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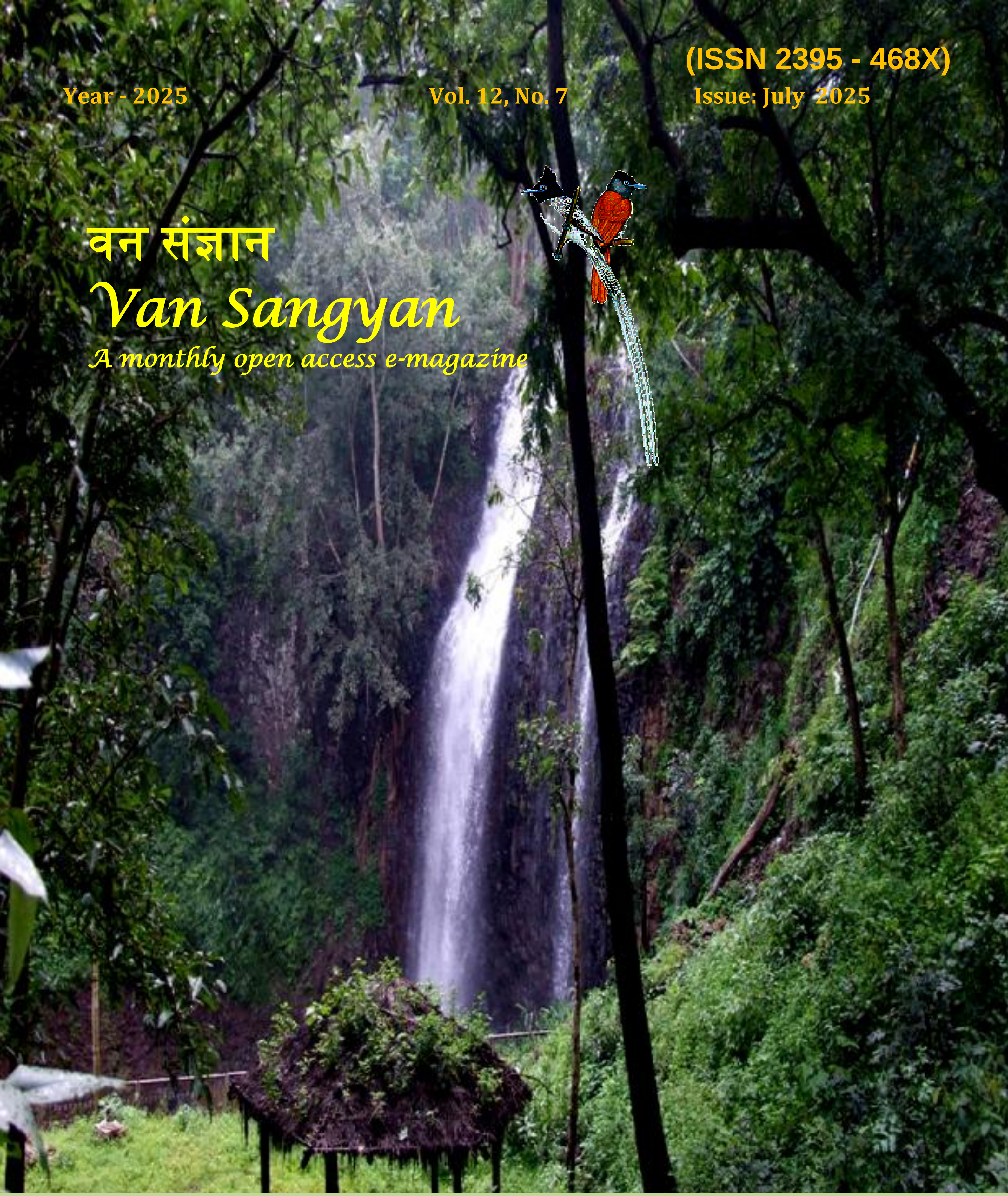

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Van Sangyan

Note to Authors:

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The articles can be in English, Hindi, Marathi, Chhattisgarhi and Oriya, and should contain the writers name, designation and full postal address, including e-mail id and contact number.

TFRI, Jabalpur houses experts from all fields of forestry who would be happy to answer reader's queries on various scientific issues. Your queries may be sent to The Editor, and the expert's reply to the same will be published in the next issue of Van Sangyan.

Cover Photo: Panoramic view of Achanakmar-Amarkantak Biosphere Reserve

From the Editor's desk

Non-Timber Forest Products (NTFPs) play a vital role in supporting the livelihoods of forest-dependent communities and preserving biodiversity, yet they remain largely neglected in forest policy frameworks. Current policies often prioritize timber, leaving NTFPs under-regulated, with unclear tenure rights, limited market access, and inadequate support for sustainable management. This neglect hampers both conservation efforts and local economic development. To address these gaps, there is an urgent need for inclusive, adaptive policies that secure community rights, invest in research and value chains, and integrate NTFPs into broader forest and climate strategies, ensuring their role in sustainable development is fully recognized and supported.

