenous communities with essential skills in furniture and craft production. However, to elevate this initiative to greater success, it is crucial to develop key organizational capabilities, attitudinal and behavioural changes in tribals, product innovation, customer relationship management, market-driven product diversification, and specialized training in marketing skills. Handholding of tribals for longer duration is must by local NGOs working on social and environmental cause and forest department, without interference of profit-making organisations.

References: Contact author at forestlady31@gmail.com

Struggle Against the Invasive *Lantana camara* – A Weed

Arathi Menon
Independent journalist, Mysuru, Karnatka

A weed is commonly defined as a plant that grows where it is not wanted. Known for their vigorous growth, weeds often establish themselves in new environments, gradually displacing native plant species. With their ability to spread and thrive rapidly, weeds can quickly dominate the areas they invade.

Lantana camara's introduction to India is deeply linked to colonial history. In 1636, Johan Maurits van Nassau-Siegen became governor of Dutch Brazil, a colony seized from the Portuguese by the Dutch West India Company. Accompanying him was artist Frans Post, who documented over five hundred plant and animal species of interest, including a flowering shrub known to Spanish colonists in the Americas as camara. Its leaves were traditionally used for medicinal infusions. Samples of the plant were soon shipped to Holland aboard Company vessels, along with other exotic species, eventually reaching botanical gardens across Europe. By 1691, London's Hampton Court royal garden had begun cultivating Lantana camara using specimens imported from the Caribbean.

The transfer of biodiversity, a key feature of what became known as the Columbian Exchange, was not confined to Europe and the Americas. British botanists were also exchanging plant samples across the empire. William Roxburgh, who took charge of the East India Company's botanical garden in Calcutta in 1798, compiled a catalogue noting that nearly a thousand plant species, including two varieties of Lantana, had been introduced to the garden from outside British India. Roxburgh's successor, Nathaniel Wallich, wrote to the EIC's Court of Directors in August 1839, requesting a continued supply of seeds from the Americas, as they "succeed, in general, remarkably well," and also asked for "as many flower seeds as possible, both for sowing in the hills and plains."

As Henry Cope, Secretary of the Horticultural Society at Meerut, explained in a letter to his colleagues in London, over the course of the nineteenth century, at least Eleven Lantana species from the Americas were introduced to botanical gardens across India. These plants, with their vibrant flowers, were widely used in decorative hedges in British settlements, such as cantonments and tea estates. The seeds soon spread to surrounding areas and eventually entered the wild.

By 1874, Botanist Dietrich Brandis recorded that Lantana could be found in the plains of north India, the Sub-Himalayan tracts up to 3,000 feet in elevation, as well as in Sindh, the Deccan Plateau, the Nilgiris, and Ceylon. Two decades later, forest authorities in Coorg reported that Lantana infestations had caused the abandonment of hundreds of coffee estates, while new sandalwood plantations were being overtaken by the weed within three years.

"Researchers warn that Lantana is reshaping the nation's forest landscapes, leading to massive biodiversity loss and an increase in zoonotic diseases. Additionally, it plays a significant role in fueling large, destructive forest fires."

"It seems almost incredible that a small ornamental hedge shrub introduced into India about a century ago should have developed into a pest of such proportions, overrun millions of acres of cultivable land and forest areas, and spread across almost every province of the country," wrote AV Varadaraja Iyengar, a Biochemist at the Indian Institute of Science (IISc), in a 1933 article for Current Science. "Yet such is indeed the case: the menace of Lantana is one of the most serious problems of India today, and unless a quick and inexpensive method of controlling its spread is soon discovered, the rapid invasion of this naturalized exotic will cause incalculable harm to agriculture and forestry in this country."

By the turn of the century, forest officers had begun organizing manual removal efforts. Similar actions have been required in around seventy countries where Lantana has been introduced. "Lantana camara is a very complex plant of hybrid origin," explained CR Babu, professor emeritus at Delhi University. "What we see now is a hybrid of multiple plant species. Over time, it has developed adaptive strategies to overcome efforts to eradicate it."

Lantana's broad ecological tolerance has played a key role in its spread. It can grow in both tropical and temperate regions and survive up to nearly 2,000 meters above sea level, helping it expand across diverse geographic areas. The weed has even reached the highlands of the Nilgiris. Anita Varghese, director of biodiversity conservation at Keystone Foundation, which is working to map invasive species in the Nilgiris, shared that, two decades ago, Lantana was scarcely seen in Kotagiri, a town at over 1,800 meters. "Now, it's found even on hedges," she said. "We don't see the native plants and flowers that once flourished there. They've been replaced by Lantana."

Raman Sukumar, Honorary Professor of Ecology at the IISc, pointed out that Lantana's population in the Americas is controlled by natural predators such as certain herbivores, insects, and pests. However, in foreign environments like India, where these predators are absent, Lantana's expansion remains unchecked.

Botanical gardens, such as the one established by the East India Company in Calcutta, imported hundreds of foreign plant species, including varieties of Lantana. (Source: Heritage art / Heritage images / Getty images)

Case studies of Bandipur National Park

Madaba belongs to the Betta Kuruba tribe, an indigenous pastoral community in Karnataka. With his deep knowledge of native grass species, he is an invaluable asset at Bandipur National Park, which has been focused on grassland restoration and management since 2019. The plan includes removing invasive weeds and replacing them with native grass species. The work is labor-intensive, as Bandipur is home to a variety of weeds, including Eupatorium, Parthenium, and Lantana. "Only tribals have the expertise to do this job," said Muniraju, a range forest officer at Bandipur, who is responsible for grassland management in one of the park's 13 ranges. He also oversees the creation of fire lines before the summer to help control the frequent wildfires that have plagued the park.

Weed removal is a crucial part of the restoration process at Bandipur. Madaba and sixty other members of his community work tirelessly for three to four months each year, removing weeds by hand, only to watch them return in greater numbers the following season. "I've been doing this work for twenty years," Madaba shared with me in November 2019. "I've seen these weeds getting worse and worse." He expressed particular frustration with Lantana camara, a thorny shrub that grows in dense thickets. "Among all the weeds," he said, "it's the most difficult to remove." The process involves hacking through the thicket, uprooting the plant, rolling it up, and pushing it aside to be burned later.

But it's not just Bandipur that's struggling with Lantana camara. Considered one of the ten worst invasive plants globally, a recent study by the Wildlife Institute of India (WII) found that Lantana is present in 154,837 of the 207,100 square kilometers surveyed.

The study estimates that 303,607 square kilometers—44% of all forest land in India—are suitable for Lantana's invasion. The plant thrives in "warm, humid, fertile areas degraded by extractive human use." Researchers warn that Lantana is gradually altering India's forest landscape, leading to significant biodiversity loss, contributing to zoonotic diseases, and playing a major role in large, destructive wildfires. Managing or eradicating it will come at a tremendous cost. The WII study estimates that clearing Lantana from India's forests would cost more than $5.5 billion—over ten times the annual budget of the Ministry of Environment.

The Soliga community of Karnataka has historically used controlled surface fires for a number of reasons, including improving visibility, easing collection of forest produce, aiding food production and regenerating grass. (Source: Siddappa Setty / ATREE)

Forest Fire

In 2019, Bandipur National Park was ravaged by a devastating wildfire that scorched over four thousand hectares of forest. Three years earlier, a fire that started in Uttarakhand's Jim Corbett National Park spread across 13 districts, destroying approximately two thousand hectares of forest. Between 2005 and 2015, a study recorded 601 wildfire incidents across four national parks in Uttarakhand.

Forest fires are not a new phenomenon in India. "Fires have played a major role in shaping our forest landscapes for centuries," Sukumar told me.For centuries, India's indigenous communities, including the Soliga people of Karnataka, have used fire as a tool in their forest management practices. The Soliga would use taragu benki - controlled surface fires set in

January and February-for various purposes, such as improving visibility, aiding in the collection of forest produce, promoting foodproduction, and regenerating grass, which grows back faster and more robustly after a fire. "Those were litter fires, ground-level or surface fires that rise only two to three feet," C Madegowda, a researcher and tribal rights activist, explained. "We had to stop this practice after the Wild Life (Protection) Act, 1972, came into effect."

The no-fire policy established by the act—reinstating a colonial prohibition that had been relaxed in some forests in the 1930s—has been a point of contention ever since. The Soliga argue that banning taragu benki has caused significant changes to the forest structure, particularly facilitating the spread of Lantana. Ecologists agree that controlled surface fires can kill Lantana seeds in the soil and restore a grass-covered forest floor. Without such measures, Lantana provides the fuel for large, destructive canopy fires every summer.

Sukumar explained that these fires further promote Lantana growth. He observed a sharp increase in Lantana in Mudumalai in 2004-05. "It wasn't just a local disturbance in Mudumalai -similar reports came from other forests in Karnataka," he said. "When we investigated, we found that South India experienced major droughts between 2000 and 2004. There was a decline in rainfall starting in 2000, followed by widespread fires in 2002." In the past, rain following forest fires would have helped grasses recover, but the lack of rain allowed Lantana to take over. "This drought-fire-drought cycle is extremely favorable for Lantana," Sukumar concluded.

In 2016, a fire that started in Uttarakhand's Jim Corbett National Park spread to 13districts in the state, destroying around two thousand hectares of forest land. (Source: ANUPSAH / BARCROFT MEDIA / GETTY IMAGES)

Ingress to Invasion: by Lantana

In natural ecosystems, native plants typically dominate by occupying all available ecological niches, leaving little room for invasive species to take hold. However, these niches become vulnerable when disturbed, offering foreign species an opportunity to sneak in. In India, Lantana camara found such an opportunity through commercial logging during British rule. Logging began in 1806 and intensified with the expansion of the railways in the latter half of the nineteenth century, just as Lantana was starting to spread into the wild.

Logging cleared the forest canopy and disrupted the micro-ecology of the area. "Initially, you would see Lantana only along the roads where there were clearings," said Sukumar. "As the forests were cleared of trees, Lantana had the chance to occupy the vacant space." Large-scale logging persisted until it was prohibited by the Forest (Conservation) Act in 1980.

Once Lantana establishes itself in an area, it can be nearly impossible to stop. Each plant can produce around 1,200 seeds, which can lie dormant in the soil for up to eleven years before germinating. Even roots left behind during removal can quickly regenerate new plants, and Lantana can sprout new roots from green stems that come into contact with the ground. Its bright flowers and strong, pungent scent attract bees, butterflies, and other pollinators, while its berries are eaten by birds that then disperse the seeds. Studies of animal scat have even shown that sloth bears contribute to its spread by consuming the fruits.

Sukumar pointed out that Lantana, like many other invasive weeds, is more tolerant of higher carbon dioxide concentrations than most native grasses, which will likely allow it to thrive as carbon emissions continue to rise.

Another factor in Lantana's success is its allelopathic properties—it releases chemicals that suppress the growth of native plants. Its very presence also hinders native species. "Under the canopy that Lantana creates, nothing really grows," explained Geetha Ramaswami, an ecologist who focused much of her doctoral and postdoctoral research on Lantana. Ramaswami and Sukumar's research at Mudumalai National Park in Tamil Nadu revealed that Lantana-dense canopies block sunlight, allowing only 57% of light to reach the forest floor, compared to 76% in areas without Lantana. This reduction in light limits the growth of other plants and can disrupt seed dispersion by animals.

The forest undergrowth that Lantana replaces is fodder to many forest animals. (Source: Michael Benanav)

Lantana's takeover of the forest floor has far-reaching consequences, not just for the plants and trees, but for the animals that rely on the undergrowth. Many herbivores depend on native vegetation for fodder, and Lantana's spread limits their access to this crucial resource. Furthermore, Lantana itself is toxic-when consumed, it harms the liver and kidneys.

It has been a major cause of livestock poisoning, especially among cattle grazing near forest edges. A 1962 study by the Council of Scientific and Industrial Research found that cattle that ate Lantana leaves developed severe symptoms, including jaundice, skin exfoliation, profuse salivation, dermatitis, and lethargy.

The consequences of Lantana taking over the forest floor extend beyond grazing animals. The 2019 study by the Wildlife Institute of India (WII) that found Lantana threatening 44 percent of India's forests was conducted across tiger reserves. When Lantana forces herbivores out of their usual habitats, carnivores, including tigers, are left to venture further in search of food. While this has yet to be confirmed scientifically, some experts speculate that the infestation of Lantana in tiger habitats might push big cats closer to human settlements. Moreover, Lantana thickets create perfect hideouts for animals, including elephants, increasing the risk of accidental human-animal encounters.

"Many times, animals are hidden behind Lantana that grows like a fence, and we realize it only when we're very close," Muniraju, the range forest officer at Bandipur, shared. "It has proven dangerous to many of us working in the forest." Varghese mentioned a recent death in Kotagiri where Lantana was partially to blame-a farmer startled a gaur hidden behind a Lantana thicket, which tragically attacked him in response.

Lantana's spread also poses a heightened risk to humans, especially in terms of zoonotic diseases. In 1957, a mysterious illness began circulating among the people living near the Kyasanur forest in Karnataka, shortly after numerous monkeys had died. Known as Kyasanur Forest Disease (KFD), or "monkey fever," the outbreak killed over five hundred people in the following decades, spreading to neighbouring states like Kerala, Goa, and Maharashtra. Epidemiologist Jorge Boshell-Manrique, who began studying KFD in the early 1960s, found that Lantana and other invasive species, such as Eupatorium and Chromolaena odorata, were common in the areas between the forest and surrounding fields.

These Lantana thickets, which had flourished as a result of deforestation, provided cover for jungle fowl and small mammals that carried ticks infected with the KFD virus. The ticks would attach to monkeys and, in turn, humans. The low biodiversity in Lantana-infested areas meant that the ticks had fewer animals to latch onto, leading to a higher chance of transmission. Sukumar and Tarsh Thekaekara, a postdoctoral fellow at the National Centre for Biological Sciences, both believe that the traditional practice of controlled surface fires may have helped keep tick populations in check by reducing Lantana growth.

Clumps of cut Lantana are placed upside down, to prevent regeneration, and allowed todry for ten days before they are burnt. (Source: ABHISHEK N CHINNAPPA)

Case studies in Corbett Vs Bandipur

In 1991, the addition of nearly 800 square kilometers of buffer zone around Jim Corbett National Park was meant to protect the park's core by relocating villages. The hope was that this relocation would enable the regeneration of the forest. Initially, forest authorities were not overly concerned about Lantana, viewing it as a source of food for birds, especially since it had been introduced in some villages as a hedge plant to protect crops from wild animals. However, Lantana soon spread rapidly across the newly created buffer zone, much to the surprise of the forest authorities.

When researchers from Delhi University surveyed a half-hectare portion of the park, they found Lantana everywhere, except in dense forests, with the highest concentration along forest roadsides and in abandoned agricultural land. The study revealed that in areas with heavy Lantana infestation, only a few perching trees remained, with no native species found. As a result, in 2005, researchers initiated a pilot project in the abandoned villages of Jharna and Laldhang to test a two-pronged approach: eradicating Lantana and restoring weed-free landscapes.

CR Babu, one of the researchers, developed an innovative method called the "cut root-stock method" (CRS), also known as the Babu-cut method. Traditional methods of removing Lantana—such as cutting, slashing, and burning—had been found ineffective. These methods often stimulated the weed to regenerate by triggering shoot buds below the cut or from underground plant tissue. Additionally, the use of heavy machinery to clear Lantana not only destroyed surrounding plants but also exposed Lantana seeds to air and light, promoting their germination. As Babu pointed out, these common practices were actually helping Lantana spread uncontrollably.

The CRS method works differently. It involves cutting the Lantana just below its reproductive part and using a hoe to chop the taproot about five centimeters below the surface. The clumps are then flipped upside down to prevent regeneration and left to dry for about ten days before being burned. This method is far less disruptive to the soil and nearby plants and requires much less manual effort than traditional methods. During the pilot project, researchers found that a single worker could clear 20 to 50 clumps of Lantana per day, which reduced costs to between two thousand and four thousand rupees per hectare.

“The grassland management program at Bandipur addresses less than one percent of the area overrun by Lantana. Given its current resources, clearing the national park of this invasive weed would take well over a century.”

In addition to testing the CRS method for Lantana eradication, the pilot project at Jim Corbett National Park focused on restoring the land to grassland and mixed woodland. The researchers identified grass and legume species favoured by herbivores like chital and sambar, which are crucial prey for the park's tigers. They established field nurseries to grow these species, planted them across the cleared areas, and conducted follow-up activities, including manual weeding.

The pilot project was highly successful. According to the researchers, Lantana seeds that were buried under the removed clumps failed to germinate because the restored community of plants created a dense cover that competed for light and space. By August 2008, the restoration efforts had expanded to over 1,600 hectares, replacing Lantana with over 150,000 clumps of grass and more than 5,000 saplings of legumes and trees.

Rajiv Bhartari, the Field Director of Corbett National Park, during the pilot project, noted in 2019 that the restoration had significantly transformed the national park. “Laldhang spot is amazing,” he said. “There are now 500 hectares of grassland. In 2006, the park had just 108 resident tigers. Today, we have 231 resident tigers and 35 regular visiting tigers. Removing Lantana and restoring the land with grass and legumes has changed the grazing patterns of animals, with more chital and their fawns now seen on the grassland.”

Building on this success, Bhartari mentioned that plans were in place to restore another 2,000 hectares of Lantana-infested land by 2020–21, with a budget of Rs 3 crore. However, he highlighted several challenges, including the difficulty of retaining trained staff in CRS methods, and declining interest in such labour-intensive work.

"This work needs endless attention," Bhartari noted, "and maintaining that effort is difficult."

Bandipur National Park initiated a similar grassland management program in May 2019, aiming to remove weeds like Lantana from 330 hectares and replace them with grasses. By November of the same year, 16 hectares had been cleared. The project was expected to continue for three years at a cost of around Rs 30,000 per hectare.

T Balachandra, a Former Director of Bandipur, explained that the program was launched after a report by Tarsh Thekaekara in 2016, which highlighted Lantana infestation in the park. Thekaekara's field survey revealed that nearly 40 percent of Bandipur was heavily infested with Lantana, while another 50 percent showed moderate infestation.

Despite these efforts, the scale of the problem remains daunting. The grassland-management program covers less than one percent of the area affected by Lantana. According to Thekaekara's calculations, at the annual project budget of around Rs. One crore, it would take more than a century to clear Lantana from the entire national park. He also pointed out that the CRS method, successful in Corbett's grasslands, may not be as effective in Bandipur's deciduous forests, where grass doesn't grow as readily to replace the removed Lantana. As a result, ecologists have urged the forest departments of Kerala and Tamil Nadu to set aside 50 hectares in each protected area for experiments to develop a more effective method for tackling Lantana in the region.

The Real Elephant Collective works

In 2021, 150 replica elephants crafted from Lantana stalks were set to grace public parks in London. These intricate sculptures were created at The Real Elephant Collective (TREC) in Gudalur, Tamil Nadu, using materials sourced from TREC's unit in the Male Mahadeshwara Hills, Karnataka. To enhance their flexibility, the Lantana stalks were first boiled in water and then dried.

This initiative, a collaboration between TREC and the UK-based conservation organization Elephant Family, aimed to raise awareness about the shrinking habitats of Asian elephants. It actively involved local tribal communities, including the Betta Kuruba, Paniya, and Kattu Nayakar. Ranjini Janaki, a Betta Kuruba with a master's degree in zoology, supervised the work. She explained that tribal men identified real elephants to be replicated, and based on photographs and sketches, "steel rods are welded into the shape of the elephants, and then Lantana stalks are built onto the skeleton." The sculptures varied in size, with the tallest reaching eleven feet. Once completed, they were auctioned in London to fund conservation efforts.

Life-sized elephants by The Shola Trust | (Source: Shola Trust)

While completely eradicating Lantana from India's forests remains a daunting challenge, ecologists and entrepreneurs are exploring innovative ways to manage the invasive weed and mitigate its impact on biodiversity. The Ashoka Trust for Research in Ecology and the Environment (ATREE) has partnered with the Soliga community to transform Lantana into furniture, turning a destructive plant into a source of livelihood.

Siddappa Setty, an ethnobotanist overseeing the project, highlighted its success: “The idea is to create wealth from waste.” He explained that around 300 Soliga artisans from the Male Mahadeshwara Hills have been trained in Lantana crafts, with 120 currently employed. “The most remarkable aspect of this initiative,” Setty added, “is that a Soliga who once earned 7,000– 8,000 annually now makes around 35,000 a year.” He also noted that Lantana could serve as a sustainable alternative to bamboo, an ecologically valuable resource, in craft-making.

In Corbett, too, NGOs working with women living on the forest's fringes have explored using Lantana to craft furniture. In parts of the Himalayas, the plant is already being repurposed—its stems serve as toothbrushes and basket materials, while its leaves are used for polishing wood and lining grain containers to deter pests.

Lantana's toxic compounds have been extensively studied since the 1940s, revealing antimicrobial and insecticidal properties. Traditionally, the plant has been used in healing practices to treat wounds, tetanus, rheumatism, malaria, and bilious fever. Various chemical extracts from Lantana have also proven effective in controlling mosquitoes, snails, termites, and even water hyacinths—another invasive species. Research on its agricultural applications suggests that Lantana leaves, rich in nitrogen, make an excellent mulch. They improve soil fertility, enhance moisture retention, promote root growth, and boost nutrient uptake, leading to higher maize and wheat yields.

“This must not be a battle against a single species," Varghese said, emphasizing that eliminating Lantana alone does not resolve the broader issue of invasive species”

Lantana also holds significant potential as biomass, serving as a source of fuel, fertilizer, and paper pulp. In some Himalayan villages, it already accounts for about 20% of total firewood consumption. Rajpal Navalkar, technology advisor and mentor at Bioen, a Bengaluru-based company specializing in waste-to-energy solutions, highlighted Lantana's viability for biogas production. He explained that Lantana-derived biogas contains 60–70% methane, with one ton of Lantana wood generating 45 cubic meters of biogas per day. Additionally, within a month, it produces 500 kilograms of undigested material, which can be repurposed as fertilizer.