In line with the above this issue of Van Sangyan contains an article on Policy issues in non-timber forest products management: Preserving nature's hidden treasures. There are also useful articles viz. Fuelwood: A traditional energy source and its implications for sustainability, consumption, and global energy scenarios, The desired traits of tree and crop interaction for agroforestry system, The amazon rainforest: Importance, threats and conservation strategies, The agricultural significance of cow dung and urine: a scientific insight, Sustainable harvesting of medicinal and aromatic plants – Indian perspective, Deadwood: The hidden jewel of forest, Gene editing in forests: How CRISPR is transforming the future of trees, Wooden handicraft clusters/industries of southernmost part of Kerala- Products, problems, and possible solutions and Advancing Indian forestry: The role of electrophysiology techniques.

Looking forward to meet you all through forthcoming issues

Dr. Naseer Mohammad

Chief Editor

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Policy issues in non-timber forest products management: Preserving nature's hidden treasures

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Introduction

Forests are often celebrated for their majestic trees and lush greenery, but there is much more to these ecosystems than meets the eye. Beyond the timber that dominates the forestry industry, there exists a rich tapestry of resources known as non-timber forest products (NTFPs). NTFPs are economically very important natural resources & hence do not deserve to be written off as "Minor" Forest Produce as they are not inferior to timber – the accepted Major Forest Produce – especially for the forest dwelling or forest dependent communities. National Forestry Commission in 2006 recommended that the term "Non-timber Forest Products" needs to be defined. This recommendation explains the state of affairs regarding scientific management of NTFPs in India (MOEF, 2006). Even today, we in India do not have an accepted legal definition of NTFP. A synonymous term which is in vogue in India is MFP – the acronym for Minor Forest Produce.

The management and conservation of non-timber forest products, however, present unique challenges that demand thoughtful policy interventions. As global demand for these valuable resources increases, coupled with growing concerns over biodiversity loss and unsustainable practices, it is crucial to address the complex array of policy issues surrounding their sustainable use. This article aims to delve into the multifaceted realm of non-timber forest products management and shed light on the pressing policy issues that emerge in this context. By examining the intricate relationship between natural resource extraction, community livelihoods, and ecological balance, we can better understand the significance of well-crafted policies in ensuring the long-term sustainability of these vital ecosystems.

Relevance of NTFP in Indian context

The report of the sub-group-ii on NTFP and their sustainable management in the 12th 5-year Plan estimated that 275 million poor rural people in India—27 percent of the total population— depend on NTFPs for at least part of their subsistence and cash livelihoods (Malhotra & Bhattacharya, 2010). The report further highlights the importance or role of this natural resource in following manner –

- It is one of India's largest unorganized sectors having a dependent population of about 275 million, and with a business turnover of more than Rs.6000 crores per annum, the NTFP sector has however and unfortunately been neglected since the pre-independence period (Pandey *et al*., 2016).

- NTFP contributes to about 20% to 40% of the annual income of forest dwellers who are mostly disadvantageous and landless communities with a dominant population of tribals.
- It provides them critical subsistence during the lean seasons, particularly for primitive tribal groups such as hunter gatherers, and the landless.
- Most of the NTFPs are collected and used/sold by women, so it has a strong linkage to women's financial empowerment in the forest-fringe areas (Ghosal, 2014).

Poor attention to NTFP conservation

The NTFP sector either pays less attention to or completely overlooks in situ and ex situ conservation, genotype identification, gene banks, use of technologies, and genetic engineering.

Overexploitation and unsustainable harvesting protocols

NTFPs are susceptible to overexploitation due to their high demand and limited supply. Unsustainable harvesting practices, including over-harvesting, destructive collection methods, and lack of appropriate harvesting guidelines, can lead to ecological degradation and the loss of NTFP species. Policies should promote sustainable harvesting practices, including setting harvest limits, promoting non-destructive collection techniques, and enforcing regulations.

Policy-level inconsistencies

Many countries lack clear legal frameworks and policies specifically addressing NTFPs. Existing forestry laws often focus primarily on timber extraction, leaving NTFPs marginalized. This creates uncertainty and hampers effective management and regulation of NTFPs, including issues related to access, rights, and benefit-sharing.

Inadequate infrastructure, and post-harvesting facilities/skills

In most places in India neither the Forest Department nor the procurement agencies nor the Gram sabha/Panchayat nor do the institutions of primary collectors have proper storage facilities. In the absence of a proper storage facility, some NTFPs that are perishable and biological in nature must be disposed of right away. Because there isn't a sufficient storage facility, the major collector is therefore susceptible to a distress sale or a sale at a low price. Furthermore, the gatherer loses of superior gain due to a lack of value addition.

Volatile market

The NTFP market is extremely diversified and subject to frequent fluctuations; as a result, interventions based on assumptions of market stability or anticipations of a steady or expanding market frequently prove commercially unviable. Primary collectors and producers receive the smallest share of their labor-intensive products, necessitating the establishment of a Minimum Support Price (MSP) by the government.

Inadequate capacity and knowledge in NTFP management

In the past, community forestry and most forestry training programmes were heavily focused on the timber sector. As a result, these traditional methods of managing forests are unable to handle the demands of today's considerably more intricate, broad-ranging, integrated, and difficult problems, such as preserving biodiversity and adapting to changing climate.