Tarsh Thekaekara, co-founder of The Real Elephant Collective (TREC), acknowledged Lantana's potential for productive use but urged caution. "There are plenty of research papers," he said, "but very little of this has been translated into action."

Varghese also emphasized a broader perspective on managing invasives. "This cannot be a battle against just one species," she noted, cautioning against the notion that eliminating Lantana would solve the larger problem of invasive species. Rather than targeting a single species, Varghese suggested it would be more practical and effective to focus on a specific landscape and work toward removing all invasive species from it.

In the Nilgiris, the Keystone Foundation, in collaboration with ATREE, is encouraging local citizens to take part in mapping invasive species using a mobile application. "Invasives are not just the responsibility of the forest department, but all of us as well," Varghese said. "We are, in a sense, responsible for this invasion by keeping these weeds in our gardens for their pretty flowers. It's time we actively participate in their management.”

Ms. Arathi Menon is an independent journalist based in Karnataka. She writes on the environment, sustainability and gender. This article was modified with the consent of the author.

Countering the Invasive Species: *Lantana camara*

Vignesh Hari Deeva R.

Independent Environmentalist and Freelance Writer
E-mail: harideevaramesh@gmail.com

Lantana Camara is a vibrant flowering plant belonging to the Verbenaceae family. Commonly known as Lantana, this plant is native to tropical regions of the Americas and is widely cultivated for its colorful blooms and robust nature. The plant has spread to numerous countries primarily due to trade or other means. With the context to India, the plant entered as a byproduct of colonialism. It has become popular in gardens worldwide, though it's also considered invasive in most region of the world.

Lantana camara is a perennial shrub that can grow up to 6 feet tall, with a similar spread. It is known for its striking clusters of small, tubular flowers that come in a variety of colors, including red, orange, yellow, pink, and white. The flowers often change color as they mature, adding an extra layer of visual interest. The leaves are rough, ovate, and emit a strong aroma when crushed. The plants have high reproductive capacity producing 12000 seeds annually.

Growing Conditions

Soil: Lantana camara thrives in well-drained soil and can tolerate poor soil conditions, making it an excellent choice for less fertile areas.

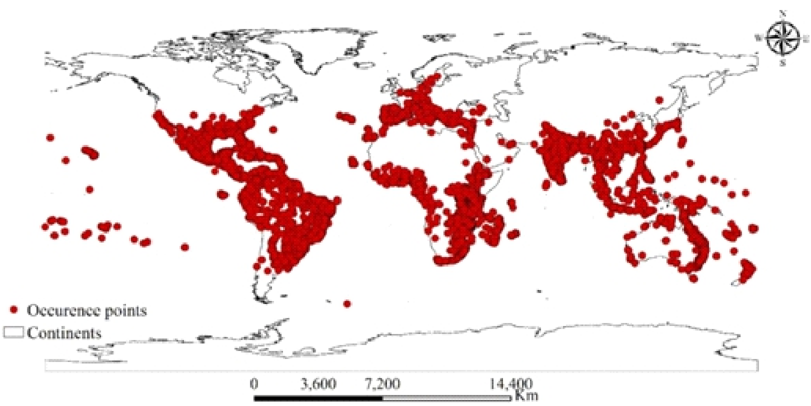
Sunlight: This plant prefers full sun but can tolerate partial shade. Adequate sunlight is essential for optimal flowering.

Watering: Lantana is drought-tolerant once established but benefits from regular watering, especially during dry spells. Overwatering can lead to root rot.

Temperature: Lantana camara enjoys warm climates and can suffer in frost. In cooler regions, it is often grown as an annual or in containers that can be moved indoors.

Table 1. Period of different phases Lantana Camera

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flowering	✓	✓	✓	✓						✓	✓	✓
Seed Formation			✓	✓	✓	✓				✓	✓	✓
Seed Drop					✓	✓				✓	✓	✓
Germination					✓	✓					✓	✓



Source: Footprints of Lantana Camara throughout the world (Adhikari et al. 2024)

Uses

Ornamental : Lantana camara is widely used as an ornamental plant due to its vibrant blooms and long flowering season. It is ideal for garden beds, borders, hanging baskets, containers and can be molded into different forms.

Wildlife Attraction : The flowers of Lantana camara are attractive to butterflies and hummingbirds, making it a popular choice for wildlife gardens.

Medicinal Properties : Traditionally used in herbal medicine for various ailments including skin issues, asthma, and ulcers. Studies have indicated antimicrobial and insecticidal properties in its extracts.

Source: Ornamental products using Lantana camara (https://www.oorjaa.in)

Downsides : *Lantana camara* has become an invasive species in many regions outside its native range, spreading rapidly across approximately 60 tropical and subtropical countries. It is particularly problematic in India, where it threatens around 40% of tiger habitats by occupying vast areas of forest. The plant's ability to adapt to different climatic conditions has allowed it to invade ecosystems where native species struggle to survive. With more numbers of plant there's an increase in pollination carried out by birds and plants paving the path to colonize the floral ecosystem. The plant is also renowned for its allelopathic properties and Hybridization.

Ecological Impacts: The invasion of *Lantana camara* poses significant threats to biodiversity. It alters ecosystem structure, competes with native flora for resources, and can lead to the degradation of natural habitats. Its rapid spread is facilitated by its reproductive traits and resilience against environmental stresses such as drought and fire.

Management strategies on countering *Lantana camara* in India:

Policies aimed at countering Lantana camara focus on integrated management strategies that encompass prevention, control, and restoration efforts. Here are the key components of these policies based on recent frameworks and guidelines:

Integrated Management Framework : India has adopted an integrated management approach to deal with Lantana camara invasion, which includes:

1. Prevention

- Implementing risk assessments to identify potential pathways for Lantana introduction and spread.
- Enhancing border controls and sanitary measures to prevent accidental introductions.
- Educating the farmers, fringe villagers and others about the risks associated with Lantana and promoting the use of native or less invasive ornamental plants.

2. Early Detection and Rapid Response

- Establishing monitoring systems to detect new infestations early.
- Forming specialized rapid response teams to quickly address new invasions.

3. Control and Management Strategies

- Employing mechanical control methods such as slashing, grubbing, and burning, although these often require follow-up treatments.
- Using chemical control methods, though this approach can be costly and may have environmental implications.
- Exploring biological control agents, including sap-sucking bugs and leaf-mining beetles, although their effectiveness has been limited.

4. Restoration Efforts

- Implementing revegetation programs with fast-growing native species after controlling Lantana infestations.
- Focusing on ecological restoration to create weed-free landscapes as part of a comprehensive management strategy.

Specific Management Techniques

1. Cut Root-Stock Method (CRS)

- This method has been implemented in various protected areas, including Corbett Tiger Reserve, Kalesar National Park, and Satpura Tiger Reserve.
- It involves cutting the main stem of Lantana close to the ground and applying herbicide to prevent regrowth.

2. Adaptive Management Approach

- Recognizing the challenges in complete eradication, policies now focus on adaptive management rather than aggressive extermination.
- This approach involves long-term studies (over ten years) conducted across various conditions to better understand and manage Lantana.

Policy Coordination and Legislation

1. Collaborative Efforts

- Enhancing coordination among government agencies, research institutions, and local communities.
- Sharing information and resources to create a unified approach to combating Lantana.

2. Regulatory Measures

- Implementing regulations to restrict the sale and use of Lantana in gardens.
- Encouraging alternative landscaping options to reduce reliance on invasive species.

Research and Monitoring

1. Long-term Studies

- Emphasizing the need for extended research to understand Lantana's behavior and impact over time.
- Focusing on habitat-oriented management and biodiversity monitoring.

2. Remote Sensing and Mapping

- Utilizing advanced technologies like GPS/GNSS and satellite imagery to monitor Lantana populations and spread.

Main challenges in implementing Lantana camara management policies in India:

Implementing management policies for Lantana camara in India faces several significant challenges. These challenges stem from ecological, economic, social, and administrative factors that complicate effective control and eradication efforts. Here are the main challenges:

1. Ecological Resilience and Adaptability

- **Invasive Nature:** Lantana camara is highly adaptable, thriving in a wide range of habitats and climatic conditions. Its ability to grow in diverse environments makes it difficult to control, as it can quickly re-establish itself after removal efforts.
- **Seed Bank Persistence:** The species has a robust seed bank that can remain viable for years, leading to rapid regeneration even after extensive removal efforts. This necessitates ongoing management rather than one-time eradication.

2. High Management Costs

- **Financial Burden:** Controlling Lantana camara is expensive, with estimates suggesting that managing one hectare costs around $200 (approximately 14 lakh per square kilometer). Given the vast areas invaded (over 13 million hectares in India), the total financial requirement for effective management far exceeds current funding levels allocated to environmental protection agencies.
- **Resource Allocation:** The financial resources required for comprehensive management often compete with other pressing environmental needs, leading to insufficient funding for Lantana control initiatives.

3. Human Resource Challenges

- **Labor Intensity:** The physical removal of Lantana often requires substantial manual labor, which can be arduous and hazardous due to the plant's thorny nature. This labor-intensive process can deter workers, especially when compensation is low.
- **Health Risks:** The health impacts of prolonged exposure to Lantana during removal efforts are not well-documented, potentially leading to reluctance among laborers to engage in such work.

4. Administrative and Policy Coordination

- **Lack of Unified Strategy:** Effective management requires coordination among various governmental departments and stakeholders. However, fragmented approaches can lead to inconsistent implementation of policies across different regions.

- **Regulatory Gaps:** While there are regulations regarding the management of invasive species, enforcement can be weak, and there may be insufficient legal frameworks to restrict the distribution of Lantana.

5. Public Awareness and Community Involvement

- Limited Awareness: There is often a lack of public awareness regarding the ecological impacts of Lantana camara. Without community engagement and understanding, local populations may inadvertently contribute to its spread through gardening or land use practices.
- Resistance from Local Communities: In some cases, local communities may rely on Lantana for certain economic activities (e.g., handicrafts), making it challenging to promote its removal without providing alternative livelihoods.

6. Long-term Commitment Required

- Need for Sustained Efforts: Effective management of Lantana requires long-term commitment and continuous monitoring. Short-term projects may not yield lasting results, leading to a cycle of repeated invasions if not managed properly.
- Adaptive Management Approach: Many studies suggest a shift from aggressive eradication to adaptive management strategies that recognize Lantana's functional role in ecosystems. This paradigm shift requires time and research investment to develop effective management practices.

NGO and startups working on *Lantana camara*

In India, a number of NGOs and startups are making strides with initiatives centred around Lantana camara, emphasizing management, restoration, and the promotion of sustainable livelihoods. Featured below are several prominent organizations along with their significant contributions: **ATREE**, the Ashoka Trust for Research in Ecology and Environment: The Lantana Craft Initiative exemplifies ATREE's innovative strategy by establishing Lantana Craft Centres (LCCs), which promote the use of Lantana as a primary resource for artisanal production.

Junglescapes Charitable Trust - Lantana Management Project: This initiative focusses on the Bandipur Tiger Reserve, where efforts are made to manage Lantana while simultaneously restoring the ecosystem and providing alternative livelihoods for local communities. This initiative utilizes techniques like the Cut Root-stock method to efficiently eliminate Lantana, all while safeguarding the survival of indigenous species in the region.

Wildlife Trust of India (WTI) WTI is dedicated to tackling the challenges posed by invasive species through a range of conservation initiatives. Strategies involve the careful monitoring and management of invasive species such as Lantana camara within protected areas, aiming to safeguard biodiversity.

TAMS Tribal Green Fuels Pvt. Ltd : This is a tribal community-led enterprise, which is at the forefront of transforming Lantana camara, an invasive species, into eco-friendly briquettes. These briquettes serve as a sustainable alternative to coal and firewood, promoting forest restoration and creating livelihood opportunities for tribal communities. This innovative initiative is supported by StartupTN under their SC/ST program, demonstrating the power of inclusive and sustainable enterprise.

Green India Initiative : The goal of this initiative is to rejuvenate ecosystems that have been compromised by invasive species, such as Lantana camara. This initiative champions the restoration of forests through afforestation and reforestation, focusing on the importance of native species and the careful management of invasive plants.

Innovative Ventures Centered on Eco-Friendly Offerings : A number of innovative startups are now harnessing Lantana to produce sustainable products, including furniture and crafts. These initiatives not only assist in controlling Lantana populations but also create sustainable income opportunities for artisans.

Obstacles confronted by non-profit organizations and emerging businesses

While these organizations are making strides in managing Lantana camara, they encounter a number of obstacles encompassing financial constraints and poor community involvement. Numerous NGOs and startups in India are diligently pursuing creative strategies to address the challenges posed by Lantana camara, focusing on community involvement, sustainable product innovation, and efforts to restore ecosystems. Their efforts are designed to tackle this invasive species while simultaneously boosting local economies and fostering the preservation of biodiversity.

Remarks

The management of Lantana camara in India poses a multifaceted problem owing to its invasive characteristics and considerable ecological consequences. Nevertheless, with the implementation of many control strategies, including mechanical removal, chemical treatments, and biological control, total eradication continues to be unattainable. The expenses related to extensive management initiatives are considerable, encompassing initial removal charges, continuous monitoring, and restoration operations.

Effective policies necessitate a comprehensive strategy that incorporates prevention, early detection, prompt response, and community involvement. The engagement of local communities and stakeholders is essential for sustainable management techniques and increasing knowledge of the ecological impacts of Lantana invasion. Furthermore, NGOs and entrepreneurs are crucial in devising novel ways that use Lantana biomass for economic advantages while concurrently curtailing its proliferation.

Nonetheless, considerable challenges remain, such as financial constraints, the necessity for sustained dedication to management measures, and the ecological resilience of Lantana itself. Coordinated efforts among government agencies, scholars, and local communities are urgently required to create comprehensive frameworks that effectively tackle these difficulties.

In summary, although the management of Lantana camara presents challenges, a cooperative strategy integrating scientific research, community engagement, and sustainable practices provides the most effective means of alleviating its effects on India's biodiversity and ecosystems. Augmenting investment in adaptive management measures will be essential for mitigating this invasive species and rehabilitating impacted habitats.

Source: Lantana Briquette initiative supported by StartupTN, by TAMS Tribal Green Fuels Pvt. Ltd.,

References: Contact author at harideevaramesh@gmail.com

Untapped Potential of *Lantana camara*: A Ligno-Cellulosic Resource

Ramkumar V. R.
ICFRE - Institute of Wood Science and Technology
Malleshwaram, Bengaluru
Email ID : vrramkumar@icfre.org

Lantana camara, one of the world's ten most invasive species, was originally cultivated as an ornamental plant but has since spread uncontrollably across fallow lands and agricultural areas, threatening approximately 44% of India's forests. Its aggressive invasion disrupts ecosystems through allelopathy, which inhibits the growth of surrounding vegetation, and its toxicity poses risks to grazing ruminants. Additionally, it significantly increases the risk of forest fires due to its highly flammable biomass, particularly when dried.

Despite numerous control measures—mechanical, chemical, and biological—these efforts have been largely ineffective, with management costs reaching approximately $18,000 per square kilometer. Given these challenges, recent research has explored the potential of L. camara as a ligno-cellulosic resource for composite manufacturing. This approach not only addresses the growing demand for ligno-cellulosic materials in the construction and automobile industries but also provides a sustainable solution for managing this invasive species.

Demand and Necessity

The increasing demand for timber has been a major driver of deforestation, leading to severe environmental consequences, including global warming and biodiversity loss. The rapid production of panel products and composites has exacerbated unregulated tree felling, necessitating alternative wood and wood-based bio-resources. However, the demand for wood-based products still exceeds supply, driving continuous deforestation without adequate replacement.

The necessity to reduce reliance on timber has revived interest in alternative raw materials, such as agricultural residues, processing wastes, and other non-wood bio-resources. These alternatives not only support a circular economy and waste management but also promote environmental sustainability, biodiversity conservation, and cost reduction for industries seeking new material sources.

Various value-added products have been developed using alternative bio-resources, including wood chips, sawmill shavings, bamboo waste, rice and wheat straws, rice husks, palm kernel fiber, kenaf particles, olive stone, and other ligno-cellulosic materials bound with suitable binders under heat and pressure. The adoption of such alternatives can significantly reduce dependence on traditional timber sources and encourage the industrial use of diverse bio-resources in composite manufacturing.

Invasive Species: Lantana camara

(Source: https://www.istockphoto.com/photos/lantana)

Ecological Impact

Biologists, ecologists, and conservationists advocate for adaptive management of invasive species rather than eradication. L. camara, native to the American tropics and subtropics, has become one of the most invasive weeds worldwide, spreading across 50 countries with varying species estimates ranging from 50 to 270. The plant's ability to hybridize, change flower color with age, and adapt morphologically has made its classification unstable. Today, it has invaded over 20 million hectares globally, and its spread continues at an alarming rate.

Spread in India

Introduced in the early 19th century as a decorative garden and hedge plant in Kolkata, L. camara has naturalized across India, thriving along roadsides, railway tracks, agricultural lands, and forests. Seven species have been recorded in India, with L. camara var. aculeata being the most common. The species' adaptability allows it to flourish in diverse environments, including tropical, subtropical, and even temperate zones, covering approximately 13.2 million hectares.

Efforts to control L. camara's spread have included biological, mechanical, chemical, and cultural strategies, but its rapid regeneration has outpaced these methods. Various studies report biomass productivity rates of 10–60 tons per hectare per year, depending on geographic conditions. Despite eradication efforts, disturbances such as mild fire, cutting, trimming, and grazing often accelerate its spread rather than suppress it.

Environmental and Socioeconomic Impact

L. camara negatively impacts native ecosystems by altering biodiversity, depleting soil nutrients, and reducing ecosystem services such as provisioning, regulating, and cultural benefits. However, some positive socioeconomic impacts have been documented. Several Indian research institutions, state forest departments, and NGOs, including ATREE and the Shola Trust, have explored the species' potential for community-based livelihood projects. Figure. 1 illustrates few impacts

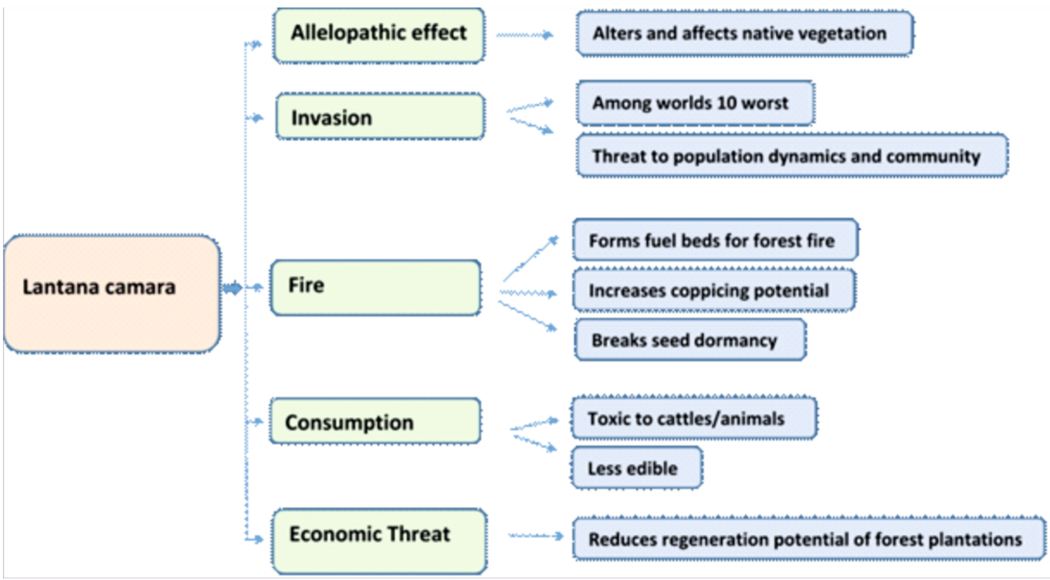


Fig.1 Various Impacts of Lantana camara (Gillela et al 2024)

Regardless of all management efforts to eradicate or control lantana, spreading continues and also substantial manpower and resources needed for policy makers even till date. Furthermore, Lantana continues the upward trajectory of spread and invasion across countries and the outburst could be tremendous in near future based on all these records and reports (Girish et al 2019).

"Regardless of all management efforts to eradicate or control lantana, spreading continues and also substantial manpower and resources needed for policy makers even till date. Furthermore, Lantana continues the upward trajectory of spread and invasion across countries and the outburst could be tremendous in the near future based on all these records and reports"

Adaptive Management: A Sustainable Strategy

Given the scale of L. camara's invasion, there has been a strategic shift from eradication to adaptive management. This approach acknowledges the ecological and socioeconomic benefits of L. camara while finding productive ways to utilize it. Researchers have explored its applications in herbal medicine, biomass fertilizers, biofuels, pulp and paper industries, fiber production, roofing materials, handicrafts, essential oils, mosquito repellents, and more.

"Adaptive management, an iterative and continuous process of learning and responding to environmental evolutions with accepting the dynamics, uncertainty and change over time"

Community-Based Utilization

L. camara has been integrated into livelihood programs in India, particularly among tribal communities such as the Soligas and artisans near Mudumalai Tiger Reserve. With the support of organizations like ATREE and the WELFARE initiative, communities have repurposed L. camara into baskets, furniture, and household utilities, providing an alternative to bamboo and rattan. At a larger scale, industrial applications remain underexplored. While pilot studies have assessed its use in furniture, particle/fiber production, essential oils, ethanol, pulp, paper, and charcoal, only few have yet reached commercial viability. Identifying its effective utilization on an industrial scale could unlock economic opportunities and further control its spread. This article presents the basic characteristics (anatomical and chemical) of L. camara which is fundamental in understanding the material and explore the utilization potential.

Anatomical and Chemical Composition

L. camara's wood anatomy reveals strong potential for industrial applications as shown in fig 2. The fibers and vessels present favorable structural properties comparable to widely used timber species such as Melia dubia and eucalyptus. Additionally, its chemical composition includes high cellulose (65–66%), lignin (25–26%), and holocellulose (65–66%), making it a viable alternative for pulp, fiberboard, and composite production as discussed

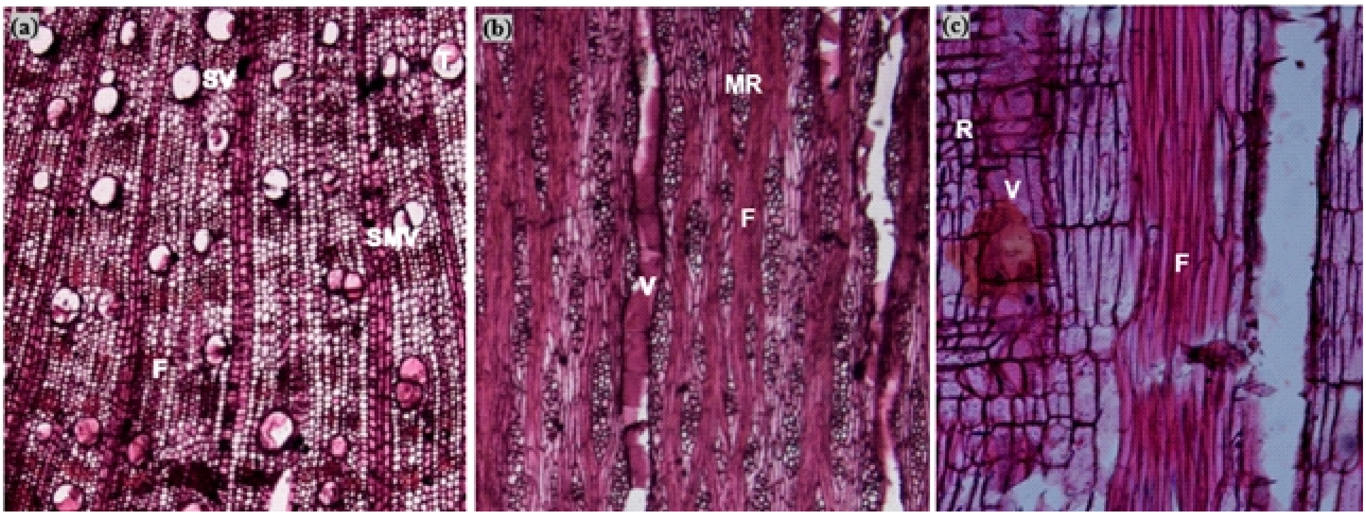


Fig 2. Wood microscopic structure of LC (a) cross-section shows radial multiple vessels (RV) and solitary vessel (SV) (b) tangential sections showing multiseriate ray (MSR) and (c) radial section shows ray vessel pit (RVP). (Source: Ramkumar et al 2024)

Structure of Lantana fibers/particles

Fibers are present in the interior part of lantana stalks and are organized in bundles of individual cells. They consist of a middle lamella and primary and secondary cell walls, formed around an opening, the cell cavity. The middle lamella, located on the outside of the cell, consists mainly of pectin (macromolecules of galacturonic acid), which holds the fibers together in a bundle. Next to the middle lamella is the cell's primary wall, which consists of a disorganized arrangement of cellulose (polymers based on glucose), fibrils in an organic matrix of hemicelluloses, lignin, and proteins. The secondary cell wall consists of three layers of cellulose fibrils with different axial orientation, interconnected by lignin and a very small amount of pectin. They present a complex structure made of polymeric cellulose chains aligned and concentrated in microfibers, which are linked together by lignin, pectin, and hemicelluloses. These substances are mainly composed of sugars (i.e., glucose, rhamnose, galacturonic acid, etc.). The fibers have the same components but in a different composition. This makes them behave differently. The amount of components depends on geographical and climatic conditions. A graphical representation of the structure and morphology of lantana stalks has been given as shown in Fig 3,4 and 5 (Source: Pereira et al. 2015 and Siouta et al 2024).

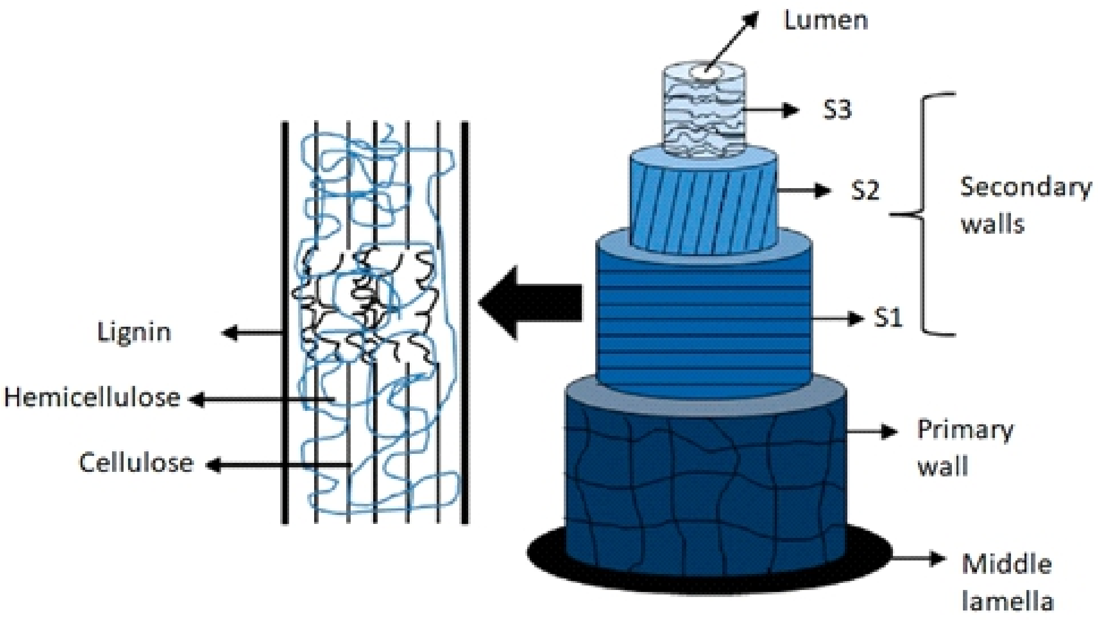


Fig 3. Structure of natural fibres (Source: Pereira et al 2015; Siouta et al 2024)

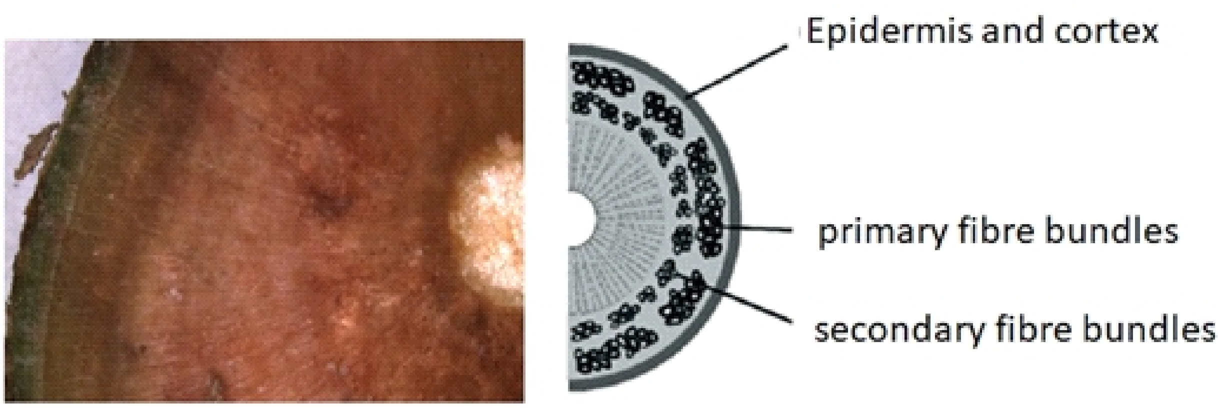


Fig 4. Structure of lantana stems. (a) Cross-section of stems

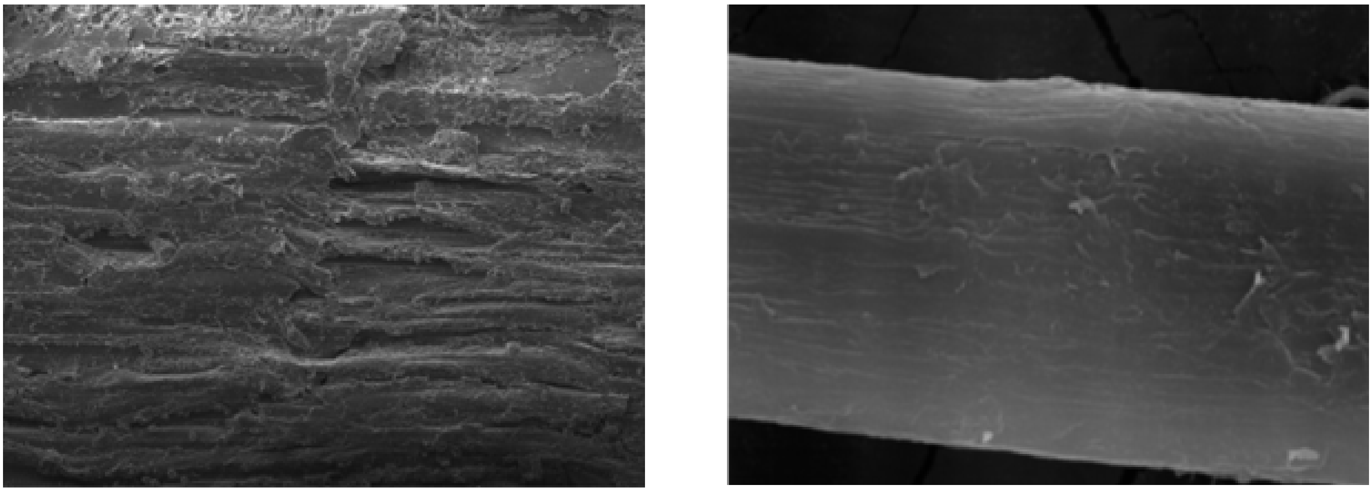


Fig 5. Microstructure of lantana particles and Lantana fibers

Table 1. Chemical composition of LC reported by few researchers

Bioresource	Cellulose, (%)	Hemicellulose, (%)	Lignin (%)	Holocellulose (%)	References
LC	-	66.5 ± 4.1	25 ± 1.0	65± 1.1	Soni et al 2006
LC	-	65 ± 1.1	26 ± 1.0	65.89–66.30	Sharma et al 2010
LC	-	-	25.0	66.5	Ramkumar et al 2024
Eq	40-50	15-20	25-30		Vieira et al 2021
Melia dubia	40- 50	25-30	20-25		Sinha et al 2019
Sisal	66	11	10	-	Gillela et al 2024
Banana	63	11	7.5	-	Gillela et al 2024
Flax	71	18.6	2.2	-	Gillela et al 2024
Hemp	74	22	5	-	Gillela et al 2024

Composite Manufacturing

With increasing environmental concerns, industries are turning to natural fiber-based composites as sustainable alternatives to synthetic materials. L. camara, with its ligno-cellulosic properties, presents a valuable resource for composite manufacturing in sectors such as construction, automotive, and packaging as listed in fig 6.

Potential Applications

- Fiber-Reinforced Polymer Composites: Lightweight structural materials with improved strength and biodegradability.
- Resin-Based Bio-Composites: Used in furniture, packaging, and insulation panels.
- Particleboard Composites: Developed using L. camara particles and adhesives like urea-formaldehyde or phenol-formaldehyde.
- Fiber-Cement Composites: Applied in building materials, enhancing strength and durability.
- Biodegradable Composites: Combined with biodegradable polymers for eco-friendly packaging.
- Hybrid Fiber Composites: Blended with jute, coir, or hemp for enhanced flexibility and toughness in automotive and aerospace applications.

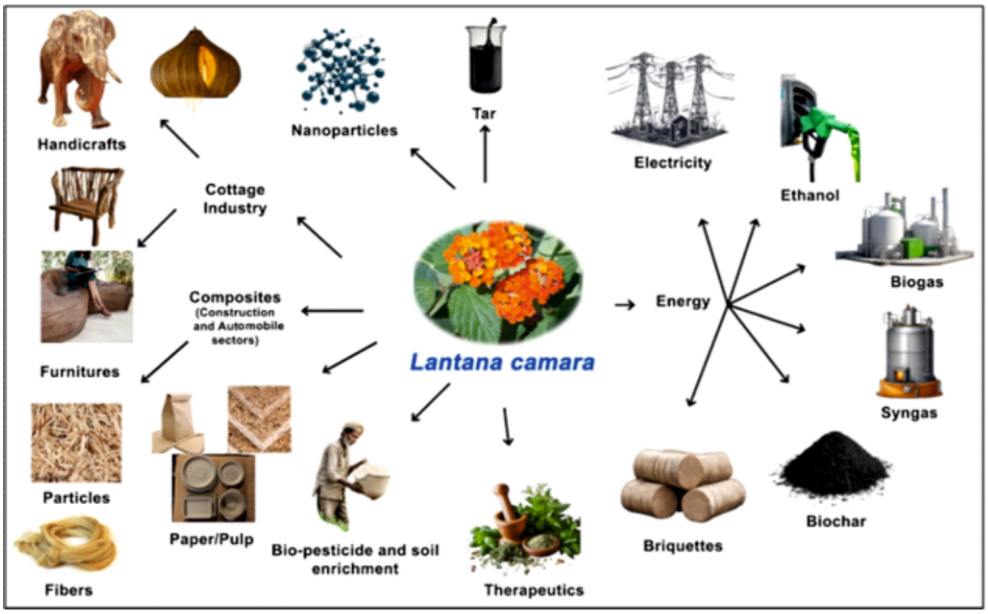


Fig 6. Potential ecological, commercial utilization of Lantana bio-resource
(Modified image: Gillela et al 2024)

Potential resource

The conversion of *L. camara* from an ecological nuisance into a valuable bio-resource aligns with global sustainability goals. By integrating its use into composite manufacturing, industries can reduce reliance on traditional wood sources, mitigate deforestation, and promote circular economy principles. Further research and industrial-scale applications could provide economic incentives for its large-scale utilization, effectively transforming a growing environmental problem into a sustainable material solution.

References: Contact author at vrramkumar@icfre.org

Bioenergy from *Lantana camara*: Invasive Forest Weed

Ritesh Kumar D.Ram

ICFRE-Institute of Wood Science and Technology, Bangalore – 560 003, India
Email: ritesh@icfre.org

The energy derived from biomass is termed as bioenergy. It is a renewable energy source which is locally available and cost-effective. The declining fossil fuel reserves and the increased environmental concerns have necessitated the demand for heat and energy from cleaner sources such as biomass. The term biomass is referred to all organic materials that originates from green plants as a result of photosynthesis. The plants through the process of photosynthesis convert solar energy into chemical energy, which can be released when the chemical bonds between adjacent oxygen, carbon, and hydrogen molecules are broken by various biological and thermo-chemical processes. Coal, oil, and natural gas are examples of fossil fuels that were derived from "ancient" biomass that underwent metamorphic geological changes and microbial anaerobic breakdown over millions of years.

Worldwide a large quantity of agriculture and forestry waste is generated that as an energy source has huge potential. India generates a large amount of biomass waste from agriculture, forestry, and industry. For example, presently, India produces about 990 MMT of agricultural biomass annually, which is the second highest after China, and this waste can be used to create energy, heat, and transportation fuel. Researchers have characterised various types of biomass in different ways such as woody biomass, non-woody biomass such as herbs, aquatic biomass waste and manure. Each type contains a different amount of cellulose, hemicellulose, lignin and a small amount of other extractives.

Fuel properties of L. camara: Depending upon the amount of moisture content the type of energy conversion method is selected. Thermochemical energy conversion way such as pyrolysis, gasification, etc., is commonly used for transforming biomass into fuels of higher heating value. Lantana camara produces woody biomass. The stem portion of lantana is typically characterised by tightly bound fibres, giving a hard external surface, indicating a higher proportion of lignin, which binds cellulosic fibres together. In order to convert biomass into different forms of energy, it is important to do chemical characterization and fuel properties analysis. One of the criteria used to determine the suitability of a plant species for further processing as an energy crop is to know the relative amounts of cellulose and lignin. Table 1 shows the physical, chemical and fuel characteristics of lantana biomass [1]. Another significant element affecting the heating value is moisture. A thorough investigation of L. camara biomass heating value, basic density, proximate analysis (ash, volatile matter, and fixed carbon), and ultimate parameters (carbon, hydrogen, nitrogen, and sulphur) was conducted [1]. The results were compared with fuelwood properties of samples taken from hybrid Eucalyptus trees [1].

One of the crucial factors that directly influence a feedstock's fuel quality is density. Because of their slow-burning characteristics and high energy content per unit volume, species with higher densities are selected as fuel. Table 1 summarizes the fundamental density (g/cm^3) results. L. camara biomass has a basic density ranging from 0.497 to 0.520 g/cm^3 [1]. Compared to the weed species, the Eucalyptus wood basic density was reported to be substantially higher, at about 0.730 g/cm^3 [1]. Any fuel's capacity to produce heat is determined by the quantitative conversion of its hydrogen and carbon to carbon dioxide and water, which is a function of the fuel's chemical makeup. Carbon-carbon bonds have more energy than carbon-oxygen and carbon-hydrogen bonds in any fuel. A higher percentage of hydrogen and oxygen in biomass lowers the fuel's energy value.

Table 1 : Physico-chemical properties and fuel characteristics of Lantana camara biomass which is compared with the properties of Eucalyptus spp

Biomass feedstock	Ultimate analysis					Proximate analysis				BD (g/cm^3)	HHV (MJ/kg)	Holocellulose (% oven dry weight)	Lignin (% oven dry weight)
	C (%)	H (%)	N (%)	S (%)	O* (%)	MC (%)	Ash (%)	VMC (%)	FCC (%)				
Lantana (Stem)	48.1	6.2	1.0	0.13	43.7	7.0	0.9	74.4	17.7	0.52	19.6	81.5	20.1
Lantana (Twig)	45.9	6.9	1.1	0.14	44.7	7.8	1.3	73.5	17.4	0.50	19.5	ND	ND
Lantana (Leaves)	43.0	5.7	1.1	0.14	42.6	7.5	7.6	67.5	17.5	ND	17.2	ND	ND
Eucalyptus spp	48.3	5.9	0.1	0.14	45.5	1.5	0.4	77.6	20.5	0.73	19.1	70.1	28.3

HHV-higher heating value, MC-moisture content, VMC-volatile matter content, FCC-fixed carbon content, BD-basic density; ND-not determined, * Calculated by difference method, ** Table 1 is taken from our earlier published work in Ref 1.

Lantana stem (20-40mm)

Lantana twigs

Lantana leaves

According to Table 1, the lantana stem, twigs, and leaves had corresponding heating values of 19.6, 19.5, and 17.2 MJ kg-1. Lantana leaves have a lower heating value because of their increased ash content. The lantana stem's heating value (19.6 MJ kg-1) was comparable to that of the E. hybrid. The main biochemical components such as cellulose, hemicellulose, lignin, and extractives, also affect the heating value of a fuel [3]. The proximate and ultimate analysis of E. hybrid and L. camara is summarized in Table 1. One crucial factor that has a direct impact on fuel quality is ash. A biomass is deemed a superior feedstock if it has a higher density and lower levels of ash and moisture. According to Table 1, the ash percentage reported for lantana stems, twigs, and leaves was 0.9%, 1.34%, and 7.55%, respectively [1]. Compared to the weed species, the ash percentage in the wood biomass of E. hybrid was reported as 0.43% [1]. A perusal of the Table 1 [1] also indicates that, the values of volatile matter and the fixed carbon do not vary much between the stem and twigs of L. camara. The values of volatile matter were found to be 73.5% and 74.4% in twigs and stems of lantana, respectively [1]. The amount of lignin and holocellulose reported in L. camara stem biomass was around 20% and 81%, respectively [1] Table 1.

L. camara charcoal:

To investigate the use of biochar in the manufacturing of steel, the Indian government established a task team. This is to lower the steel industry's carbon emissions. According to a steel ministry document, the 14th task force was established to support the use of biochar in the domestic steel industry's carbon reduction efforts. Since biochar has also been identified as an important lever for the reduction of carbon emissions in the steel industry, the 14th Task Force on 'Use of Biochar and Other Relevant Products in Steel Making' was constituted on December 5, 2023," said the ministry. Continuing the initiative taken by the Government of India, Tata Steel has effectively led the way in the use of biochar at its Jamshedpur facility. This action brings the steel manufacturer one step closer to its 2045 Net Zero goal and reaffirms the company's dedication to sustainability. The company started using biochar as a trial in January 2023 and has since replaced over 30,000 tonnes of fossil fuel with it. More than 50,000 tonnes of carbon dioxide emissions might be cut yearly using this strategy. By partially substituting pulverized coal injection, it also increases energy efficiency, demonstrating Tata Steel's commitment to sustainable industrial practices and environmental responsibility. A major worldwide achievement is also represented by the successful utilization in blast furnaces that produce more than 3000 m^3 and 9000 tons per day (tpd).

Given the massive amount of biomass that L. camara produces, it was investigated as a feedstock for the creation of biochar. Ritesh et al. (2013) pyrolyzed the stem biomass of L. camara at various carbonization temperatures, namely 300, 400, 500, 600, 700, and 800oC [4]. It was examined how the temperature at which carbonization occurs affects the yield and energy value of charcoal. Charcoal's fuel qualities, including its ash concentration, volatile content, fixed carbon content, and calorific value, were examined. It was observed that the yield of charcoal decreased from 40% to 25% when the carbonization temperature was increased from 300C to 800C. A marginal increase in calorific values was observed with an increase in carbonization temperature up to 600 0C (32.0 MJ/kg). This can be attributed gradual increase in fixed carbon content (FCC) and reduction in volatile matter content (VMC) of charcoal with temperatures. The FCC rose from 57% to 84% when the carbonization temperature was elevated from 300°C to 800°C. Additionally, the ash content (AC) rose from 2.7% to 4.6%. However, the VMC dropped from 40 to 11%, when the temperature was raised from 300°C to 800°C [4]. The charcoal produced from L. camara was compared with the charcoal prepared from other wood species such as Acacia nilotica and Eucalyptus globulus under similar experimental conditions. The quality of charcoal produced from L. camara was found to be as good as from other species in terms of energy value, ash content and yield [4].