Poor progress in research & development NTFPs often lack adequate scientific research and development support compared to timber resources. Policies should prioritize research on NTFPs, including species identification, ecological dynamics, sustainable harvesting methods, processing techniques, and product development. Investment in research and development can improve the understanding of NTFPs, inform policy decisions, and support innovation in sustainable management and utilization.

Absence of complimentary mechanism for NTFP crop failures

For many NTFPs, periodic crop failure is a natural phenomenon; however, as a result of climate change, this phenomenon is occurring more frequently. NTFP crop failure or bad crops have a severe negative impact on prehistoric tribal groups and hunter-gatherers, but there is no policy or mechanism in place to help the most vulnerable in these situations. (Planning Commission, 2011)

Recommendations for NTFP Management Resource Management

- Conservation of all genotypes including RET species, Development and Sustainable Harvesting with locally feasible models of community participation like People's Protected Areas in Chhattisgarh in deserving areas.
- Resource augmentation and development
- A zone wise GIS-based inventory of availability, cultivation status, demand and supply for NTFPs
- A cluster based approach after few successful pilot initiatives, for further development of NTFPs

Marketing

- Minimum support price (MSP) for NTFPs.
- Mechanism for market intelligence and information system.
- Efficient Certification system for improved trade.
- Revolving Fund or similar financial support to primary collectors and their institutions.
- Value chain development by aggregation, primary processing, grading, branding and certification.
- Eco- services of NTFP such as herbal ecotourism and local enterprise development.

Capacity Building and IEC (Information, Education & Communication)

- Formation and strengthening of local institutions-SHGs, FPCs etc.
- Strengthen & restructure existing institutions, particularly public sector procurement & marketing agencies.
- Modular training for primary collector, grower, entrepreneurs and traders.
- National and International exposure visits of relevant stakeholders.
- User friendly IEC material.

Research and Development

- Strengthening existing potential National/State R&D institutions.

- Undertaking state of art research on NTFPs, including nationally coordinated projects, collaborative projects.
- Prime focus on developing new/alternate marketability for single market NTFPs, low value high volume NTFPs, silviculture and conservation biology of NTFPs.
- The concept of Payment for Ecosystem Services (PES) needs to be tapped in future.
- Study on impact of non-anthropogenic factors like climate change.

Enabling Policy and Institutionalization

- Adopt a national level comprehensive policy on NTFPs
- Convergence of schemes implemented by different Ministries.
- Empowerment and strengthening of local institutions such as Gram Sabha, JFMC, Van Panchayat, primary cooperative societies and other procurement agencies.
- Ensure better Access and Benefit sharing mechanism with necessary legal provisions.
- Provide special compensatory support like additional quota in PDS, for NTFP crop failure, particularly for primitive tribals, hunter gatherers, etc.
- Ensure integrated and compatible policy environment for NTFP development (Bagh *et al*, 2011).

Some Government Schemes in NTFP Management

Van Samridhi, Jan Samridhi Scheme Period

April 2018 - March 2038

Goals

- Aims at enhancing economic returns to the rural households engaged in collection and selling of NTFPs
- Improving post-harvest handling, value addition and marketing of NTFPs

Major Scheme Components

- Identification and formation of Community User Groups (CUGs)
- Allocation of forest areas to CUGs
- Multilayered augmentation plantations to strengthen NTFP resource base
- Harvesting, postharvest handling and developing marketing facilities

Minimum Support Price Scheme Scheme

Mechanism for Marketing of Minor Forest Produce (MFP) through Minimum Support Price (MSP) and development of value chain

Introduced: 2013-2014

Initially, the scheme included 10 MFPs in 9 States. It was later expanded to 24 MFPs and in all States in 2017

Objectives

- To provide fair price to the MFP gatherers for the produce collected by them and enhance their income level
- To ensure sustainable harvesting of MFPs
- Emphasizes the development of a value chain for MFPs, which includes creation of cold storage facilities, warehouses, processing units

Van Dhan Yojana

Launched - 14th April, 2018

The Van Dhan Yojana or Van Dhan Scheme, a component of the 'Mechanism for Marketing of Minor Forest Produce (MFP) through Minimum Support Price (MSP) & Development of Value Chain for MFP' implemented by TRIFED as the nodal agency at the national level

Aim

Socio-economic development of the tribal population involved in collection of MFP helped them in optimum utilization of natural resources and providing them sustainable livelihood.

- An initiative targeting livelihood generation for tribal gatherers and transforming them into entrepreneurs.
- The idea is to set-up tribal community-owned Van Dhan Vikas Kendra Clusters (VDVKCs) in predominantly forested tribal districts.

Conclusion

The sector of NTFP hasn't received the attention among the policy & decision makers that it is worthy of. Among the forest managers also, this has long been a much neglected subject. So, the changes have to start from within the forest departments. Despite all the gaps in this sector, there are quite a few good practices going on in many states. They need to be studied, analyzed & documented for larger learning. The international community of forest managers has been working on the concept of Sustainable Forest Management (SFM) for a long time. There is very little movement in that direction in India. But, looking at the scale of below poverty line population in our country & their dependence on the NTFP resources, it is probably the topmost priority for us to start working on Sustainable NTFP Management in high earnest.