Lantana camara stem biomass

Charcoal

Lantana camara fuel briquettes:

The demand for energy has skyrocketed in recent decades due to rapid industrialization, population growth, and shifting lifestyles. Although fossil fuels have been a major contributor to the social and economic advancement of the world for many years, the increasing demand for energy worldwide cannot be sustained indefinitely by these non-renewable energy sources. Furthermore, the economy and environment are seriously impacted by dependency on these fossil fuels, which are mostly imported. Therefore, attempts are being made to look for some alternative energy sources that may be locally accessible, reasonably priced, and environmentally friendly all at the same time. In this regard, researchers and policymakers have been interested in biomass as an energy feedstock, and government policies have required the cofiring of coal and biomass. Coal and biomass co-combustion offers a number of benefits. It is thought to be the most effective strategy for reducing the use of fossil fuels like coal in order to satisfy the rising demand for energy. In addition, the addition of biomass fuel to coal promotes improved combustion reaction performance.

The biomass feedstocks have a higher volatile matter content (often over 50%) than coal, which is thought to generate a steady flame during combustion. According to the updated government regulation, all thermal power plants must now co-fire 5% biomass in addition to coal. The Ministry of Power and New & Renewable Energy claims that this requirement will rise by up to 7% from the previous fiscal year. The woodland plant Lantana camara is referred to as an invasive weed in several nations around the world.

Table 2: Technical specification for biomass briquettes/pellets for thermal power plants

Sl.no	Parameter Pellets/ briquettes	Value
1	Gross calorific value (non-torrefied)	>14.2 MJ/kg
2	Gross calorific value from torrefied biomass	16 to 18 MJ/kg
3	Ash content	< 10%
4	Fixed carbon content	15-20%
5	Volatile matter content	60 to 65%
6	Moisture content	< 14%
7	Fines (length less than 3mm)	< 5%

L. camara plants are very competitive. It moves swiftly over open terrain. It seriously harms the local biodiversity and environment. Although this species is ecologically adaptable, the density of infestation is acknowledged as a potential hazard to ecosystems in the future, more so than its extensive range. In India, a number of control methods are used to reduce its infestation. Briquetting of biomass presents a possible avenue for a large scale and sustainable utilization biomass resources for energy production. The technical specification designed with the intent to cover the various relevant aspects and requirements of agro residue based biomass pellets (non- torrefied/ torrefied) to be supplied to a coal based thermal power plant for co- firing in the boilers along with coal (Table 2).

Fig 1. Briquette making machine and biomass fuel briquettes

Kumar et al., (2020) has systematically studied and optimized the processing parameters for producing briquetting of lantana biomass. They reported a high calorific value (19.5 MJ/kg); high energy density (23.05 GJ m^{-3}) and a high density (1.2 g cm^{-3}) in L. camara fuel briquettes. The briquettes were made without any binder and for proper densification, the L. camara should have an ideal moisture content of 10–12%. Briquettes made from L. camara have a lower ash level (2%), which improves their quality. L. camara (47%) have an additional benefit due to the high CaO content of their ash. Higher CaO content increases the ash melting and fusing temperature in the furnace. The briquettes produced passes the technical specification required for its use in boilers and thermal power plants.

Conclusion:

If we are to make the necessary changes to address the effects of global warming, the usage of renewable energy sources is becoming more and more important. Around the world, biomass is the most widely used renewable energy source. Finding appropriate biomass species that can produce high energy outputs to replace traditional fossil fuel energy sources has received a lot of attention lately. In this lines, the L. camara is one such biomass which has a woody stem, has less moisture content and high calorific value. These properties of lantana makes it an appropriate biomass for energy conversion through thermochemical conversion process such as charcoal, gasification and liquid fuel. The lantana has high lignin content which make it a suitable species for binder less pellets and briquetting process. It can be a suitable species for even direct combustion in thermal power plants and boilers because of high calorific value, high fixed carbon content and less ash content.

References: Contact author at ritesh@icfre.org

Lantana camara - A Potential Raw Material for Wood - Thermoplastic Composites

Shakti Singh Chauhan
ICFRE-Institute of Wood Science and Technology, Bengaluru
E mail : shakti@icfre.org

Wood thermoplastic composites generically known as wood polymer composites (WPC) have already established their niche in India. Quite a few industrial units and start-ups have embarked on the production of WPC products. The composite material provides an opportunity to utilize woody residues (saw-dust, chips, etc.) generated by wood-based industry, bamboo dust from bamboo processing units and agro-residues (like rice husk, coffee husk, etc.) for high-value products supporting the waste-to-wealth concept. At the same time, the idea behind WPC is to recycle thermoplastic polymers (plastics) like polypropylene, low-density polyethylene and high-density polyethene which are used in large quantities and pose a significant challenge in their disposal. One of the major focuses in the industrial production of WPC is on expanding the choice of raw materials.

Lantana camara has become a dominant weed in forest areas, fallow land and even in agricultural fields and is becoming a major cause of concern affecting biodiversity and wildlife in forest areas and crop productivity in agricultural lands. Significant attention is being paid by government agencies, NGOs and others to eradicating the lantana menace from the affected areas. The economic utilization of such bioresources could be one of the strategies to support the eradication programmes. There have been many efforts in utilizing lantana stems for furniture, composites, pulp, energy, etc. Wood polymer composites provide the opportunity to utilize lantana stems for a range of applications. The thin stems of the species can be ideal raw material for preprocessing line chipping and pulverization which is required for the preparation of WPC. The stem is also known to possess high strength and stiffness which is expected to provide a superior reinforcement effect as compared to other fibers like rice husk, coffee husk, etc.

This article provides the method of preparing WPC using lantana stems and polypropylene as the polymer. The physical and mechanical properties of lantana fiber-reinforced composites were evaluated. The prepared composites have also been used to develop injection moulded and profile extruded final products for demonstration of the feasibility of the technology. Other polymers like HDPE and LDPE can also be used as the base polymer depending on the product and properties required.

Process of manufacturing lantana–polymer composites:

Lantana camara stems are collected from the affected areas and are chipped. The chipping can be carried out in the field using a mobile chipper to reduce the logistic costs. The chipped lantana is pulverised into flour using a pulverizer with hammer mill action. A laboratory scale chipper and pulverized are shown in Fig.1. The flour can be sieved using a gyrator screen to get fibers of different mesh sizes (BSS mesh sizes: -60+80; -80+100, -100) if required for a specific product (Fig.2). The pulverized flour becomes the reinforcing material in the composite.

Fig. 1: Chipper and pulverizer for the primary processing of lantana stems

Fig. 2: Lantana chips and pulverized flour

The pulverized flour is dried in an oven to a moisture content below 5% for compounding with the polymers. The composites are prepared by the extrusion process using a twin-screw extruder (Fig. 3). The known quantity of pulverized flour, polymer, coupling agent (2-5% of fibers), lubricants (1-2%) and antioxidants (0.5- 1%) are mixed in a high-speed mixture. Additionally, additives like UV stabilizers, colouring agents, fungicides, and fire-retardant can be added during the mixing depending on the application. The mixture is then extruded in the form of thin strands, cooled and palletized. The strands and pallets are shown in Fig. 3.

Fig.3: Lantana-polypropylene composite strands (left) and pallets (right)

The pallets are dried in an oven to remove any moisture. The dried pallets can either be injection moulded (Fig.4) or profile extruded (Fig. 5). For injection moulding, lantana content in the composites would be less than 50% whereas for extruded products it can be as high as 75%.

Fig 4: Injection moulding of Lantana-PP composites

Fig. 5: Profile extrusion of Lantana-PE composites

Properties of the composites:

At IWST, research has been carried out on the effect of fiber content, the effect of polymer type and the effect of coupling agents on the properties of composites. Understanding the properties of such composites is essential to ascertain the suitability of the composites for a specific product. Density, tensile strength, flexural strength, flexural modulus, notched and unnotched impact strength, melt flow index (MFI) are some of the major properties of WPCs. In one of the studies, the mechanical properties of lantana-PP composites have been compared with composites prepared using other fibers. In this study, composites were prepared with 40% fiber content, PP (H110MA) as the base polymer and maleic anhydride grafted PP as the coupling agent. Table 1 describes the strength parameters of such composites.

Table 1: Mechanical properties of Lantana-PP, Rubberwood –PP, Bamboo-PP composites along with pure PP

Reinforcing material	Tensile Strength (N/mm^2)	Tensile Modulus (GPa)	Flexural Strength (N/mm^2)	Impact Strength (J/m)
Lantana	**48.32**	**3.92**	**54.90**	**168.04**
Bamboo	45.00	5.20	54.86	124.00
Rubber wood	40.87	4.29	60.26	144.78
Pure PP	33.00	1.40	36.00	600.00

The tensile strength of Lantana fiber PP composite is 45% higher than pure PP and also is comparable with the tensile strength of Wood and Bamboo filled PP composites at the same fiber loading. This effect is due to the reinforcement of lantana fibers in PP. Flexural strength exhibited a 52% improvement over virgin PP. The tensile modulus of lantana-filled composites was 2.8 times that of pure PP but it was lower than bamboo and wood-filled composites. The impact strength of lantana-filled PP composites was better than wood and bamboo-filled composites at the same fiber loadings. The desirable mechanical properties suggest the suitability of lantana as a reinforcing agent for thermoplastic composites.

The effect of lantana content on the tensile strength, flexural strength, tensile and flexural modulus and unnotched and notched impact strength of the composites is shown in figures 6-11. Tensile strength, flexural strength, tensile modulus, flexural modulus and impact strength of virgin PP (H200 MG) are 37.70 MPa, 38.83 MPa, 1.48 GPa, 1.37 GPa and 321 J/m, respectively. It is evident that both the tensile and flexural strengths of the composites declined in the case of control samples (without coupling agent) with increasing filler content. Tensile strength decreased from 37.79 MPa to 27.8 MPa when filler content increased from 10% to 50%. With the MAPP coupling agent, the tensile and flexural strengths increased slightly with increasing lantana content. The increase in strength in MAPP-coupled composites indicates good interfacial adhesion between lantana fiber and PP. In the case of control samples, lantana flour acts only as a filler rather than a reinforcing fiber.

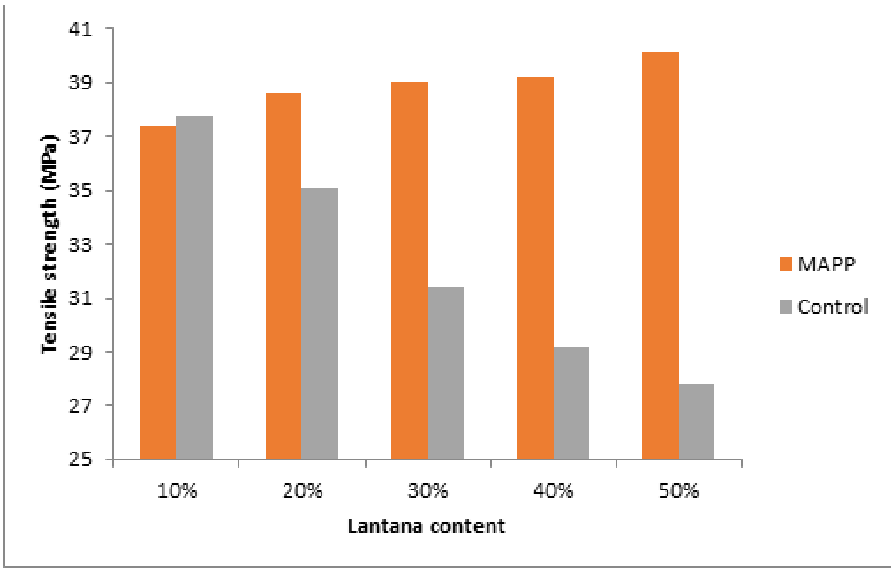


Fig. 6: Tensile strength of Lantana-PP composites at varying Lantana content

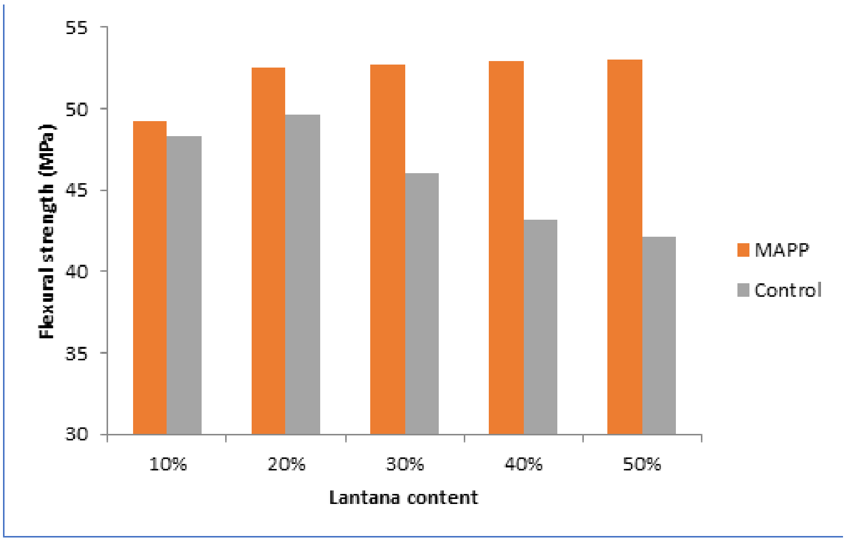


Fig. 7: Flexural strength of Lantana-PP composites at varying Lantana content

Tensile and flexural modulus (Figs 8 and 9) increased with increasing filler content in all three cases. However, MAPP-coupled composites exhibited a superior modulus of elasticity as compared to composites without coupling agents. The modulus values were 2.5 to 3 times higher at 50% lantana content compared to the virgin polymer. The results are in agreement with the observed on other lingo-cellulosic fibers. The increase in modulus of elasticity composites with the increase in lantana content is mainly attributed to the higher modulus of elasticity of lantana fibers compared to polymer and the modulus is governed by the Rule of Mixtures. Higher modulus of elasticity with increased fiber content implies that the product thickness can be reduced to get the desired performance as compared to the product made from pure polymer. This can lead to substantial savings in the material.

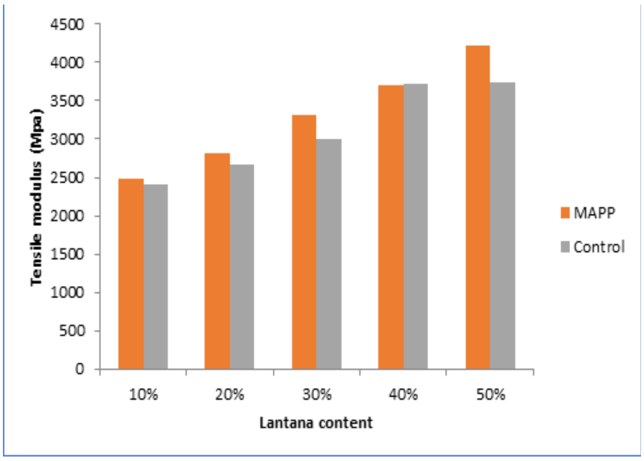


Fig. 8: Tensile modulus of Lantana - PP composites at varying Lantana content

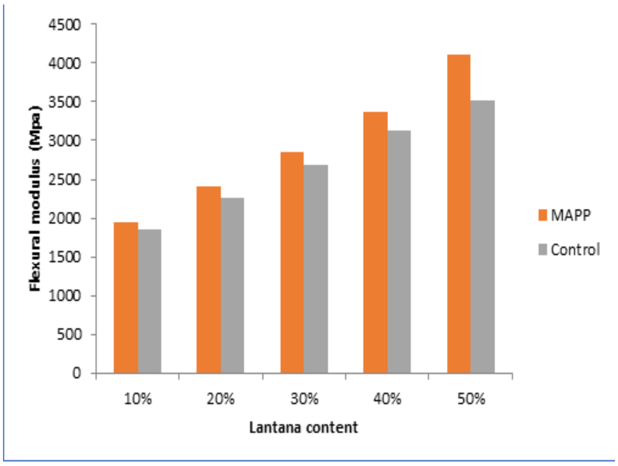


Fig. 9: Flexural modulus of Lantana - PP composites at varying Lantana content

Un-notched impact strength in filled composites generally decreases with increasing filler content. Similar results were obtained in this case also. There was no significant difference in the impact strength of composites with and without coupling agents at all filler levels. The impact strength of virgin polymer is 321 J/m which decreased sharply to about 200 /m at 10% filler. At 50% lantana loading, the impact of the strength was about 100 J/m. The notched impact strength of virgin polymer was higher than filled composites. In the case of coupled composites, it was found to increase above 30% lantana. In control samples, the notched impact strength declined sharply after 20% filler loading and was 19 J/m at 50% lantana.

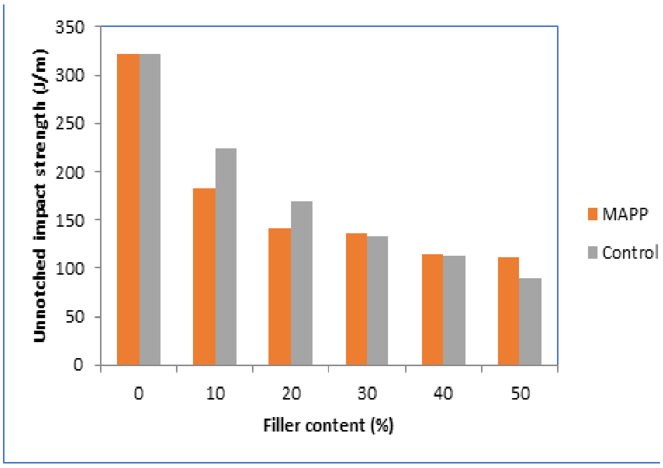


Fig. 10: Unnotched impact strength of Lantana - PP composites at varying Lantana content

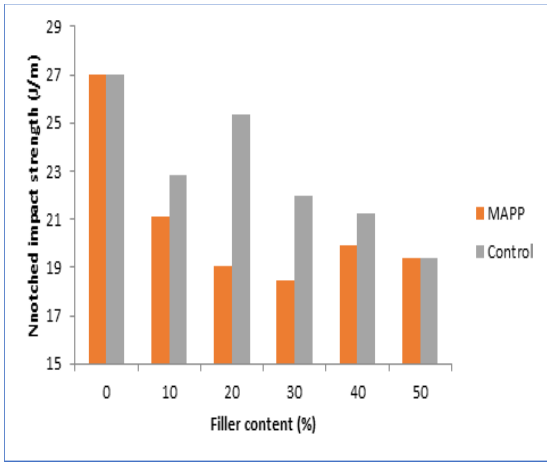


Fig. 11: Notched impact strength of Lantana - PP composites at varying Lantana content

Product development:

Efforts have been made to develop various products from the lantana-PP composites. It was observed that for injection moulded products, a lantana content of about 30-40% is optimum to get defect-free moulded products. Moisture content in the composite granules plays a critical role in the quality of the product. The slight presence of moisture in the granules leads to silver streaks and discolouration of the product which impacts the aesthetics of the final product. Therefore, it is essential to dry the composite granules before the injection moulding process. The injection pressure and speed should be optimized based on the product profile.

There are challenges in extruding lantana-filled PP profiles. Even in a commercial plant, it was observed that the lantana–PP profile was not flowing smoothly and was breaking intermittently. This behaviour may be due to the presence of extractives in lantana, which might interfere with the flow behaviour of composites in the extrusion die. Thermal degradation, non-uniform pressure and deformation in the extruded profile are some of the parameters which need to be tackled during the extrusion process.

Several products have successfully been developed at IWST by optimizing various process parameters are shown in Fig. 12.

The utility of lantana stems as the reinforcing fiber material for wood polymer composites has successfully been demonstrated at IWST. The properties of the composites were at par with wood and other lignocellulosic fiber-filled composites. The composites prepared with lantana fiber can be used for injection moulded and profile extruded products. Products were developed and demonstrated. Specific formulations can be developed for specific applications. Commercial production of the lantana-PP composites would depend on the extraction cost of the lantana and further processing before the preparation of composites. The cost of virgin polypropylene is about Rs. 100/kg. The additives like coupling agents, anti-oxidants, lubricants, colouring agents, UV stabilizers, etc. (master-batch) cost around Rs. 250-300/kg and they are added 1-5% on a weight basis depending on the end-application. The cost of the raw material would depend on the lantana processing cost, fiber content in the composites and additives content. Commercial production requires machinery for fiber processing like chippers, pulverizers, size separators, dryers, high-speed mixers, a compounding line (twin screw extruder) and a palletizer. The palletized granules of composites can effectively be used as the raw material for injection moulded products. For profile extrusion, the essential requirement is a polymer with a low melt flow index, high fiber filling and effective processing additives like UV stabilizers. The extruded products require a profile extrusion system with desired dies for a specific product line.

References: Contact author at shakti@icfre.org

Potential of *Lantana camara* Leaves as Source of Natural Dyes for Textile Applications

Rakesh Kumar
ICFRE - Institute of Wood Science and Technology, Bengaluru
Email: rakesh@icfre.org; colourrakesh@gmail.com

The search for environmentally friendly and sustainable alternatives to synthetic dyes has gained significant momentum in recent years, driven by the harmful environmental impacts associated with their production and use. Natural dyes derived from plants present a promising solution, and one such source is Lantana camara, a widely distributed and invasive plant species that remains largely untapped for natural dye production. This article highlight the potential of L. camara leaves as a source of natural dyes for textile applications. It covers the extraction process, dyeing techniques, colour characteristics, and the eco-friendly benefits of using L. camara leaf extracts. The research findings indicate that L. camara leaves can be used to produce a variety of vibrant and durable shades on textile fabrics, offering valuable contributions to the sustainable fashion industry.

The people of India have been considered as a pioneer in the art of natural dyeing. Natural dyes and pigments are used in the colouring of textiles, food items, drugs, cosmetics, paper, jute, wall paintings, and many other things of common use. As per ancient writings, there had been thousands of different natural sources of dyes at one time and trade in natural dyes was considered as a measure source of economic prosperity of nations. Natural materials had been the only source of dyes until 1856. However, with the accidental synthesis of mauveine by Perkin in Germany in 1856 and its subsequent commercialization, coal-tar dyes began to compete with natural dyes. Finally, with the production of synthetic indigo blue substitute in 1900, the use of natural dyes became very limited. The advent of synthetic dyes caused a rapid decline in the use of natural dyes, which were completely replaced by the former within a century. However, edible dyes like annatto from Bixa orellana, saffron from Crocus sativus and turmeric from Curcuma longa remained in use for colouring various food items. Research across the world has shown that synthetic dyes are suspected to release harmful chemicals that are allergic, carcinogenic and detrimental to human health. Ironically, in 1996 Germany became the first country to ban certain azo dyes. The use of synthetic dyes involves the release of enormous amounts of hazardous chemicals in the water bodies and environment during their production and subsequent use. With environmentally benign products becoming a top priority in recent years, the dye industry has turned its attention to newer products which cater to fashion trends as well as to environmental specifications. The ban on the production and use of un-substituted benzidine, an important intermediate for direct dyes possessing carcinogenic properties, has led all major dye stuff manufacturers to search for benign alternatives. It is worth mentioning that the use of natural dyes represented 6,000 years of trial, discovery and refinements. Natural dyes of plant origin are still used to a considerable extent all over the world. Dyes of plant origin are less toxic, less polluting, less health hazardous, non-carcinogenic and non-poisonous. Added to this, they are harmonizing colours, gentle, soft and subtle, and create a restful effect. Above all, they are environment-friendly and can be recycled after use. India's vast natural resources comprising myriad populations of plant species inhabiting a wide range of ecological niches have enormous economic potential. Due to its rich biodiversity, it is not only one of the world's twelve mega-diversity countries but also one of the eight major centres of origin and diversification of domesticated taxa. These genetic resources yield a wide range of bio-molecules of industrial importance, including natural dyes and pigments from shrubs and herbs and there is ample scope to revive the application of natural dyes on textiles with more scientific knowledge base. Lantana camara, a tropical shrub and now widely found in tropical and subtropical regions of the world, has been recognized as a weed and occupies forest and agricultural land. While the plant is often considered an invasive species, its leaves contain pigments that can be harnessed as a source of natural dye for textile applications. This article highlights the potential of Lantana camara leaves as a natural dye source, analyzing its extraction, application, and potential advantages for sustainable textile dyeing.

Dye

For a substance to act as a dye, certain conditions must be fulfilled:

- It must have a suitable colour,
- It must be able to "Fix itself or be capable of being "Fixed" to the fabric,
- The fixed dye must have fastness properties viz. fastness to light, washing, rubbing and fastness against human perspiration,
- Resistance to the action to water, dilute acids, alkalis and various organic solvents used in dry cleaning, etc.

By definition, only those coloured compounds, which are soluble in water and have an affinity for the fibre on which they are applied, can be classified as dyes. A dye may be defined as a colourant that has substantivity for a substrate, either inherent or induced by reactants.

Type of dye/colourants

Dyes are categorized based on their sources, chemical structure, and method of application. Broadly, they are classified into two main groups: natural dyes and synthetic dyes, depending on their source.

Synthetic dyes:

The synthetic dye industry is considered to have started when Perkins synthesised mauveine (mauve) in 1856 in the UK. The industry quickly developed, mainly in Germany, Switzerland and the UK. Since then the significant dyes discovered were: alizarine red, 1868, by Grabe and Lieberman; indigo in 1870 by Von Bayaer; the azo dyes in 1880; anthraquinone vat dyes in 1901 by Bohn; disperse dyes for cellulose in 1922; fibre reactive dyes by ICI in 1956. There are very many synthetic dyes available now. Their tinctorial strength, concentration, colour range and colour fastness, particularly to light and detergents, make them superior to natural dyes for nearly all uses. They are relatively cheap and have other advantages, e.g., mordants may not be necessary, but they can colour synthetic fibres. Manufacturers and processors using dyes have to deal with potential health, effluent disposal and other environmental requirements, usually to statutory limits. Synthetic dyes are prepared from aromatic compounds. The original source is Coal-Tar thus also known as Coal-Tar Dyes (Azo, Nitroso, Nitro, etc.). The use of synthetic dyes involves the release of enormous amounts of hazardous chemicals into the environment during their production and subsequent use. With environmentally benign products becoming a top priority in recent years, the dye industry has turned its attention to newer products which cater to fashion trends as well to environmental specifications.

Merits of Synthetic Dyes

Although about synthetic dyes people hypothesize that they are not eco-friendly and toxic to human beings. Despite that synthetic dye has some advantages such as:

- Synthetic dye can be prepared in lab/industry
- Large numbers of Synthetic dyes are available
- It is available in huge quantities and
- It produces numerous bright and fast shades

Demerits of Synthetic Dyes

- The synthetic dyes have the following disadvantage.

Natural dye

Natural dyes are obtained from vegetable, animal and mineral sources. The vegetable dye can be obtained from bark, flowers, fruits, leaves, roots, seeds and wood of the different plant species.

Merits of natural dyes

The advantages of using natural colourants are manifold as they are eco-friendly, safe for body contact, unsophisticated and harmonized with nature, while most synthetic dyes cause environmental pollution during their production and use. Moreover, the fabric dyed with azo dyes may cause different kinds of skin turmoil. Environmental awareness as well as the presence of toxicity in synthetic dyes has revived the interest in renewable, biodegradable and eco-friendly natural dyes. Therefore the demand for natural dyes is increasing constantly. Also, some unique shades can be obtained by suitable combinations of natural dyes and mordants. Recently biotechnological methods like tissue cultures are in place to produce natural dyes for use in food, pharmaceutical and cosmetic applications. Keeping in view of the changing trends towards accepting safer and eco-friendly natural colourants, it is high time to go down the lanes of history when natural colourants were once praised and appreciated.

Why natural dyes

- They are biodegradable, and thus no disposal problem,
- They are nontoxic and thus no health hazard,
- They are environment friendly,
- Several shades can be developed from a dye,
- Shades can be produced similar to synthetic dyes,
- Fastness can be achieved by using proper mordant,
- Practically no or very mild chemical reactions are involved in their preparations,
- It may help in the utilization of wasteland which leads to employment and revenue generation.

Classification of natural dye

The natural dyes are obtained from vegetables, animal and mineral sources as thus can be classified as under.

- Vegetable dyes
- Animal dyes
- Mineral dyes

Vegetable Dyes

The dyes obtained from plants are known as vegetable dyes. Vegetable colouring substances are obtained from all of the plants viz. flower fruits, bark, wood, root and seeds. A large variety of colours can be obtained from vegetable sources. These are obtained from almost all parts of the plants. The class of compounds responsible for colours may consist of flavonoids, quinones, indigoids, polyphenols etc.

Vegetable dyes obtained from different parts of the plants are

Leaves	Lawsonia inermis
Flower	Butea monosperma
Seeds	Mallotus philippensis
Bark	Morinda citrifolia
Wood	Pterocarpus santalinus
Fruits	Terminalia chebula
Roots	Rubia cordifolia

Animal Dyes

These dyes are prepared from the dried bodies or exudates of some insects and animals and are of historical interest only. The most important are: Tryian purple (Molluse dye), Cochineal, Kermes, Lac.

Mineral Dyes

It includes earth pigments such as orchers, umbers, and siennas, which owe their tinctorial property to the oxides and hydrated oxides of iron and manganese and are very insoluble in water and other solvents and must therefore be attached to fibre surfaces with binders. Minerals provide such dyes as Prussian-blue, chrome yellow and iron buff. Represented mainly by khaki dyeing on cotton by using a mixture of iron and chromium salts. Though formerly it was of considerable importance, this class of colour is now nearly obsolete. These dyes as a rule are exceedingly fast to light and washing. The general method of dyeing with these colours involves impregnating the fibre with a solution of another compound, which is capable of yielding a coloured precipitate with the metal already present. By and large, compounds of iron, lead, manganese, copper, cobalt and nickel are used for colouring purposes. Mineral colouring matters are represented mainly by the khaki dyeing on cotton which consists of a mixture of the oxides of iron and chromium.

Natural dye from *Lantana camara* leaves

Extraction of dye from Lantana camara leaves

The dye is extracted by simmering dried Lantana camara leaves in distilled water for 60 to 90 minutes. This method is carefully designed to ensure the optimal release of natural pigments from the leaves, resulting in a rich and concentrated dye solution. The heat from boiling helps break down the plant material, allowing the colour to infuse more deeply into the water. After the boiling process is finished, the mixture should be filtered to remove any remaining plant residue, leaving a clear, vibrant liquid. This purified liquid then becomes the dye bath, ready for use in dyeing textiles, offering a sustainable and eco-friendly alternative to synthetic dyes.

Dyeing procedure

The pre-treated fabrics are immersed in the dye extract obtained from Lantana camara leaves. The fabrics are then boiled in the dye bath for 45 minutes, with the duration adjusted according to the desired colour intensity. The longer the fabric remains in the dye bath, the more intense and vibrant the colour will become, resulting in a deeper hue. After dyeing, the fabrics are carefully rinsed in cold water to remove any excess dye, ensuring the colour is evenly set and properly adhered. Once rinsed, the fabrics are left to air-dry in the shade, protecting them from direct sunlight to prevent fading and preserve the dye's integrity. This process supports a consistent, high-quality result while maintaining the eco-friendly advantages of natural dyeing.

Determination of colour fastness properties of dyed fabrics:

The dyed fabrics need to be assessed for their colourfastness and colour strength properties, with precise measurements taken to evaluate both colourfastness and colour intensity. The colourfastness may evaluated by subjecting the dyed textiles to wash, light, and rubbing tests. The colour changes recorded and compared to assess the stability of the dye.

- **Colourfastness to washing (IS 687: 1979)**

This method is used to assess the impact of washing on the colourfastness of textiles. After conducting the experiment, the change in colour of the treated test specimen, as well as the degree of staining on the two adjacent fabric pieces, is evaluated using the grey scale.

- **Colourfastness to perspiration (IS 971: 1983):**

This method is designed to determine the colourfastness of textile materials in all forms to the effects of human perspiration. Samples of the textile, in contact with adjacent fabrics, are treated with two different solutions containing histidine, then drained and placed between two plates under a specified pressure within a testing device. The specimens and adjacent fabrics are dried separately. The colour change of each specimen and the staining of the adjacent fabrics are then evaluated using the grey scale.

- **Colourfastness to crocking/rubbing (IS: 766: 1988):**

The rubbing fastness test is used to determine the colourfastness of textile materials to rubbing and staining of other materials. Two tests are conducted: one with a dry rubbing cloth and the other with a wet rubbing cloth. The textile specimens are rubbed with both the dry and wet cloths using a rubbing finger. The test specimen is secured to the rubbing device with clamps, ensuring that the long direction of the specimen aligns with the track of the device. The colour change of each specimen and the staining on the adjacent fabrics are subsequently assessed using the grey scale.

- **Colourfastness to light (IS: 2454: 1985)**

Colour fastness of textile materials to daylight is of significant importance to consumers. Since daylight exposure requires a lengthy period to complete a test, a quicker method to assess colour fastness to light involves using artificial light, such as Xenon light. A textile specimen is exposed to Xenon arc light under prescribed conditions, along with eight standard dyed wool patterns, to evaluate its colour fastness.

Analysis of fastness determination results:

The results demonstrated that the dyed and mordanted fabrics showed excellent colourfastness, retaining their vibrant hues even after repeated washing, rubbing, and exposure to perspiration. This indicates that the natural dye extracted from *Lantana camara* leaves offers a stable and long-lasting colour, making it a reliable option for textile applications. These exceptional colourfastness results emphasize the potential of *Lantana camara* leaf extracts as a sustainable alternative to synthetic dyes, providing not only visual appeal but also enhanced durability and eco-friendliness in the textile industry.

Fig. 1: Dyed wool using dye extracted from leaves of Lantana camara

Fig. 2: Dyed silk fabrics using dye extracted from leaves of Lantana camara

Conclusion : The study suggests that Lantana camara leaves hold considerable potential as a natural dye source for textile applications. The dye extracted from the leaves yields a variety of vibrant colours, particularly when paired with suitable mordants. By utilizing this abundant and environmentally friendly resource, the textile industry can lessen its ecological impact and support the increasing demand for sustainable fashion. Additionally, using invasive plant species like Lantana camara for dye production helps address their ecological effects while providing a viable alternative to synthetic dyes that depend on petrochemical derivatives.

References: Contact author at rakesh@icfre.org

Lantana camara for Medium Density Fibreboard (MDF)

Prakash V., Ramkumar V.R., Manish Ranjan, Thanigai K. and Kiran M.C.
ICFRE - Institute of Wood Science and Technology, Bengaluru
Email : vijayp@icfre.org

Acute demand for timber raw material for wood-based industries (WBIs) has put tremendous pressure on forests leading to drastic degradation of forest resources contributing to global climate. In India, commercial logging from natural forests being banned by the Honourable Supreme Court of India, WBIs source raw material entirely from plantations outside the forests. It is forecasted that the timber demand of the nation in million cubic meter (cu. m) round wood equivalent by the year 2030 would be 97.81 Million cu. m, a major portion of which i.e. 57.49 Million cu. m is the demand for plywood and other wood-based industries. The bandwidth of demand and supply gap for timber is always witnessing an increasing trend leading to a situation where a major number of industries are operating below their capacities due to the non-availability of raw material. In this paradoxical scenario, possible alternatives to wood are to be explored to satisfy the raw material needs of WBIs. Research on suitability studies of lesser known tree species, agro residues, agro waste and invasive weeds for manufacturing various wood-based composites is thriving to support WBIs and at the same time to conserve forests and the environment. .

Global Invasive Species Program (GISP, 2020) defines an invasive species as "non-native organisms that cause/have the potential to cause harm to the environment, economies, or human health" . Invasive plant species have negative ecological impacts such as displacing indigenous plants and invertebrates. These invasive plant species affect biodiversity by impacting indigenous vegetation and the food webs associated with this vegetation . Lantana camara (LC) has become a major weed worldwide in tropical, subtropical, and warm temperate regions. It invades pastures, plantation crops, and a range of disturbed-open natural and modified scrubland, woodland, and forest communities, displacing the indigenous biota and limiting public access and use. Because of its broad distribution, invasive ability in both agricultural and natural ecosystems, and local persistence, LC is considered one of the world's top ten weeds. Management strategies that can bring solutions to the threats posed by this weed is being worked out by many researchers. In the Indian sub-continent, Lantana has invaded vast tracts of dry-moist forests and other culturable wastelands and has potentially altered biodiversity, landscape ecology and ecosystem services. It has invaded most Indian pasture lands (13.2 million ha) besides forest and fallow areas, and the cost of its control is considerably high. This invasive weed stands out because of its rapid spread, intensity of infestation, allelopathy, opportunistic growth behaviour, reproductive biology traits and tenacious resistance to cutting and burning and also rapid spreading of invasive plant species Lantana camara, pose a serious threat to wildlife habitat and their migration . ICFRE-IWST is currently working on exploring the potential of LC as raw material for particleboard and other such lingo-cellulosic panels (Ranjan et al. 2017, Ramkumar et al. 2023, 2024). It is found that the species can be economically used as raw material for producing medium-density particleboard. In similar lines, attempts were made to explore the possibilities of fiber generation from Lantana camara which can further be pressed into medium-density fibreboard (MDF) using a suitable binding agent.

Fig 1. Various colors of flowers of Lantana camara L. in different stages

Fig 2. Invasion of Lantana Camara in Dubare, Karnataka

Medium-density fibreboard (MDF) is a composite wood product that is made by breaking down wood into fibre in a defibrator. Fibers are then added with a synthetic resin binder such as urea formaldehyde (UF) or Phenol formaldehyde and an additive like wax, resin and forming board by using high temperature and pressure . MDF is available in a range of thicknesses from 2 to 100 mm and a very wide range of panel sizes. The density of these panels varies from about 500 to 900 kg/m3. MDF have smooth, high-density faces and are pink-brown to dark brown in colour unless a dye has been added during manufacture. MDF is used extensively in factory-assembled and ready-to-assemble furniture, as well as in cabinets, underlayment, drawer fronts, molding, and countertops. Finishes and overlays can be used to provide a grain pattern typical of lumber, and many wood finishing components such as door edgings, decorative trim, frames, and cornices are made from MDF. MDF can be made from small dimension logs/branches or from agro and forest residue. The conversion ratio from wooden chips to fibre varies from 80-85%. MDF possesses certain improved physical-mechanical properties similar to solid wood. In most of the end uses, MDF can replace solid wood and plywood because of the improved qualities of MDF. Due to the friendly nature of the product, the demand for MDF is increasing in India. MDF panels can be made from wood fibers derived even from species like Casuarina equisetifolia (Uday et al.2001)

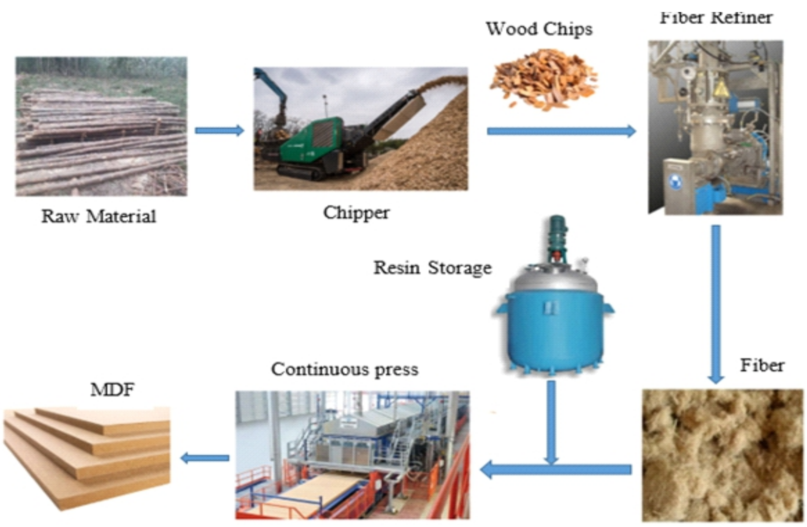


Fig 3. Pictorial flow chart of MDF manufacturing

Fig 4. Preparation of Lantana chips for refining

Experimentation with *Lantana camara* for fiber generation Lantana sticks were harvested from Gottipura near Hosakote in Karnataka. These sticks were converted into chips manually to optimize the chip size for lab-scale refiner. Chips were soaked in water for 24 hours, after draining excess water, the chips were loaded into a digester of a Lab scale refiner which was cooked for 5 minutes under a pressure of 5 bar. The cooked chips were then refined using a lab-scale mechanical refiner shown in fig. 5. Initial trials have resulted in promising findings which infer that by optimising cooking and refining parameters, lantana camara can be successfully refined into fibers which can be utilized for MDF production. Fibers obtained post refining are shown in Fig 7. Further trials are being undertaken at IWST-IPIRTI facility to optimize the process parameters. Once fiber refining is optimized, suitable resin system can be worked out to develop MDF for various end-use applications.

Fig 5. Lab Scale Refiner

Fig 6. Refining of Lantana fibers

Fig 7. Refining of Lantana fibers

Future perspectives

It may be concluded that the forest weeds, viz. Lantana camara, Prosopis juliflora, etc can be utilized for producing medium-density particle boards. Future studies can be explored for optimization of the requirements of wood fibers sizes, amount of binders to be used, and pressure and temperature conditions to obtain quality raw material and product as per Indian Standards Specifications.

References: Contact author at vijayp@icfre.org

Utilization of *Lantana camara* in Developing Cement Bonded Particle Board

Manish Ranjan
ICFRE - Institute of Wood Science and Technology ,Bengaluru
E mail : ranjanm@icfre.org

Wood-based panel products play a crucial role in domestic, commercial, and industrial applications. However, India's wood-based industries are struggling with a widening gap between the demand and supply of solid raw materials, necessitating the search for viable alternatives. To address this challenge, significant research has been conducted on mineral-bonded wood particle boards, which help reduce the dependence on expensive wood raw materials and introduce new possibilities for wood-based panels. Early initiatives, such as "Duratuff" and "Bison Panels" explored these alternatives nearly five decades ago. A key advantage of such boards is their ability to eliminate the need for costly resin-based adhesives like phenolic and urea-formaldehyde resins, which are petroleum-derived and expensive. The continuous evolution of glue-based panel technologies has helped mitigate the anisotropic behavior and growth stress issues associated with plantation-grown solid wood. Compared to conventional resin-bonded wood composite panels, cement-bonded wood composites offer superior fire resistance, insect and fungal resistance, and durability. Cement, in particular, provides excellent bond strength and enables the production of weather-resistant building materials suitable for prefabricated housing.

Modern consumers are increasingly concerned about environmental sustainability and cost-effectiveness, driving the demand for value-added products derived from waste materials. Recognizing this trend, extensive research has been conducted on cement-bonded composites made from agricultural and wood residues, particularly for low-cost housing projects in developing countries. Cement-bonded boards have found widespread applications in shuttering, insulation, ceilings, and sandwich-type panels as shown in figure 2. They offer superior physical properties, including low thermal conductivity, effective sound absorption, and high mechanical strength. Additionally, they are classified as Class-I fire-resistant materials based on surface spread-of-flame tests, making them a preferred choice for low-cost housing and the construction of industrial and commercial developments.