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Fuelwood: A traditional energy source and its implications for sustainability, consumption, and global energy scenarios

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Introduction

Fuelwood, also known as firewood, is one of the most traditional and widely used sources of energy across the world, particularly in rural areas and developing nations (May-Tobin, 2011). It refers to wood that is used as fuel for heating, cooking, and generating energy. As one of the oldest forms of energy used by humans, fuelwood has sustained households and industries for centuries. In many parts of the world, especially in areas with limited access to modern fuels, fuelwood continues to be a vital source of energy (Jagger and Shively, 2014)

Fuelwood is collected from forests, often in the form of fallen branches, twigs, and logs. In domestic settings, it is used to generate heat for cooking, space heating, and water heating, as well as for food preservation through smoking. It is also an essential resource in rural areas where access to electricity or gas is limited (Bailis et al., 2015). In developing countries, fuelwood plays a central role in the daily life of millions of people, providing an affordable and reliable source of energy. However, its collection and use can have environmental impacts, such as deforestation and air pollution (Masera et al., 2015).

Global Scenario

The global consumption of fuelwood is vast, with estimates ranging between 220 to 300 million tonnes annually. This usage contributes to a market valued at approximately nine billion US dollars, a number that continues to rise as the demand for fuelwood grows. In countries like India, fuelwood accounts for 20-30% of total energy consumption, with the domestic sector utilizing more than 90% of it (Shrivastava and Saxena, 2017). In other nations like Kenya and Sri Lanka, fuelwood is also widely used by industries, although its primary usage remains in households.

India Scenario

In India, fuelwood remains a critical energy source for many rural communities, where it is often used for cooking and heating. In India, the share of traditional biomass fuels in total energy consumption has been slowly falling and amounted to about 24.6% in 2010, assuming that wood accounts for 72.6% of total traditional energy consumption, the share of wood in total energy consumption of the country is estimated to be about 18%.S.C. (Bhattacharya, 2015) Despite the increasing availability of modern energy sources, the consumption of fuelwood continues to rise due to population growth, economic factors, and limited access to cleaner alternatives. Fuelwood use, however, is not without its challenges. In addition to its environmental impacts, the inefficient use of fuelwood can lead to health problems from indoor air pollution and contribute to the depletion of forest resources.

Key Characteristics

Source

Fuelwood comes from trees, shrubs, and sometimes agricultural residues or forest waste. It can be collected from natural forests, woodlots, plantations, or farm boundaries.

Forms: Fuelwood is usually found in the form of logs, twigs, branches, and wood chips. It can also be processed into charcoal, which is a more efficient fuel in terms of energy output and burning properties.

Uses

Cooking

In many parts of the world, especially in rural and developing regions, fuelwood remains the primary energy source for cooking.

Heating

Fuelwood is commonly used for space heating in colder climates, especially in traditional wood-burning stoves or fireplaces.

Energy Production

In some countries, fuelwood is used on a larger scale in biomass plants for generating electricity.

Importance

Sustainability

When managed properly, fuelwood is a renewable resource. However, over-harvesting can lead to deforestation and environmental degradation.

Economic Role

It provides an affordable energy source for millions of people, especially in developing countries, where alternatives like electricity or fossil fuels may be expensive or inaccessible.

Cultural and Social Role

For many communities, gathering fuelwood is part of their traditional way of life and provides livelihoods for people involved in collection, processing, and selling wood.

Challenges

Deforestation

In some regions, excessive use of fuelwood has led to deforestation, soil erosion, and loss of biodiversity.

Health Risks

The use of fuelwood in open fires or inefficient stoves can result in indoor air pollution, leading to respiratory diseases.

Sustainable Solutions

As a sustainable energy solution, alternative methods such as the production of charcoal created by heating wood in the absence of oxygen have gained popularity in certain regions. Charcoal provides some benefits over fuelwood, including cleaner burning and longer shelf life, but it also faces its own set of inefficiencies. The Government of India (GOI) has implemented several initiatives and policies aimed at reducing dependence on fuelwood and promoting cleaner, more sustainable alternatives. The primary goals of these initiatives are to address environmental concerns, improve health outcomes related to indoor air pollution, and promote energy efficiency in rural and urban areas.

Promotion of Clean Cooking Technologies

The GOI has launched several programs to replace traditional fuelwood use for cooking with cleaner alternatives. One of the key programs is the Pradhan Mantri

Ujjwala Yojana (PMUY), which aims to provide LPG (liquefied petroleum gas) connections to low-income households, particularly in rural areas.

National Biomass Cookstoves Program

This initiative focuses on promoting the use of improved biomass cookstoves, which are more efficient and produce less smoke compared to traditional fuelwood stoves.

Afforestation and Forest Management

To mitigate the depletion of forest resources due to fuelwood collection, the GOI has emphasized afforestation programs such as the National Afforestation Programme (NAP) and the Green India Mission. These programs aim to enhance forest cover and improve sustainable management of forest resources, ensuring that fuelwood collection does not lead to long-term environmental degradation.

Promotion of Alternative Fuels

The government has also supported the development of alternative sources of energy, such as biogas and renewable energy technologies. The National Biogas and Manure Management Program (NBMMP) encourages the use of biogas plants in rural areas, which provide an alternative to fuelwood for cooking and energy needs, while also managing organic waste.

Charcoal and Improved Carbonization Technologies

The GOI has promoted the development of efficient charcoal production technologies. Charcoal, produced through controlled pyrolysis of biomass, has lower emissions than traditional fuelwood and is often used in urban settings.

Policy and Regulatory Measures

The GOI has also implemented policies aimed at reducing deforestation and controlling the over-exploitation of forest resources. The Forest Conservation Act 1980 and National Forest Policy 1988 provide frameworks for the sustainable management of forest resources and encourage the use of alternative, renewable energy sources to reduce fuelwood dependency.

Criteria for Selection of Species for Fuelwood production

When selecting species for fuelwood, several factors are considered to ensure sustainability, efficiency, and adaptability to local environmental conditions.

High Calorific Value (Energy Content)

Species with high calorific values are preferred as they produce more heat and are more efficient in cooking or heating. This ensures less fuelwood is required for the same amount of energy output. **Examples**: *Acacia nilotica* (Babul) and *Prosopis juliflora* (Khejri)

Fast Growth Rate

Fuelwood species should ideally grow rapidly to ensure a sustainable supply. Fast-growing trees can be harvested more frequently, reducing the pressure on forests. **Examples**: *Leucaena leucocephala* (Subabul) and *Eucalyptus camaldulensis* (Eucalyptus)

Coppicing Ability

Coppicing is the ability of a tree to regenerate shoots from the stump after it has been cut. This trait is crucial for maintaining a renewable source of fuelwood without needing replanting. **Examples**: *Gliricidia sepium* (Gliricidia) and *Albizia lebbeck* (Siris)

Drought Resistance

Fuelwood species should ideally be drought-tolerant, especially in arid and semi-arid regions, where water is a limiting factor. **Examples**: *Azadirachta indica* (Neem) and *Acacia tortilis* (Umbrella Thorn)

Adaptability to Different Soil Types

The species selected should be able to grow in a wide range of soil types, including degraded or poor soils, to make it easier to establish fuelwood plantations in marginal lands. **Examples**: *Casuarina equisetifolia* (Casuarina) and *Salix spp.* (Willow)

Minimal Management Requirements

Low maintenance species are favored, as they require fewer inputs (such as fertilizers or irrigation) and are resistant to pests and diseases. **Examples**: *Azadirachta indica* (Neem) and *Moringa oleifera* (Drumstick tree)

Non-invasive or Environmentally Friendly

In many regions, care is taken to avoid planting invasive species that could disrupt local ecosystems. The selected species should contribute positively to soil health and biodiversity. **Examples**: *Tamarindus indica* (Tamarind) and *Madhuca longifolia* (Mahua)

Ash Content

Species with low ash content are preferred for fuelwood, as they produce less residue during burning, making them more efficient and cleaner to handle. **Examples**: *Tectona grandis* (Teak) and *Gmelina arborea* (Gmelina)

Other Uses

Multipurpose species are often selected, as they can also provide fodder, timber, or other valuable products besides fuelwood. This adds economic and ecological value to the species. **Examples**: *Melia azedarach* (Drek) and *Faidherbia albida* (Apple-ring acacia)

Conclusion

In conclusion, while fuelwood remains a vital energy resource in many parts of the world, its sustainable use is increasingly important in the face of growing environmental concerns and the need for cleaner, more efficient energy sources. The scenario in India and other developing nations highlights the need for improved energy solutions, better management of forest resources, and greater access to alternative energy options.

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The desired traits of tree and crop interaction for agroforestry system

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Abstract
Around the world, agroforestry is gaining a lot of attention as a sustainable way to mitigate the effects of global warming and climate change. Agroforestry has been in one form or another since the dawn of mankind. Nonetheless, it is being extensively marketed as a type of climate-resilient farming that will not only be able to endure altered environmental impacts, but also increase the quantity of vegetation. Therefore, more information regarding the optimal and desirable characteristics of tree species and crops is required in order to promote the stakeholders' acceptance and wider use of an agroforestry system. In an agroforestry system, successful integration of trees and crops depends on how well their interactions support productivity, sustainability, and environmental benefits. The goal is to promote positive interactions (like nutrient cycling and microclimate improvement) while minimizing negative interactions (such as competition for light, water, or nutrients).

Keywords: Agroforestry, climate-resilient, Farming, Sustainable

Introduction

Crops and woody perennials are purposefully planted together in an agroforestry system, which aims to make the best and most sensible use of the resources (land, water, sunlight, etc.). Consequently, agroforestry systems yield more perunit area, suggesting increased land production, in contrast to their individual sole systems. Agroforestry has been practiced in one form or another since the beginning of time. However, it is currently widely promoted as a climate-resilient agricultural production system to increase green cover in addition to overcoming the challenges posed by the climate. For the benefit of all parties involved, it is necessary to fully describe the ideal/desirable traits of tree species and crops for agroforestry systems.The main criterion for selection of a tree species is that it be liked by the farmer. A well-known tree is better than an unknown tree, but when a new species is introduced it is, of course, necessary to work with an unknown tree. A tree that is disliked by the farmer, for whatever reason, is always a non-starter in extension.

Desirable Characteristics of Tree Species for Agroforestry Systems

Soil and Water Management

Minimal Soil Moisture Interference

Tree species should not interfere with soil moisture.