Today, wood-cement boards, fibre-cement boards, gypsum fibre boards, and gypsum particleboards are manufactured worldwide. The growing emphasis on sustainability presents industries with an opportunity to utilize locally available Lignocellulosic materials for the production of durable, high-performance building products. Over the years, researchers have tested numerous Lignocellulosic raw materials for compatibility with cement in particleboard manufacturing. One of the most promising materials is *Lantana camara*, an exotic woody shrub belonging to the Verbenaceae family. Native to tropical regions of the Americas and Africa, *Lantana camara* is now widely found across India. It grows to a height of 0.5 to 2.0 meters and has low soluble sugar and tannin content, ensuring minimal interference with the hydration process during the cement setting. This characteristic makes it highly compatible with Portland cement, allowing for strong and durable bonding. Given its abundance and suitability, *Lantana camara* presents a futuristic raw material option for sustainable panel production.

Cement-bonded particle boards have gained widespread acceptance across industries due to their superior properties and diverse applications. Compared to resin-bonded particleboards, medium-density fibreboards (MDF), plywood, and other composite products, cement-bonded boards offer enhanced fire resistance, durability, and environmental sustainability, making them a preferred alternative for modern construction and furniture industries.

Advantages of Cement Bonded Particle Board (CBPB):

1. Fire Resistance: CBPB is highly fire resistant and has been classified as an incombustible material in many countries around the globe.

2. Weather Resistant: With cement constituting 62% of its composition the CBPB gives excellent resistance to weather. The board has been subjected to many cycles of soaking, freezing and heating without any sign of disintegration. The board should generally be painted for external application to provide a weather seal.

3. Biological: Due to the mineralization of wood particles by cement, CBPB is resistant to termite and termite attack. It does not support fungus growth. Even untreated samples exposed to contact with the ground surface for several years have shown no sign of rot or decay.

4. Sound Insulation: Airborne sound reduction varies between 30 and 37 dB for the frequency range 100- 3150 HZ according to the thickness of CBPB. When used in stud partitioning, a reduction of over 60 dB can be achieved with suitable construction.

5. Chemically Stable: CBPB is produced by an irreversible process combining cement and wood particles into a chemically stable building material that maintains its strength with time and exposure to elements. The board is unaffected by many dilute chemicals such as brines, bleaches, detergents and chlorine solutions.

6. Dimensionally Stable: CBPB has excellent dimensional stability in variable ambient temperatures and humidity conditions. The swelling in thickness after 2 hours of immersion in water is 1% and after 24 hours of immersion is only 1.5%. Longitudinal and transverse swelling will be approximately 0.3% for change in relative humidity of air from 30% to 95% at 20℃.

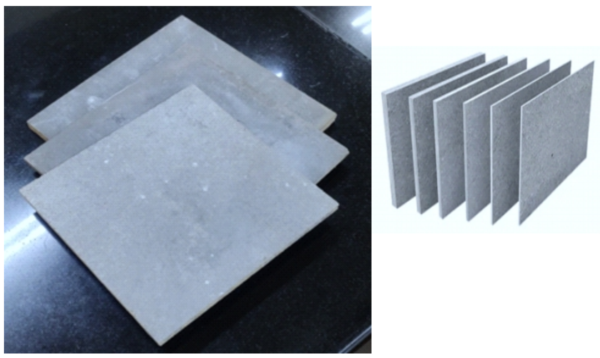


Fig : 1 Cement bonded lantana board by IWST

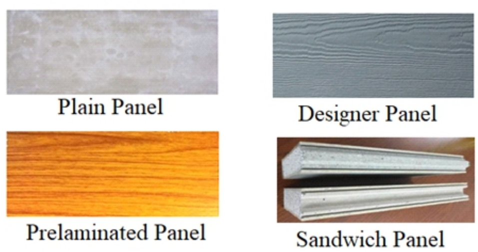


Fig 2. Different forms of cement bonded panels

Manufacturing Process

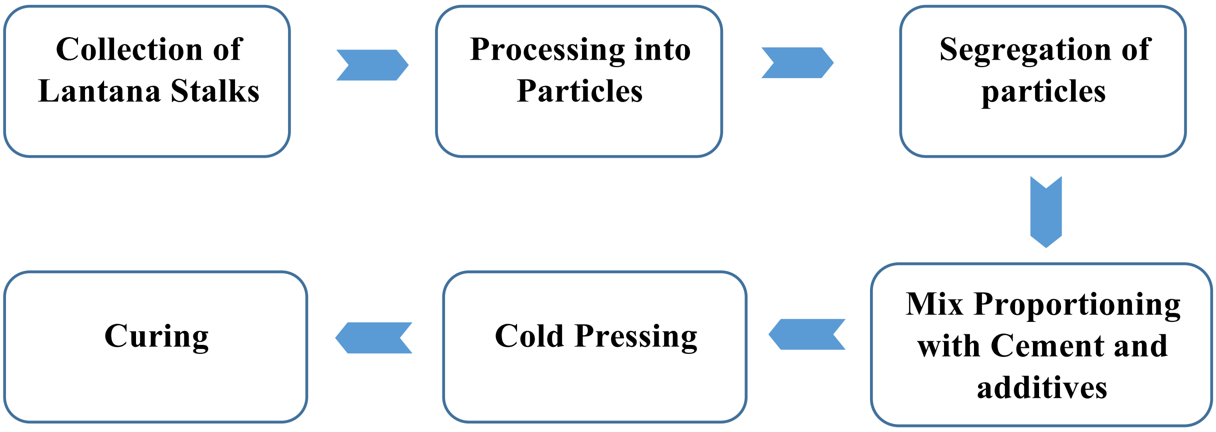
Raw materials

i. Lantana camara (Particles)

ii. Cement as binder

iii. Additives [Sodium Silicate (Na_2SiO_3) and Aluminium Sulphate (Al_2SO_4)3)]

The properties of the final product largely depend on the type and quality of the particles used. Therefore, particle preparation is a crucial step in the manufacturing process of Cement-Bonded Lantana Board (CBLB). Key factors influencing board quality include the type of particles, cement-to-particle ratio, and processing techniques such as handling, drying, screening, mixing, and mat formation. Figure 3 demonstrate a simple manufacturing process.



A Lab Scale Study and Demonstration

To develop a cement-bonded particle board, Lantana particles were used in two different ratios: 2.5:1.0 (R1) and 3.0:1.0 (R2) of Cement to Lantana particles. Cement-bonded boards with a thickness of 10 mm were produced for both ratios by applying a specific pressure of 30 kg/cm² for 6 hours using a cold press. The prepared boards were then conditioned and tested for physical properties, including density, moisture content, water absorption after 2 hours and 24 hours, and pH. Table 1 presents the mean observations of the physical properties of CBLB and its comparison with IS: 14276 (2009).

Table 1: Physical Properties of Cement Bonded Lantana Boards

Cement: Particle Ratios	Density (g/cm^3)	Moisture Content (%)	Water Absorption (%)		pH
			2 hrs	24 hrs	
2.5:1.0 (R 1)	1.3 4	6.9 4	12. 44	18. 61	11.0
3.0:1.0 (R 2)	1.3 7	6.6 1	12. 05	17.65	11.6
IS: 14276 (2009)	1.25 (Min.)	6.00 - 12.00	13.00 (Max.)	25.00 (Max.)	11 -13

The mean density of CBLB was found to be 1.34 g/cm³ and 1.37 g/cm³ for the Lantana particle boards. A significant increase in density was observed with a higher cement-to-particle ratio. Both ratios met the desired density criteria specified in IS: 14276 (2009). Compared to MDF and particle boards, CBLB exhibited a considerably higher density due to the higher weight of cement particles compared to wood particles.

The mean moisture content was recorded as 6.94% for R1 and 6.61% for R2, both of which met the minimum requirements specified in IS: 14276 (2009). The moisture content decreased with an increasing cement-to-wood ratio. Similarly, water absorption by CBLB was found to be 12.44% and 12.05% after 2 hours, and 18.61% and 17.65% after 24 hours of soaking in water for R1 and R2, respectively. The results revealed that water absorption nearly doubled after 24 hours compared to 2 hours. According to IS: 14276 (2009), the board should have a maximum water absorption of 13% after 2 hours and 25% after 24 hours, both of which were met by the prepared boards.

The pH values of all boards ranged between 11.0 and 11.6 across all cement-particle ratios. It was also observed that moisture content and water absorption (both after 2 and 24 hours) decreased with an increasing cement-to-wood ratio. This can be attributed to the hygroscopic nature of wood; a higher proportion of wood particles in CBLB leads to greater water absorption. Additionally, cement particles form a protective coating around the wood particles, reducing their ability to absorb water.

Table 2: Mechanical Properties of Cement Bonded Lantana Boards

Cement: Particle Ratios	**Modulus of Rupture (N/mm^2)**		**Modulus of Elasticity (N/mm^2)**		**Screw Withdrawal Face (N)**	**Tensile Strength (N/mm^2)**
	Dry	**Wet**	**Dry**	**Wet**		
2.5:1.0 (R1)	9.08	7.55	4755	4522	1472	0.42
3.0:1.0 (R2)	9.21	7.71	4814	4642	1479	0.43
IS: 14276 (2009)	09 (Min.)	5.5 (Min.)	3000 (Min.)	2200 (Min.)	1250 (Min.)	0.40 (Min.)

The mechanical properties of the boards, including modulus of rupture (MOR), modulus of elasticity (MOE) in both dry and wet conditions, screw withdrawal strength (face), and tensile strength (internal bonding), were determined and are presented in Table 2.

The mean MOR of CBLB at R1 and R2 was recorded as 9.08 and 9.21 N/mm² in dry conditions and 7.55 and 7.71 N/mm² in wet conditions. Both R1 and R2 cement-to-particle ratios meet the minimum criteria specified in IS: 14276 (2009).

The mean MOE was found to be 4755 and 4814 N/mm² at the two different cement-to-particle ratios. According to IS: 14276 (2009), a cement-bonded particle board should have a minimum MOE of 3000 N/mm², which was achieved at both ratios. Additionally, it was observed that both MOE and MOR increased significantly with a higher cement content in CBLB.

The mean screw withdrawal strength (face) was recorded as 1472 and 1479 N for cement-bonded boards with R1 and R2 ratios, respectively. These results indicate that the alignment of particles in the board plays a crucial role in screw withdrawal strength, as screws are more difficult to withdraw across the grain than along it. However, the screw withdrawal strength of boards manufactured at both cement-to-particle ratios met the requirements of IS: 14276 (2009). This suggests that higher mechanical strength is achieved at higher cement-to-wood ratios, showing a significant improvement compared to lower ratios.

The mean tensile strength (internal bonding) of CBLB was determined to be 0.42 and 0.43 N/mm². It was observed that the presence of cement particles in the board contributed to the development of strong internal bonding, further enhancing the board's tensile strength.

Inference from the study

Cement-bonded particle boards were prepared using Lantana particles with two different cement-to-particle ratios: 2.5:1.0 (R1) and 3.0:1.0 (R2). The density of the boards increased with a higher cement proportion. The moisture content of the Lantana cement board was lower in the R2 ratio, and overall, the moisture content decreased as the cement-to-particle ratio increased. The lowest water absorption was also recorded in the R2 ratio.

Regarding mechanical properties, parameters such as MOR, MOE (both dry and wet), tensile strength, and screw withdrawal strength improved with an increased cement ratio in the board. The physical and mechanical properties of cement-bonded Lantana boards at both R1 and R2 ratios met the requirements of IS: 14276 (2009). However, no significant difference was observed between the two cement-to-particle ratios.

Scope and Applications

Table 3: Cement Bonded Particle Board Recommended Thickness

Application	Panel Thickness in MM
False Ceiling	**6-8**
Doors	**12-18**
Almirah	**12-20**
Furniture	**6-14**
Partitions	**40**
Modular Kitchen	**8-18**
Temporary Structure	**40**
Floors	**16-30**
Wall claddings	**10-16**

The utilization of Lantana camara in developing cement-bonded particleboard presents a promising solution for development of sustainable construction materials. This initiative highlights its potential to enhance eco-friendly building practices by reducing dependency on traditional wood sources while addressing the invasive nature of Lantana camara. The findings suggest that properly treated Lantana camara particles can achieve satisfactory mechanical and durability properties in cement-bonded boards. Further research on optimization techniques and large-scale applications can enhance its feasibility. Overall, integrating Lantana camara into construction materials offers an innovative, cost-effective, and environmentally beneficial alternative for sustainable development in the construction industry.

References: Contact author at ranjanm@icfre.org

Thermal Modification of *Lantana camara* For its Value Addition

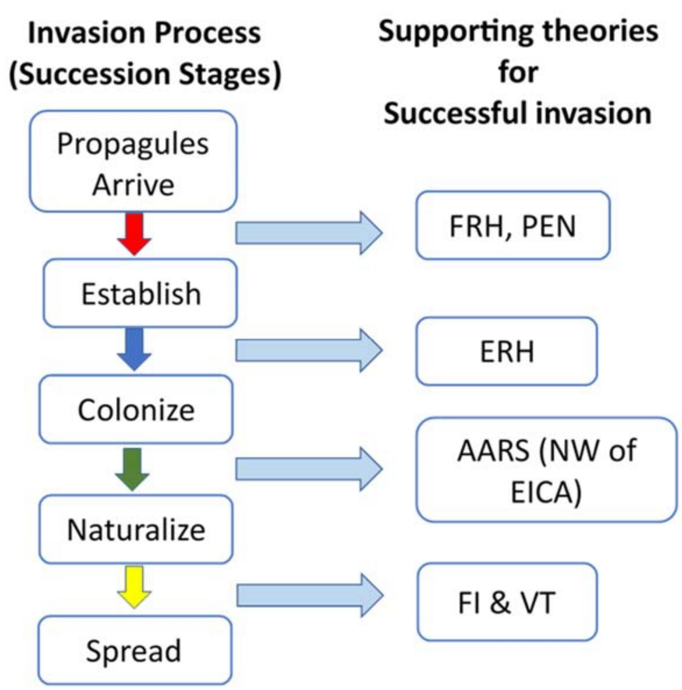
Sanmitra Dan
ICFRE - Institute of Wood Science and Technology , Bengaluru
E mail : sanmitra.dan@gmail.com

Lantana camara is a well-known woody, erect, or sub-scandent, robust shrub, which is currently in abundance in India's tropical and subtropical zones, and it has encroached into many protected forest areas as well as the temperate zone of the Indian subcontinent. The low, erect, or sub-scandent, robust shrub Lantana camara L. which has a woody square-shaped cross section stem which on being matured can be up to 15cm thick is considered as an obnoxious invasive species in many tropical and sub-tropical areas . This diversified and vast geographical range explains Lantana's high ecological tolerance.

Following are two most accepted factors for successful establishment of Lantana camara;

1. Growth under varied climatic conditions,
2. No cap on temperature or rainfall limit.

The flow chart given below as per demonstrates the stages of Lantana invasion with different theories explaining the transition from one stage to other succession stage;



The stages of Lantana invasion with different theories applicable for the transition from one to the other stage.

1. AARS, Allelopathic Advantage Against Resident Species;
2. EICA, Evolution of Increased Competitive Ability;
3. ERH, Enemy Release Hypothesis;
4. FI, Faunal Interaction;
5. FRH, Fluctuating Resource Hypothesis;
6. NW, Novel Weapon;
7. PEN, Presence of Empty Niche;
8. VT, Vegetative Traits

Lantana is now considered a concern to ecosystems owing to its several harmful elements, such as its allelopathic effect on crops and other plant species which results in biodiversity loss of other plant species . The most commonly noted negative impacts of L. camara are listed below;

1. It diminishes the native biodiversity and also hampers the ecological succession.

2. Lantana has a number of allelopathic qualities which results in reduced vitality in native plant species which limits their net output and also interferes with their harvesting processes –
3. It causes damage to pastoral lands which are considered as grazing areas.
4. It causes livestock poisoning, Lantana biomass i.e. leaves and flowers consist toxins viz. lantadene A and B which are very unfit for consuming ruminants (Patel, 2011).
5. Lantana is a potential competitor for native pastures hence it hampers the agricultural outcomes.
6. In case of direct contact with the plant it may lead to several allergic reactions and skin irritations for human beings.
7. Lantana causes significant reduction in the viability of orchard plantations (Holm, 1979).
8. Due to the presence of flowers of different colours Lantana serves as the harbor for different pests (Day et al., 2003).

Thus, Lantana management is very necessary, as is the use of Lantana biomass. The biomass obtained from Lantana is very efficient for fertilizer, energy, fuel wood, pulp, paper fiber and developing roofing material purposes. Examining several aspects of Lantana to be used as an end product, L. camara has potential to be utilized for making value added products such as -cellulose and its derivatives, handmade paper, wood composites and furniture products . Lantana biomass and its extracts have potential to be used as antioxidant, antibacterial and cytotoxic potential of silver nanoparticles synthesized using terpenes rich extract of Lantana camara leaves . Green synthesis and characterization of silver nanoparticles has been carried out using Lantana camara leaf extract .

Thermal modification:

Thermal modification is a common environmentally friendly treatment that does not utilize any hazardous chemicals. Thermal modification of wood has been extensively studied in response to the rising demand for safe approaches to enhance durability without the use of hazardous chemicals. The technology for thermally modifying the wood was initiated in Germany which was further commercialized in 1980 based on Burmester's work, but it couldn't get industrialized. Buro, studied thermal treatment of wood in molten bath and in gaseous atmosphere. Dearth of supply of good quality timbers had led to the use of thermally modified timber in industrial applications. Besides, due to gradual restriction and ban on use of certain preservative treated wood for particular applications in view of health and environmental hazards in many parts of the world, the thermal modification of wood is being preferred.

Heat treatment changes the chemical, physical, and mechanical properties of wood. Thermal modification makes the wood dimensionally stable and also increases the longevity of the wood . Thermal modification causes the colour of wood to darken due to hemicellulose breakdown and phenolic component oxidation, which is relevant from an aesthetic standpoint. Thermal modification often changes the colour of wood because it has a direct influence on the wood's basic components: cellulose, hemicellulose, and lignin. While these components are resistant, high temperatures cause deterioration and destroy chemical connections. Notably, significant and irreversible changes in wood occur within the temperature range of 180°C to 250°C –. The degradation of hemicellulose, condensation of lignin, and increased hydrophobicity are defining characteristics of thermally modified wood. Thermal modification refers to the heat treatment of wood at temperatures between 160°C and 260°C in a low oxygen environment, which may include vacuum, nitrogen atmosphere, steam heating, and oil application.

Vacuum heat modification:

In this process wood is being modified using the combination of efficient vacuum drying and thermal modification. During the thermal modification phase, the gas, including oxygen, within the vessel is evacuated to provide a partial vacuum, and heating is facilitated by forced convection. The wood is initially dried in a hot air oven at 100°C until the moisture content attains 0%. Subsequently, during the treatment the temperature is elevated to 160−220°C in a vacuum environment. The wood is ultimately cooled to 100°C. The entire duration ranges from 5 to 9 hours. Fig. 1 shows a graphical representation of temperature v/s time curve during vacuum heat treatment at 200°C for 6 hours. The vacuum pump incessantly eliminates all volatile chemicals that would otherwise lead to the breakdown of polysaccharides in the cell wall. This modification is characterized by lower weight loss and the odourless end product that can be attributed to the vacuum pump, in that it continuously removed volatile compounds that would otherwise interact with the degradation process.

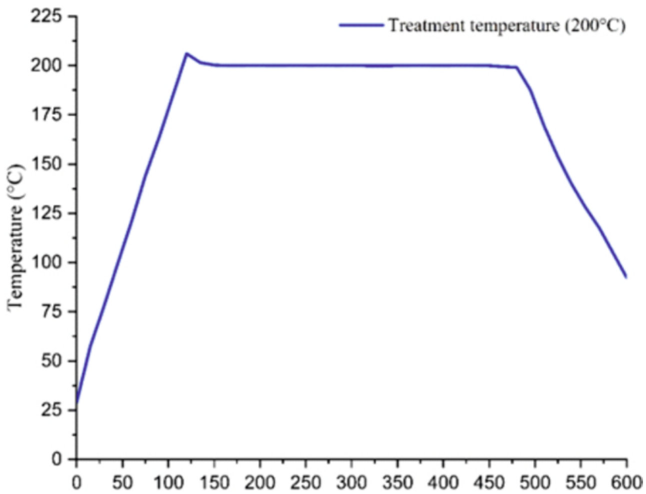


Fig. 1: Temperature profile for vacuum heat treatment process.

Oil heat modification:

The wood is being treated at high temperatures in presence of vegetable oils such as rapeseed, linseed or sunflower oil, at a temperature between 180°C and 220°C for a period of 2–8 hours. This process was developed by the Menz Holz company located in Germany. The application of oil in thermal modification techniques necessitates significantly elevated temperatures (typically 180–220°C), leading to chemical alterations in the wood components. In this process the modified wood takes up the oil resulting in net weight gain.

Steam heat modification:

Steam heat modification is conducted with steam under pressure at varying temperatures. The standard treatment temperature varies from 180 to 260°C. Since just water serves as the treatment medium, no toxic chemicals are employed. Consequently, hydrothermal modification is one of the most commercially viable method for enhancing certain qualities e.g. dimensional stability, hygroscopicity, etc. of wood among wood modification techniques .

Thermal modification of *Lantana camara*

Although thermal modification has been thoroughly investigated for several wood species, its utilization in Lantana camara stalks has yet to be examined. There is a knowledge gap that needs to be addressed by examining the effects of thermal modification, thereby offering a comprehensive understanding of their impact on the wood properties of this invasive species. One recent study on value addition and utilization of L. camara by means of thermal modification showed some significant outcomes. In the particular study, L. camara stalks underwent thermal modification via vacuum heat treatment (VHT), oil heat treatment (OHT), and steam heat treatment (SHT) at temperatures of 180°C and 200°C, followed by an analysis of alterations in their physical, chemical, and mechanical characteristics. The methodology has addressed the information about thermal modification of L. camara wood and have allowed a comparative evaluation of the effectiveness of various thermal treatments in this woody biomass.