Low Water Requirement

Selected species should require minimal water.

Non-competitive for Water

Trees should not compete with agricultural crops for water.

Deep Tap Rooted

Trees should have deep tap roots to access water from deeper soil layers.

Nutrient Management

Non-competitive for Nutrients

Tree species should not compete with crops for nutrients.

Low Nutrient Utilization

Trees should not deplete soil nutrients significantly.

Soil Fertility Enhancement

Trees should contribute to building soil fertility.

Leguminous Species Preferred

Species that can fix atmospheric nitrogen through their roots are preferable.

Sunlight Management

Non-competitive for Sunlight

Trees should not block sunlight needed by crops.

Light Branching Habit

Trees should allow sufficient light penetration to support crop growth.

Promote Crop Yield

Trees should facilitate better crop and pasture growth and yield.

Pruning and Maintenance

Withstand Pruning

Trees should endure pruning without hampering growth.

High Survival Rate

Trees should have a high survival percentage and establish easily.

Low Mortality

Trees should tolerate transplanting shocks well and regenerate lateral roots quickly.

Growth and Adaptability

Fast Growing

Trees should exhibit rapid growth, especially in the early years, and have short rotation periods.

Widely Adaptable

Trees should be adaptable to various agroforestry combinations.

Fodder Production

High Palatability

Trees should be palatable to livestock and have high digestibility.

Shelter and Soil Stabilization

Shelter and Soil Stabilization

Trees should provide protection for soils, crops, and livestock, and help control soil erosion.

Management Practices

Withstand Extensive Pruning

Trees should tolerate extensive pruning and lopping without significantly restricting growth.

Nutrient Cycling and Nitrogen Fixation

Nutrient Recycling

Trees should recycle nutrients effectively, returning them to the soil through decomposing leaves, twigs, and other organic matter.

Nitrogen Fixation

Species capable of converting atmospheric nitrogen into usable nitrogen through symbiotic relationships with Rhizobium bacteria are beneficial. Leguminous trees like Acacia, Leucaena, and Prosopis, as well as non-leguminous ones like Casuarina spp., are particularly useful for this purpose.By carefully selecting tree species with these characteristics, agroforestry systems can be optimized for productivity, sustainability, and ecological balance.

Sparse branching pattern

For understory crops to receive sunlight, the tree used for agroforestry needs to have a light/sparse branch pattern. Crops rely heavily on sunlight as a resource for growth. The lack of sunshine not only affects the duration of the crop by changing various developmental processes, but it also has an impact on physiological processes, which in turn reduce the yields of understory crops. Thus, tree species for agroforestry systems should be sparsely branched.

Deep tap rooted system

Most crops have shallow roots and draw water and nutrients from the top soil layer. Therefore, the introduction of woody perennials with deep tap root systems is preferred to avoid competition for growth resources between crops and tree species in agroforestry systems. The deeper soil layers supply the tap deep-rooted woody perennials with the water and minerals they need.

Quick rotation, fast growing Agroforestry prefers tree species that develop quickly and require little care.These kinds of tree species require less funding to establish and maintain, and because of their shorter gestation periods, they begin to generate income early.

Figure 1: Eucalyptus and wheat crop interaction in agroforestry system

Figure 2: Bund plantation based agroforestry system

Characteristics of crops in agroforestry system

Rapid growth and short duration

Agroforestry systems work best with short-duration crops that have a rapid growth habit and a 45–60 day life cycle. These crops lower irrigation water requirements, allow for multicropping, expenses for labor and inputs, in addition to avoiding conflict with tree species for growth resources. Because of their short lifespans and rapid phasic development, these crops are also the ones that tree species have the least effect on.

Tolerable to some shade

Crops that are sufficiently adaptable to shade should be used in agroforestry. By altering their morphology or phenology to adapt to low irradiance, these crops produce a yield with a modest yield penalty as compared to other agricultural crops. Shade-tolerant crops are therefore very sought after.

Supportive of dense tree growth

Because an agroforestry system modifies light, water, nutrients, and space, crops selected for it must be able to withstand high tree densities. Collectively, these have an impact on the physiological functions and general crop performance. For agroforestry systems, crops that thrive in high tree densities should be selected.

The capacity to withstand a variety of stressors

Both annual and perennial elements make up the agroforestry system, and in order to live, grow, and expand, these elements must contend for the same resources. To improve an agroforestry system's functioning and compatibility, crops that can withstand and partially tolerate both biotic and abiotic stresses should be selected.

The amazon rainforest: Importance, threats and conservation strategies

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The amazon rainforest- a global treasure

Amazon rainforest, a biodiversity hotspot, known for its incredible and rich biodiversity, is the largest tropical rainforest in the world, spans over 5.5 million square kilometers in South America with the majority located in Brazil. Stretching across nine countries (Brazil, Bolivia, Peru, Ecuador, Colombia, Venezuela, Guyana, Suriname and French Guiana), this region constitutes one of the most vital ecosystems of the planet (Butler, 2024).

Source: Unsplash/ Vlad Hilitanu

Amazon rainforest holds immense importance as it supports varying biodiversity, helps in maintaining climate stability by sequestering carbon, ensures fresh water supply by annual precipitation, influences weather patterns, provides various economic resources and also has cultural and spiritual importance. Apart of this, it sustains life on the Earth as it absorbs carbon dioxide and releases 20% of the world's oxygen contributing to Earth's breathable air supply known as "the Lungs of the Earth" (Das and Saha, 2021). Approximately 40% of the world's remaining tropical rainforests are located within the Amazon region (Das and Saha, 2021). It provides invaluable ecosystem services to the Earth majorly:

Precipitation

The Amazon rainforest plays a crucial role in generating its own precipitation, with transpiration processes accounting for approximately 50-75 % of this phenomenon. The trees release significant amounts of water vapor into the atmosphere through the process of transpiration. Although a considerable portion of this moisture precipitates locally as rain, some is transported by air currents to other regions of the continent. This phenomenon has been metaphorically described as "flying rivers" (Ferrante *et al.*, 2023).

Carbon storage

The Amazon rainforest, comprising around 390 billion trees, serves as a substantial reservoir of carbon, sequestering significant quantities within its foliage, branches and trunks (Plotkin, 2020). A study published in Global Change Biology estimated that this forest sequesters approximately 86 billion tons of carbon, representing over one-third of the total carbon stored in tropical forests globally (Lorenz, 2010).

Biodiversity

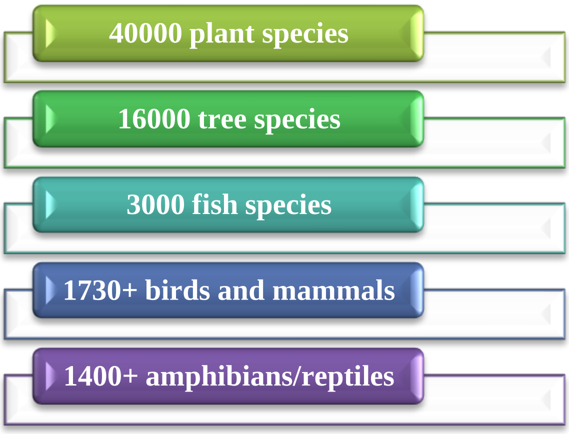
The Amazon rainforest harbors a greater diversity of plant and animal species than any other terrestrial ecosystem globally, with estimates suggesting that approximately 30 % of the world's species reside within its confines. Beyond their inherent worth as living entities, these species hold significant potential for human benefit, particularly in the realms of medicine, nutrition, and various other products.

Local benefits

The Amazon Basin's significant population mostly relies on the ecosystem services provided by the forest. The river systems serve as primary transportation routes, while logging and the harvesting of non-timber forest products constitute vital economic activities in numerous urban and rural areas (Ramirez-Gomez *et al.*, 2015). The rainforest plays a crucial role in mitigating, not entirely eliminating and fire risks but by improving air quality. Additionally, the fish populations in the tributaries of the Amazon are a critical source of protein for local communities. The annual flooding events contribute to the replenishment of nutrients in floodplain regions, which are essential for agricultural practices (Tregidgo, 2016).

Structure of the amazon rainforest

The Amazon is Earth's largest rainforest with diverse ecosystems and vegetation types, which include rainforests, seasonal forests, deciduous forests, mangroves and savannas reflecting varying environmental conditions and consisting of nearly 30% of all known species on the Earth. In addition to rich fauna, it hosts approximately about 40,000-80,000 floral species many of which are still undiscovered holding medicinal potential. The Amazon River is the second-longest river in the world after the Nile which influences the forest's lifeline.



Source:https://worldrainforests.com/amazon

Major keystone species

The Amazon rainforest serves as a habitat for a greater diversity of flora and fauna than any other terrestrial ecosystem globally. The keystone species significantly influence the forest and helps to maintain the ecological balance and ecosystem health. Different kinds of keystone species form a unique ecosystem in the amazon rainforest like predator keystone species control the population of other species which impact the food chain whereas ecosystem engineer keystone species help to create, destroy and alter habitats and mutualists are those that interact for mutual benefits. Among the forest inhabitants, there is plethora of well-known creatures which are becoming endangered due to habitat loss, over-exploitation, climate change, etc. that needs global concern and international conservation efforts to preserve biodiversity from extinction.