As per the experiment results of Dan et al. , the vacuum and steam heat-treated samples had weight loss, which grew with rising temperatures, with the highest weight loss noted in the steam heat-treated samples. The oil heat-treated specimens witnessed a weight increase owing to oil absorption, which reduced as the treatment temperature rose (fig. 2)

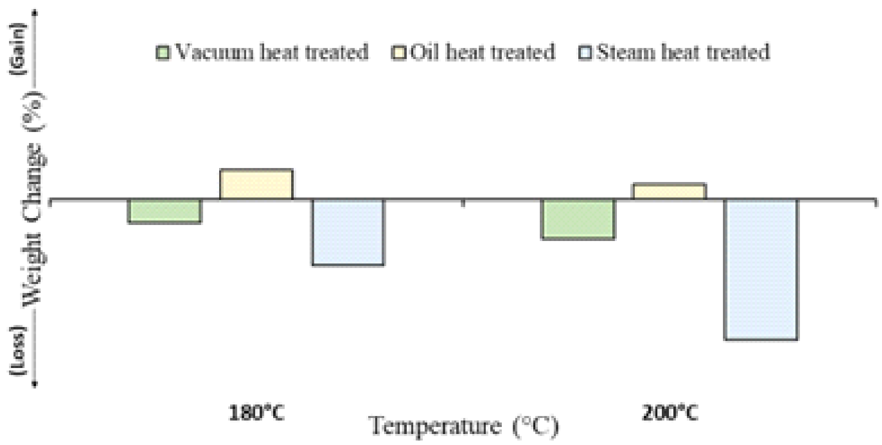


Fig. 2: Weight percent change in thermally modified samples.

Heat treatment resulted in a uniform darkening for L. camara; the severity of the darkening increased with increasing temperature (fig. 3).

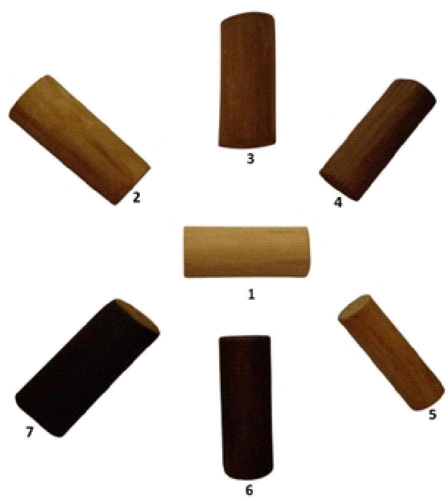


Fig. 3: Lantana stalks after treatment. 1: Control (untreated), 2: VHT at 180 °C, 3: OHT at 180°C, 4: SHT at 180°C, 5: VHT at 200°C, 6: OHT at 200°C, and 7: SHT at 200°C.

OHT samples had the highest amount of darkening, which was consistent with the FTNIRS interpretation. Both the reduction of hygroscopicity and the enhancement of dimensional stability were the two most significant achievements that the heat treatments brought about. The decrease in hygroscopicity that occurs as a result of the disintegration of certain hemicelluloses is the primary factor that is responsible for the elevated dimensional stability of the L. camara that has been subjected due to the heat treatment. The anti-swelling efficiency (ASE) increased with temperature, attributed to the degradation (de-acetylation) of hemicellulose, which was most pronounced in the SHT samples relative to the VHT and OHT samples. The characterization through FTIR and FTNIRS revealed that lignin exhibits the least susceptibility to heat treatments when compared to cellulose and hemicellulose. The heat treatment did not produce a notable impact on flexural strength properties i.e. dMOE.

Conclusion:

Hence, it was observed that the thermal modification of Lantana camara specimens by three different methods viz. VHT, OHT and SHT exhibited similar behaviour and imparted value addition like other heat-treated hardwood species. Yet underutilized, this abundant woody biomass holds high application potential as a result of this value addition. But, certain crucial elements in thermal modification require additional investigation to optimize the application of L. camara. This material requires evaluation for long-term durability under various environmental circumstances, including both biotic factors (exposure to insects, fungi, bacteria, etc.) and abiotic variables (exposure to UV radiation and fluctuations in moisture and temperature).

References: Contact author at sanmitra.dan@gmail.com

From Noxious Weed to Sustainable Solution: Unlocking the Potential of *Lantana camara*

Sumit Manohar Yadav

Department of Forest Products and Utilization, Forest College & Research Institute, Hyderabad

Email ID: sumitmyadav13@gmail.com

In a world grappling with climate change, resource depletion, and environmental degradation, the need for sustainable solutions has never been more urgent. Modern industries, from construction to automotive, rely heavily on materials that are durable, lightweight, and cost-effective. However, the production and disposal of such materials often leave a significant environmental footprint. This conundrum has pushed researchers to explore renewable and eco-friendly alternatives and among the unlikely heroes is *Lantana camara*, a plant notorious for its invasive nature.

Lantana camara has long been viewed as a troublesome weed, spreading aggressively across ecosystems, displacing native flora, and posing risks to livestock due to its toxic properties. Yet, what if this invasive species could be transformed from an ecological villain into an industrial asset? Recent research has unveiled its potential as a source of lignocellulosic fibers, paving the way for sustainable polymer composites that can rival synthetic counterparts in performance while reducing environmental harm. This transformation of Lantana camara from an ecological nuisance to a valuable resource not only addresses the challenges of waste management and material sustainability but also exemplifies the ingenuity of science in finding solutions within nature's complexities. By harvesting and repurposing this weed, industries can simultaneously mitigate its ecological impact and unlock a wealth of opportunities for green innovation.

The Problem with Conventional Composites

Synthetic fiber-reinforced composites, such as those made with glass or carbon fibers, are widely used in industries like automotive, construction, and aerospace due to their strength and durability. Despite their advantages, these materials come with significant drawbacks. Their production processes are energy-intensive, rely heavily on non-renewable resources, and generate substantial waste. Additionally, synthetic composites are not biodegradable, contributing to long-term environmental pollution.

Natural fiber composites (NFCs) have emerged as a sustainable alternative. Made from renewable resources, these materials are biodegradable, lightweight, and cost-effective. However, they often lack the strength and versatility of their synthetic counterparts. This is where Lantana camara's unique properties come into play.

Why Lantana camara?

Lantana camara a perennial shrub, is infamous for its invasive nature and adaptability to diverse environments. Introduced as an ornamental plant in India during the 19th century, it quickly spread across ecosystems, outcompeting native species and altering ecological balances. Today, it is considered one of the world's most invasive species, causing significant challenges in agriculture, forestry, and biodiversity conservation. While its toxic properties pose risks to livestock and native fauna, its robust and fibrous stems present a largely untapped opportunity for sustainable material development.

What makes Lantana camara so promising is the composition of its stems, which are rich in lignocellulosic fibers. These fibers consist of cellulose, hemicellulose, and lignin the essential building blocks for creating durable and versatile composites. Cellulose provides tensile strength, hemicellulose contributes to flexibility, and lignin adds rigidity and resistance to degradation. This unique combination makes Lantana fibers comparable, if not superior, to other natural fibers such as jute, coir, and hemp in terms of strength and versatility.


Lantana camara plant

Additionally, the abundance of *Lantana camara* is another factor that amplifies its potential. The plant grows prolifically in tropical and subtropical regions, often forming dense thickets that are difficult to eradicate. This overabundance has made it a persistent problem for land management, but it also means that a vast and renewable source of raw material is readily available. Utilizing Lantana camara for fiber extraction not only provides an eco-friendly alternative to synthetic fibers but also contributes to controlling its spread, thereby mitigating its ecological impact. Furthermore, Lantana fibers have demonstrated remarkable compatibility with polymer matrices, particularly when subjected to chemical treatments such as alkaline washing or benzoylation. These treatments enhance the fibers surface properties, improving their bonding capabilities with polymers like epoxy and polypropylene. The resulting composites are lightweight, strong, and resistant to environmental factors such as moisture and wear, making them ideal for a wide range of applications, from automotive parts to construction materials.

Table 1. Fiber microfibril size and chemical content of L. camara stem

Fiber length, (µ)	
Min.	684.0
Max.	1134.20
Avg.	912.0
Fiber diameter (µ)	22.0
Lumen diameter (µ)	16.0
Cell wall thickness (µ)	3.06
Holo Cellulose (%)	65.89 - 66.30
Lignin (%)	26.32 - 27.54
Ash content (%)	Negligible

By turning this invasive species into a resource, industries can address multiple challenges simultaneously. Not only does this approach reduce dependency on non-renewable materials, but it also provides an innovative way to manage an ecological menace. The story of *Lantana camara* exemplifies how science and innovation can transform a problem into a solution, opening doors to a more sustainable and resilient future.

Transforming a Weed into Wonder Material

Researchers have developed innovative methods to extract and treat Lantana fibers to enhance their compatibility with polymers. Treatments such as alkali washing, benzoylation, and acetone processing improve fiber bonding, reduce moisture absorption, and increase mechanical properties. These processes prepare the fibers for use in creating high-performance composites.

Manufacturing with Lantana

Lantana fiber-reinforced composites can be produced using methods like hand lay-up, extrusion molding, and compression molding. These techniques allow the fibers to be combined with polymers like epoxy or polypropylene, creating versatile materials suitable for automotive parts, furniture, and even biofuel applications.

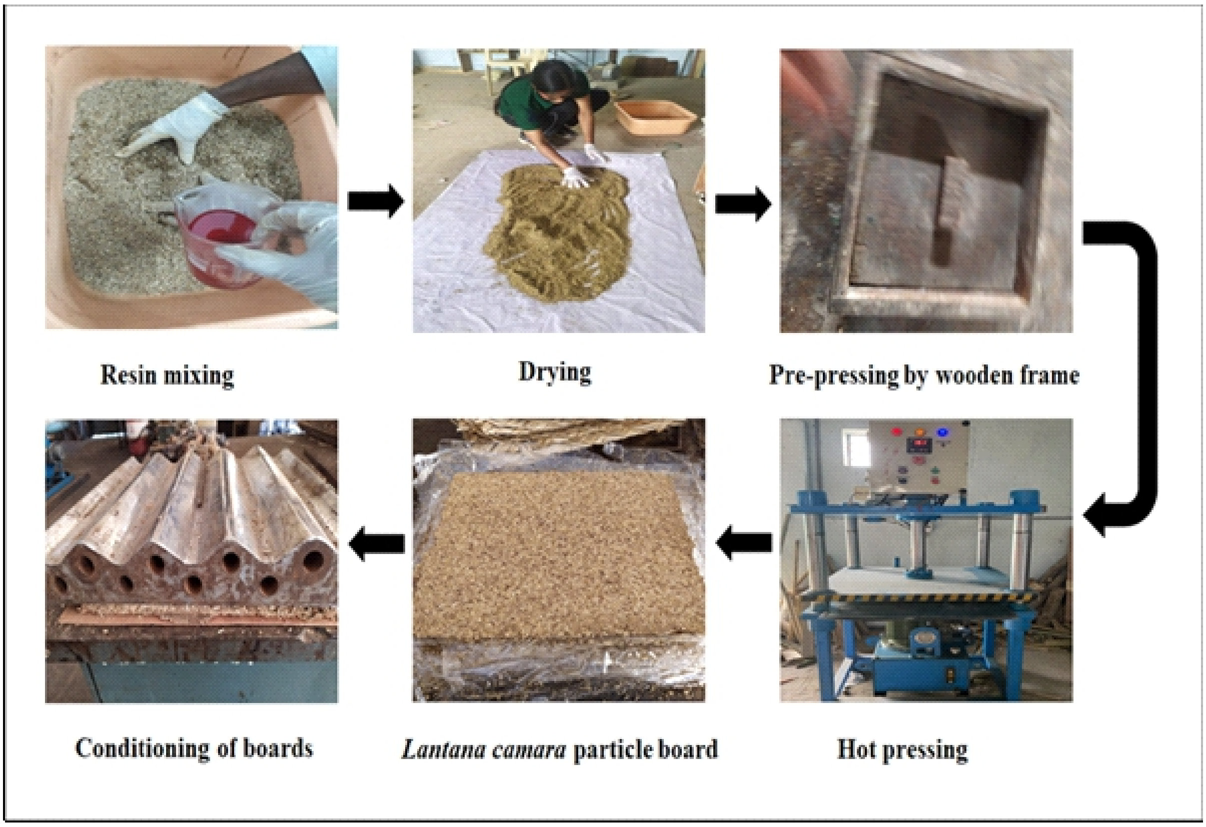
Performance Highlights

Lantana-based composites have demonstrated impressive mechanical properties. For instance:

Strength and Flexibility: Tensile and flexural strengths rival or exceed those of traditional materials like coir and jute.

Water Resistance: Treated Lantana fibers exhibit reduced water absorption, making them ideal for humid environments.

Wear Resistance: These composites show excellent resistance to abrasion, increasing their durability in demanding applications.



Fabrication of *Lantana camara* composites

A Green Revolution in Materials Science

The journey of Lantana camara from an invasive weed to a sustainable material highlights a pivotal moment in the evolution of materials science. The plant's ability to address both environmental and industrial challenges makes it a symbol of innovation in sustainable development. By utilizing the natural properties of Lantana fibers, researchers have discovered a means to transform an ecological threat into a resourceful solution. Lantana fiber-reinforced composites (LFRCs) are not just materials; they are a statement about the possibilities of aligning industrial needs with ecological preservation. These composites have the potential to replace non-renewable, synthetic fibers, drastically reducing environmental pollution and resource dependency. Furthermore, the versatility of LFRCs spanning applications in automotive parts, construction materials, and even biofuels underscores their transformative impact across multiple sectors.

This green revolution emphasizes the importance of reconsidering underutilized resources. Invasive species like *Lantana camara*, often dismissed as nuisances, can become game changers when paired with innovative science. The plant's abundant growth, combined with advancements in chemical treatments and polymer integration, makes it an exemplary model for sustainable practices. As we face increasing environmental challenges, the story of *Lantana camara* serves as a beacon, showcasing how thoughtful innovation can turn problems into opportunities. The journey of Lantana camara from invasive weed to sustainable material is a testament to the power of innovation. By leveraging its natural properties, researchers are turning an ecological challenge into an industrial opportunity. LFRCs offer a glimpse into a future where materials are not only high-performing but also kind to the planet.

As industries continue to prioritize sustainability, Lantana camara could play a pivotal role in reducing our environmental footprint. Its potential as a resource highlights the importance of rethinking how we view invasive species and other underutilized materials. With continued research and development, this humble plant may well become a cornerstone of the green materials revolution.

Future Directions

While the promise of *Lantana camara* fiber composites is undeniable, significant advancements are needed to fully harness their potential. Future research should focus on integrating advanced biopolymers to create entirely biodegradable composites, ensuring maximum environmental benefits. Investigating the thermal stability of Lantana-based composites will enable their use in high-temperature applications such as automotive engines and industrial machinery. Long-term durability studies in real-world conditions are crucial to validate their performance and reliability over time. Additionally, exploring innovative manufacturing techniques, such as 3D printing or automated fiber integration, can enhance production scalability and cost-efficiency. By addressing these gaps, the utility of Lantana camara fibers can expand, paving the way for a new era of sustainable materials.

References: Contact author at sumitmyadav13@gmail.com

Energy Potential of *Lantana camara*: Transforming an Invasive Weed into a Sustainable Bioenergy Source

Jaydeep Uniyal, Venkata Chandra Sekhar Palla, And Thallada Bhaskar

CSIR-Indian Institute of Petroleum, Haridwar Road, Mohkampur, Dehradun
Email: tbhaskar@iip.res.in

Invasive plants are recognized as one of the "evil quartet", the four primary factors contributing to the decline of global biodiversity. These alien species often exhibit heightened invasive potential, largely because they face fewer natural predators in non-native environments. Consequently, invasive plants profoundly alter ecosystem dynamics and species diversity, underscoring the urgent need for effective management strategies. One highly aggressive invasive species is Lantana Camara, belonging to the Verbenaceae family. Originally native to the Americas, L. Camara has become naturalized in India, where it poses a significant threat to local biodiversity. This species has invaded over 60 countries, primarily in tropical and subtropical regions, and can thrive at elevations of up to 2000 meters (Kaushik et al., 2024). Lantana Camara commonly known as wild sage, is native to the tropical forests of South America. In 1807, Lantana species were brought to India as ornamental plants and first planted at the Acharya Jagadish Chandra Bose Botanical Garden in Kolkata, presently known as the Royal Botanical Garden, Calcutta (Chaterjee et al., 2015).

This invasive weed has invaded upon a significant portion of Indian pasture lands (13.2 million hectares), in addition to forest and fallow regions, especially, in the Himalayan foothills, 13.7 tonnes per hectare of Lantana Camara is being produced. Its rapid spread is caused by intense infestation, allelopathic properties, opportunistic growth behaviour, reproductive biology, and strong resistance to cutting and burning (Negi et al., 2019). Its natural spread mainly occurs via seeds dispersed by birds in their droppings or through the feces of moving flocks of sheep and goats (Sharma, O. P. et al. 1988).Lantana possesses characteristics that make it highly susceptible to fire. When exposed to fire, it readily resprouts, which not only increases its ability to thicket formation but also breaks seed dormancy, promoting significant new growth. Fire has a beneficial effect on Lantana's growth, causing it to regenerate more vigorously compared to areas that are not affected by fire. Lantana Camara releases chemicals that stop the growth of native plants, disrupting the ecosystem. This effect helps Lantana thrive in various conditions. It reduces biodiversity and affects the growth of other plants. Lantana leaf extracts decrease seed germination and growth in food crops like mustard and radish. Its toxic properties also harm water hyacinth by preventing leaf bud growth and causing decay. The impact varies across different crops. Moreover, the leaves of Lantana are toxic to many animals, especially cattle, buffalo, sheep, and goats. When these animals eat Lantana leaves, they can develop severe health issues like jaundice, skin problems, and sensitivity to sunlight due to specific toxic compounds. Even though livestock usually do not prefer Lantana leaves, they may eat them when other food is scarce, leading to health issues. The toxic compounds in Lantana leaves remain harmful even after being processed for animal feed. Additionally, eating green berries from Lantana can be deadly to humans (Negi et al., 2019). Hence, it is essential to develop innovative and cost-effective strategies to manage invasive shrubs such as Lantana Camara. The estimated cost of controlling it in India is around US$ 70 per hectare.

Therefore, to benefit both the environment and a sustainable economy, an effective strategy is to redirect waste from invasive species to industrial processes, aiming to produce value-added products (Chongloi et al., 2024).

Lantana Camara has shown great potential for valorization in the form of composites. Lantana Camara stems are a valuable source of lignocellulosic fibers for composite materials, demonstrating excellent mechanical properties. Composites with Lantana fibers showed high tensile and flexural strengths, reaching up to 37 MPa and 56.32 MPa, respectively. Chemical treatments, such as alkaline and benzoylation treatments enhance fiber-matrix adhesion, improving the composite's mechanical properties. These treatments increase the surface roughness of the fibers, leading to better bonding with the polymer matrix and resulting in composites with superior strength and durability. Using Lantana Camara fibers for composite materials provides both environmental and economic benefits. It helps manage invasive species and offers a renewable, low-cost raw material for composite production, aligning with sustainable development goals by promoting natural resource utilization and reducing reliance on synthetic fibers. This makes Lantana Camara fibers a promising option for high-performance, eco-friendly materials in the engineering, automotive, and construction industries (Gillela et al., 2022)

Biomass is one of the most widely used, abundantly available and the only carbonaceous renewable energy resource available in nature. Its potential has been acknowledged as an effective means to meet both domestic and industrial energy needs in India, Biomass fuels are economical and provide a viable alternative to fossil fuels (Ezhumalai et al., 2017). Lantana Camara is a promising source of solid biofuels due to its high-energy content and favorable properties. The biomass of Lantana Camara can be converted into dense forms like briquettes and pellets. The calorific value of dried Lantana Camara biomass ranges from 17.2 MJ/kg to 20.0 MJ/kg, which makes it a suitable candidate for utilization as a solid fuel. Additionally, its low ash content (up to 2%) and low sulphur content (up to 0.2%) contribute to its environmental friendliness. Utilizing Lantana Camara as a solid fuel not only provides a renewable and abundant energy source but also helps manage this invasive species, benefiting both the environment and the economy (Malik et al., 2022).

The thermochemical conversion process, known as pyrolysis, has become an attractive technique for waste valorization, leading to a significant increase in research in this area over the past decade. Low-emission and carbon-neutral biofuel production methods like pyrolysis help reduce pollution and support socioeconomic progress in rural areas. The bio-oil produced from Lantana Camara biomass through pyrolysis has a gross calorific value (GCV) of up to 30.99 MJ/kg. This high-energy content makes it a viable candidate for biofuel applications. The bio-oil consists of 64.95% elemental carbon, which is essential for combustion and energy applications (Chongloi et al., 2024).

Lantana Camara has shown significant potential for Biochar and syngas production through thermochemical conversion processes. The Biochar produced from Lantana Camara biomass has a high carbon content and can be used as a soil amendment to improve soil fertility and sequester carbon (Ezhumalai et al., 2017).

Additionally, the gasification of Lantana Camara biomass using a downdraft gasifier produces syngas with a lower heating value (LHV) of 6.4 MJ/Nm^3. These syngas can be used as a fuel for power generation or as a feedstock for the production of chemicals such as methanol and ammonia (Kaushik et al., 2024).

Our activity at CSIR – IIP
Pelletization for Energy / domestic application

The pelletization process of Lantana Camara biomass began with the collection of fresh stems from the open fields of the IIP campus, as shown in Figure A, on Day 1, which had an initial moisture content of approximately 60.9 wt.%. The biomass was spread out for sun-drying, and due to the cold and damp conditions of the winter season in the Dehradun, the drying process (shown in Figure B) took about 29 days to achieve effective moisture reduction. Over the course of the drying period, proximate analysis was conducted at regular intervals (on the 1^{st}, 3^{rd}, 5^{th}, 7^{th}, 9^{th}, 11^{th}, 13^{th},15^{th}, 17^{th},19^{th}, 21^{st}, 23^{rd}, 26^{th}, and 29^{th} days) to monitor changes in moisture content. The moisture content decreased significantly from 60.9% on Day 1 to 9.9 ± 0.15% by Day 29, making the biomass suitable for pelletization. This transformation highlights the effectiveness of the drying process in enhancing the biomass's fuel properties, making it a viable candidate for pellet production.

Fig A. Fresh *Lantana Camara* biomass in open fields

Fig B. Sun-dried *Lantana Camara* biomass

Once the biomass was adequately dried, it was chipped into smaller pieces using a biomass shredder and then pulverized into a fine powder using a biomass pulverizer shown in Figure C. The powdered biomass was subsequently formed into pellets using a pelletizer with a 9 mm pellet dies, ensuring uniformity and ease of handling for energy applications.

c) Pulverized and chipped *Lantana camara* biomass

(d) *Lantana camara* biomass Pellets

Throughout the entire process, the activities were carefully documented with photographs and videos. A comprehensive documentary video was created to highlight the systematic procedure, highlighting the challenges faced during the winter season and the successful transformation of Lantana Camara biomass into a usable form. This documentation serves as a valuable resource for future reference and knowledge sharing.

According to the Research conducted by Ezhumalai and Kumar (2017), the fuel properties of L. Camara wood, including its basic density, calorific value, and proximate analysis, are summarized in Table 1. Biomass with higher density is preferred for fuel applications due to its high-energy content per unit volume and slow-burning characteristics. The basic density of L. Camara wood was determined to be 0.55 g/cm³, making it a suitable candidate for pelletization, as denser biomass is easier to compress into high-quality pellets.

Table 1: Fuel properties analysis of L. Camara wood [Ezhumalai and Kumar (2017)]

Species	BD (gm/cm3)	Ash (wt.%)	VMC (wt.%)	FCC (wt.%)	CV (MJ/Kg)
L. Camara	0.55 (±0.07)	1.2 (±0.1)	80.0 (±0.08)	19.2 (±0.02)	19.51 (±0.04)

Values in parentheses are standard deviation BD basic density; VMC volatile matter content; FCC fixed carbon content; CV calorific value

The ash content of biomass is a critical factor influencing its suitability as a fuel. High ash content reduces the desirability of biomass for energy applications. L. Camara wood has a low ash content of 1.2%, which is comparable to many conventional wood species. This low ash content is advantageous for pelletization, as it minimizes slagging and fouling during combustion, thereby enhancing the efficiency of pellet-based energy systems.

The volatile matter content (VMC) and fixed carbon content (FCC) of L. Camara are 80% and 19%, respectively. High volatile matter content contributes marginally to the heating value of solid fuels and is helpful for the production of liquid and gaseous through pyrolysis and gasification processes, respectively. For pelletization, a balanced proportion of volatile matter and fixed carbon is essential to ensure stable combustion and energy output. The calorific value of L. Camara wood was 19.5 MJ/kg, which is comparable to many other wood species. This high calorific value, combined with its low ash content, makes L. Camara a promising feedstock for pellet production.

Table 2: Ultimate Analysis of L. Camara Wood

Species	Carbon (%)	Hydrogen (%)	Nitrogen (%)	Sulphur (%)
L. Camara	46.9 (±0.01)	6.42 (±0.02)	1.04 (±0.01)	0.13 (±0.00)

The ultimate analysis of L. Camara wood revealed a carbon content of 46.9% and a hydrogen content of 6.42%. The H/C ratio was calculated to be approximately 0.14, indicating a higher proportion of carbon-carbon bonds, which is desirable for high energy density. Additionally, the low nitrogen (1.04%) and sulphur (0.13%) content of L. Camara wood is environmentally favourable, as it reduces the emission of harmful gases during combustion.

In conclusion, the favourable fuel properties of L. Camara wood, combined with its suitability for pelletization, highlight its potential as a renewable energy source. The production of pellets from L. Camara biomass can contribute to the development of sustainable energy solutions while addressing environmental concerns. The Government of India has introduced new regulations requiring all thermal power plants to co-fire a minimum of 5% biomass alongside coal. This mandate, set forth by the Ministry of Power and the Ministry of New & Renewable Energy, the obligation mandate shall increase to 7% from F.Y. (https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1945245). Biomass, including potential sources such as the invasive woodland weed Lantana Camara, is gaining recognition as a sustainable alternative to fossil fuels

Conclusion

The extensive analysis of Lantana Camara biomass highlights its significant potential as a renewable energy source and a sustainable solution for managing invasive species. The favorable fuel properties of L. Camara, including its high basic density (0.55 g/cm^3), low ash content (1.2%), and high calorific value (19.51 MJ/kg), make it an excellent candidate for pelletization and other bioenergy applications. The low nitrogen (1.04%) and sulphur (0.13%) content further enhance its environmental suitability by reducing harmful emissions during combustion. Additionally, the high volatile matter content (80%) and balanced fixed carbon content (19%) ensure efficient energy production through processes like pyrolysis and gasification.

The pelletization of L. Camara biomass not only addresses the challenges posed by its invasive nature but also provides a cost-effective and eco-friendly alternative to fossil fuels. The successful conversion of L. Camara into pellets, as demonstrated in our activities at CSIR-IIP, underscores its viability for domestic and industrial energy applications. Furthermore, the Government of India's mandate for co-firing biomass in thermal power plants aligns with the potential of L. Camara as a sustainable energy source, meeting the technical specifications for biomass pellets and briquettes. In conclusion, the valorization of Lantana Camara biomass into pellets and other bioenergy products offers a dual benefit: it contributes to the management of invasive species while promoting renewable energy solutions. This approach aligns with global sustainability goals, supports rural economies, and reduces reliance on fossil fuels, making L. Camara a promising resource for a greener and more sustainable future.

Acknowledgements:

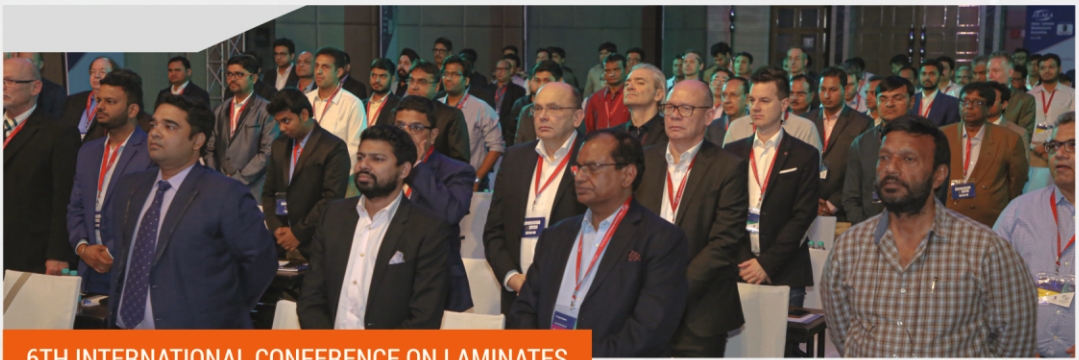
The authors would like to acknowledge the financial support from the Ministry of Environment Forest and Climate Change (MoEFCC), Govt. of India, for the project titled "Mapping, Monitoring and Management of Lantana Camara through Utilization for Improving Livelihood of People in Fringe Villages of India".

References: Contact author at tbhaskar@iip.res.in

www.ilma.org.in

INDIAN LAMINATE MANUFACTURERS ASSOCIATION

ILMA



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)

FOR REGISTRATION

Contact us on +91 9904125666/ +91-79-400 53443
Write to us at ilma@live.in
Join us on Facebook.com/ilma.org.in
Visit our Website www.ilma.org.in

REACH OUT TO US AT

INDIAN LAMINATE MANUFACTURERS ASSOCIATION
Regd. Office:
301, ILMA, Shubham Complex, Nr. Vastrapur Lake, Opp. Sanjeevani Hospital, Vastrapur, Ahmedabad, Gujarat, INDIA 380015.

ICFRE – Wood Industries Committee of India (ICFRE-WINCOIN)

(formed vide Notification No. F.No. 36-5/2022-ICFRE dated 23rd Dec, 2022)

WINCOIN MEMBERSHIP APPLICATION FORM

1. Name of the Organization to be printed on Membership Certificate			
2. Address to be printed on Membership Certificate			
3. Correspondence Address, if different from 2. above.			
4. GST No. of the Organization at 1. above			
5. Name of Head of Organization			
6. Contact details: **Land line with STD:**		**Fax No:**	
Mobile No.:		**Email:**	
7. Details of erstwhile IPIRTI Membership, if any.(Please enclose copy of earlier Membership certificate)		**Year of Membership :**	
		Membership Type: Associate/SSI/MSI/LSI/Life Member	
8. Membership Required, **Please choose one**		Associate/SSI/MSI/LSI/Life Member	
For the financial year:		**If Renewal, then year of commencement :**	
9. Structure of Organization: **Please tick one**		Public Ltd./Private Ltd/Partnership/Proprietary Concern	
10. Registered as (**Enclose copy of Registration Certificate**)		Large/Medium/Small Scale Industry or any other	
11. Products Manufactured *			
12. Installed Capacity*			
13. Annual Production*			
14. Whether BIS Licensee*			
15. Total no. of employees		No. of Technical Persons	
16. Details of application fee paid		**D.D.No./Transaction Id:**	
Issuing Bank/Branch		**Amount:**	**Date:**
(DD to be drawn in favour of The Director, IWST CORPUS FUND, payable at Bangalore; Please see overleaf for complete bank account details and fee structure of ICFRE-WINCOIN)			
17. Any other details			
18. For further Information please contact		Secretariat ICFRE-WINCOIN, Institute of Wood Science & Technology P.O. Malleshwaram, Bengaluru- 560 003 (India) Email: dir_iwst@icre.org; icfre_wincoin@icfre.org, Tel +91-80-22190103 ; +91-80-30534050, +91-80-30534021	

As per Government of India, Ministry of Environment, Forest and Climate Change, Order No. F.No. 16-1/2022-RT dated 22.10.2022, Indian Plywood Industries Research and Training Institute (IPIRTI), has been merged with Institute of Wood Science and Technology (IWST), Bengaluru

Details of Membership Type (Category) and Membership fees are as under:

Membership Category	Membership Fee
(i) Life Membership SSI:	(i) Rs.1,20,000/- + 18% GST (In one lumpsum or in 4 instalments of Rs.30,000+18%GST payable half-yearly)
(ii) Life Membership MSI/LSI:	(ii) Rs.2,40,000/- + 18% GST (In one lumpsum or in 4 instalments of Rs.60000+18%GST payable half-yearly)
(iii) Annual Member SSI	(iii) Rs.12,000 + 18% GST for Small Scale Industries / units
(iv) Annual Member MSI/LSI: Manufacturers of panels from wood and other lignocellulosic materials and associated industries like machinery, resins, chemicals, etc	(iii) Rs.24,000 + 18% GST for 1" year and thereafter for renewal Rs.18,000+ 18% GST every year for Medium/ Large Scale Industries / Units
Associate Member: For Associations & Individuals	Rs. 6000/- per year +18% GST

Benefits for industrial members of "ICFRE-WINCOIN":

a) Technical support services related to processing and production of wood & wood-based products.

b) Provide solutions to common problems of the industries and their needs through regional workshops/meetings.

c) Arranging Training and Education for the candidates sponsored by the industries through regular short term vocational courses as well as specially conducted courses as per the request of sponsors.

d) Preference in providing well educated and trained production workforce to the wood & wood based industries.

e) Focus will be given to problems and needs of the industries in R&D projects.

f) Undertaking sponsored projects given by the industry for their process and product development.

g) Enlighten the members as well as non-members for the Wood and Wood based Industries regarding the significant achievements and other important events conducted in the Institute.

h) Formulation of specifications for the new products developed by the industry and issue of draft amendments to existing standards.

i) Undertaking sponsored projects given by the factory for their process and product development.

The membership fees may be paid through Demand Draft/Online to the following account:-

The Director, 'IWST-Corpus Fund'
A/c No. 64013600791
State Bank of India
(03295)-Yeshwanthpur (Bengaluru)
Tumkuru Road, Near APMC Yard,
Yeshwantpur,
Bengaluru-560 022, Karnataka
IFSC Code: SBIN0003297

आई सी एफ आर ई - काष्ठ विज्ञान एवं प्रौद्योगिकी संस्थान
ICFRE - INSTITUTE OF WOOD SCIENCE & TECHNOLOGY
(भारतीय वानिकी अनुसंधान एवं शिक्षा परिषद)
(Indian Council of Forestry Research & Education)
(पर्यावरण, वन और जलवायु परिवर्तन मंत्रालय, भारत सरकार का एक स्वायत्त निकाय)
(An Autonomous body of Ministry of Environment, Forest & Climate Change, Govt. of India)
डाकघर मल्लेश्वरम / P.O. Malleswaram, बेंगलुरु / Bengaluru – 560003

सं/No:16-214/2023-24/IWST/EXTN/Incubation Centre/436(a) दिनांक/Dated: 17.01.2024

GUIDELINES FOR REGISTRATION AT INCUBATION CENTRE OF ICFRE-IWST

About ICFRE-Institute of Wood Science and Technology (IWST), Bengaluru

ICFRE-IWST is a premier research Institute under Indian Council of Forestry Research and Education (ICFRE) with specialized mandate to work on the research aspects of wood science and technology. In order to promote innovation and entrepreneurship among students, faculty and stakeholders, ICFRE-IWST has established Incubation Centre for wood products under the guidance of expert scientists of ICFRE-IWST.

Vision

To nurture the culture of invention and entrepreneurship in the wood products among students, faculty, stakeholders and community inventors.

Mission

i. To focus on invention by identifying problems and providing solutions that would be commercialized into venture development.
ii. Product development would be prime focus by normalizing resources.

Objectives

i. Identifying areas, proof of concepts to prototype modules and translating them into product development.
ii. Conducting hackathons and wood camps to engage and develop interest among students, faculty, stakeholders and community inventors.
iii. To inculcate generation of Intellectual Property Rights (IPRs) among students, faculty, stakeholders and community inventors.

Contd….

Incubation Space

ICFRE-IWST has full-fledged Incubation Centre with 250 sq.mt. work space with modern wood working machineries to assist the inventors and entrepreneurs. Institute also host IT Cell and library to access the knowledge in the field of wood science and technology. ICFRE-IWST host Wood Properties and Processing (WPP) Division and Plywood and Panel Product Technology Division with experienced wood scientists and technical officers to guide and assist students, faculty, stakeholders and community inventors on their invention ideas into business model.

Fields of incubation

i. Wood and bamboo based products
ii. Engineered wood
iii. Wood polymer composites
iv. Wood modification
v. Wood and lignocellulose panel products
vi. Forest Protection
vii. Tissue Culture
viii. Forest management and certification

Process of Registration and Operationalization

Interested students, faculty, stakeholders, community inventors and entrepreneurs who like to work in the Incubation Centre of ICFRE-IWST on wood products shall register by submitting duly filled necessary data in Registration Form enclosed. The applicants shall pay ₹10,000/- (Rupees Ten Thousand only) as a deposit amount to ICFRE-IWST.

The incubation after registration has to sign a Memorandum of Association with IWST and bear cost of material required for developing prototypes, charges for machine usage and meet any other financial obligations as agreed in the Memorandum of Association.

REGISTRATION FORM TO WORK IN ICFRE-IWST INCUBATION CENTRE

PHOTOGRAPH

PERSONAL INFORMATION		
1.	**Name:**	
2.	**Contact Number:**	
3.	**E-mail Id:** ✉	
4.	**Postal address:**	
BUSINESS INFORMATION		
1.	**Name of the business:**	
2.	**Which topic is most aligned with your idea?**	
3.	**How long you have been working in your business idea?**	
4.	**Any progress so far made?**	
5.	**Any prototype model developed (if applicable)?**	
6.	**How would your business idea contribute to improve life using business as a force for good things?**	

Signature of the applicant

With Best compliments from

FEDERATION OF ALL INDIA TIMBER MERCHANTS, SAW MILLERS AND ALLIED INDUSTRIES

(Registered under Companies Act)

White Pearl, Flat No. 201, 1st Floor, # 269/1-1, Kasturiba Nagar,
Opp. Union Bank of India, Mysore Main Road, Bengaluru- 560026. Karnataka State.
E-mail : faitmsmai@gmail.com

Regn. No. : CIN-U51909WB2008NPL131579 - Dtd. 30-12-2008

PRESIDENT

ARJUN HIRJI PATEL
Mandya - Bangalore
94482 73375 / 82170 99809
E-mail : arjunhirjipatel@gmail.com

VICE PRESIDENT

PRABHUDAS K. PATEL
Nagpur
97658 57857

VICE PRESIDENT

CHAKILAM RAMANAIYA
Hyderabad
93910 13985

GEN. SECRETARY

MANSUKH K. PATEL
Nadiad - Gujarat
98255 62847
E-mail : shardavsm@yahoo.com

SECRETARY

KANTILAL D. PATEL
Delhi
98112 51020

JOINT SECRETARY

LAXMAN G. PATEL
Kolhapur
94230 40457

TREASURER

VISHRAM L. CHHABHAIYA
Bangalore
98440 35112

JOINT TREASURER

JIVRAJ V. PATEL
Bangarpet, Kolar
94480 77032

HON. ADVISORS

NAVAL KEDIA
Kolkata
98302 00497

DWARA RAMAKRISHNA
Rajamundry
94401 76081

CA RAMNIKLAL M. VAGADIA
Bangalore
98453 75577

HIMMATBHAI R. PATEL
Mumbai
98211 19116

CA BHAVANBHAI H. PATEL
Mumbai
98200 82969

WOOD IS GOOD

"GROW MORE TREES & PRESERVE THE ENVIRONMENT"

"UNITY IS STRENGTH TO REACH THE GOAL"

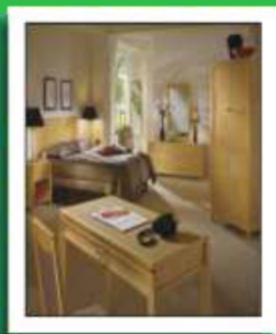
FEDERATION OF INDIAN PLYWOOD & PANEL INDUSTRY (FIPPI)

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.



FEDERATION OF INDIAN PLYWOOD & PANEL INDUSTRY (FIPPI)

404, Vikrant Tower, 4, Rajendra Place, New Delhi110 008, India
Ph.: (Direct) +91-11-25755649, Other Nos. +91-11-25862301
Fax: +91-11-25768639, E-mail : fippi@fippi.org

Website : www.fippi.org

THE INDIAN ACADEMY OF WOOD SCIENCE

Working Office: Institute of Wood Science & Technology Campus,
P.O. Malleswaram, Bengaluru-560 003 (India)
E-Mail: iaws.india@yahoo.com Website: http://www.iaws.org.in

The Indian Academy of Wood Science was founded in 1968 to advance the knowledge of wood science & technology and covers in its activities all the aspects related to wood, cellulose and their products such as logging, saw milling, wood working, plywood, fibre boards, particle boards, improved and composite woods, cellulose and cellulose based sciences and industries and allied fields. The Academy runs a Journal called "Journal of the Indian Academy of Wood Science". In addition to this, it also organises seminars and workshops. During some annual meetings, lectures from eminent scientists are also arranged. The Academy has joined hands with Springer, an internationally reputed publishing house, for bringing out the journal fully online for wider international readership. Authors may submit the manuscript of their research papers online following the Springer publication link http://www.editorialmanager.com/jiaw

APPLICATION FOR MEMBERSHIP

To,

The General Secretary
Indian Academy of Wood Science
Institute of Wood Science & Technology Campus
P.O. Malleswaram, Bangalore-560 003 (India)

Sir,

I wish to become a member of the Indian Academy of Wood Science and give below the necessary particulars for enrolling as "Corporate Member/Institutional Member/Individual Member" (as the case may be). Necessary remittance of Rs.* .... is made by a Demand Draft/Cash, which may please be acknowledged. I agree to abide by the constitution of the academy and agree to the code of ethics contained therein.

Place: .... (Signature of the Applicant)

Date: ....

1. Name of applicant in full (in block capitals)	
2. (a) Date of Birth, (b) Age (in case of individuals only)	
3. Academic and professional qualifications (in case of individuals only)	
4. Present employment/how engaged and brief history of previous career in case of individuals (separate sheet may be attached, if necessary)	
5. Brief description of general activities in case of Corporate, Institutional Members	
6. Address to which communications should be sent including phone, fax & e-mail	

* *Demand Draft should be drawn in favour of 'Indian Academy of Wood Science' and payable at Bangalore.*

Membership Type	Annual Fee	Life Time Fee
Indian :		
Corporate	N. A.	Rs. 100,000
Institutional	Rs. 2,000	N.A.
Individual	Rs. 500	Rs. 5,000
Foreign :		
Corporate	N. A.	US $ 2,500
Institutional	US $ 50	N.A.
Individual	US $ 20	US $ 200

(To be Photocopied for Use)

Action TESA®

HDF LAMINATE FLOORING

Action TESA® Celebrating

100 MILLION

SQFT FLOORING FLOORED

The very 1st Laminate Flooring manufacturing facility in India **"MADE IN INDIA, FOR INDIA"**. Action TESA Flooring is manufacture by Direct Pressure Laminated (DPL) flooring process where in the anti-abrasive aluminium oxide overlay along with the melamine impregnated decorative film is Directly Fused with the core substrate & the balancing film at the back. Action TESA is the 1st flooring manufacturer in India by forward integrating HDF from its own Plant.

ANTIVIRO™

KILLS 99.99% VIRUS, BACTERIA & OTHER MICROBES

Enriched With JOME TECHNOLOGY | Environment Friendly | Balanced Construction | ZERO BUBBLE FINISH | WAX COATING ON EDGES | Stain Resistant | BORER RESISTANCE | Cigarette Burn Resistant | Glue Free Installation | Fade Resistant | DIMENSIONALLY STABLE | Impact Resistant | Wear Resistant

Customer Care Service:

1800 3090 707

customerservices@actiontesa.com

www.actiontesa.com

Published by:

Institute of Wood Science and Technology
Indian Council of Forestry Research & Education
(An Autonomous Body under the Ministry of Environment, Forest & Climate Change)
P.O. Malleshwaram, Bengaluru - 560 003, Karnataka, India
E-mail: dir_iwst@icfre.org I Website: https://iwst.icfre.gov.in