Keystone species of the Amazon rainforest

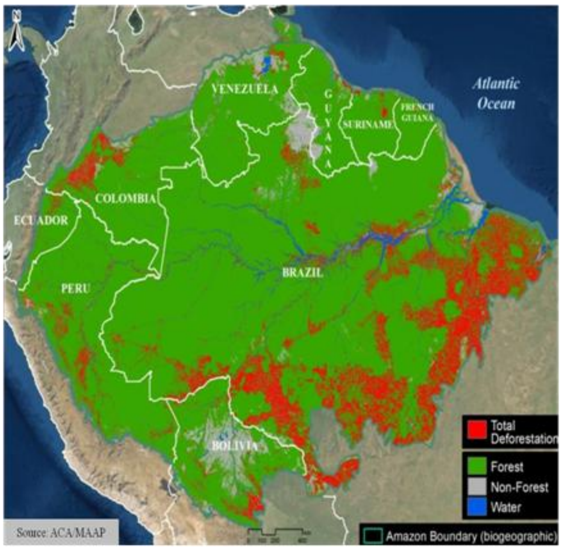
Predators	Ecosystem engineers	Mutualists
Jaguar (*Panthera onca*)	Leafcutter Ants (*Atta* and *Acromyrmex* spp.)	Brazil nut (*Bertholletia excels*) and Agouti (*Dasyprocta* spp.)
Harpy Eagle (*Harpia harpyja*)	Giant Otters (*Pteronura brasiliensis*)	Fig tree (*Ficus* spp.) and Fig wasps
Green Anaconda (*Eunectes murinus*)	Bees (*Melipona* spp.)	Howler Monkeys (*Alouatta* spp.) and Fruit trees
Black Caiman (*Melanosuchus niger*)	Capybara (*Hydrochoerus hydrochaeris*)	Orchid bees (*Euglossini* bees) and Orchids
Piranhas (*Pygocentrus nattereri*),	Giant Armadillo (*Priodontes maximus*)	Ceiba tree (*Ceiba patendra*) and Bats
Amazon River Dolphin (*Inia geoffrensis*)	Bromeliads	Acacia trees and Ants (*Pseudomyrmex* spp.)

The growing threat - tipping points of amazon

Deforestation and habitat destruction

It has been recorded as one of the major cause for the depletion of the Amazon forest which is accelerating at an alarming rate. Due to deforestation driven by logging, mining and large-scale agriculture, it releases significant amounts of carbon posing several consequences (Kalamandeen *et al.*, 2018). Deforestation in turn causes destruction of wildlife habitat. Each year, extensive areas of forest are destroyed, endangering wildlife and contributing millions of tons of carbon emissions into the atmosphere. Satellite images have shown dramatic losses in the forest cover (Butler, 2024).

Researchers warn and raise concern that if deforestation continues at its current rate, the Amazon could reach a point where it can no longer sustain itself leading to



"dieback". Large parts of the forest would dry out, transforming into savannah-like environment (savannization) and further accelerating climate change.

Global climate change

Climate change alters the rainfall patterns, leading to more frequent and severe draughts. The worst drought in the Amazon occurred in 2005. Remote towns were cut off when rivers dried up, and trade came to a complete halt. Scientists noticed an apparent relationship between precipitation in the Amazon and sea surface temperatures in the Atlantic Ocean during the drought.

Illegal activities

Illegal activities like mining, selective logging and clear-cutting disrupt ecosystem causing destruction of wildlife. Wildlife trafficking, illegal hunting and poaching also threatens biodiversity at a greater extent.

Fire

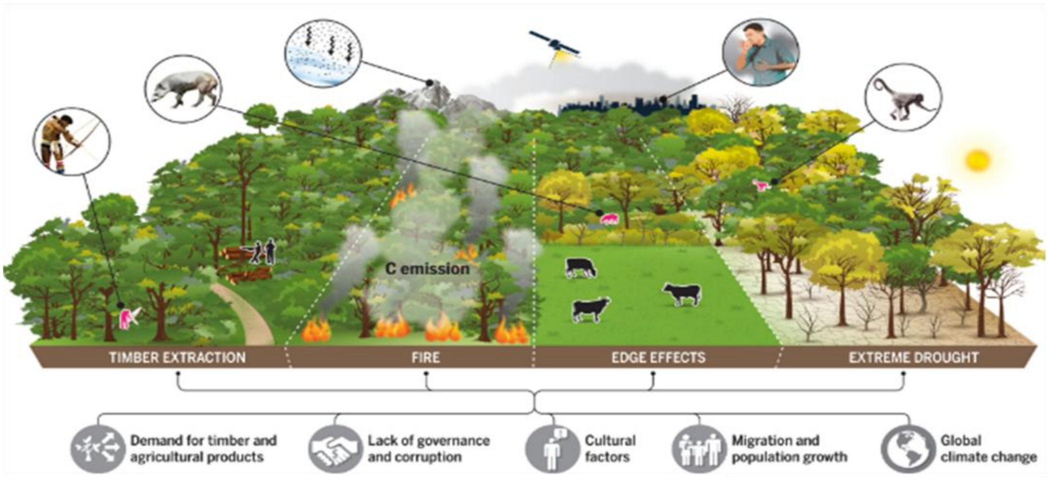
Due to changing climate, fires have also plagued around destroying ecosystem and endangering wildlife. High temperatures dry out the rainforest making it more susceptible to fire. According to Rhett A. Bulter (2019), over 100 million metric tons of carbon was released into the atmosphere as thousands of square kilometers of land burnt for months at a time.

Indigenous rights violation

Land is crucial for social identity and wellbeing, as it validates cultural identity and provides autonomy for collective decision-making. As indigenous tribes remain isolated from the outer world, they are often forced to leave their land due to lack of governance and corruption. Therefore, indigenous communities due to their rights violation are struggling for their survival. Owing to this, they may lose their cultural identity and traditional way of living.

Over-exploitation of resources

Over-exploitation of resources by indigenous communities to meet their basic needs including overfishing, overhunting, and over-harvesting of forest products deplete natural resources. Clear-cutting often due to large-scale deforestation for timber extraction and meeting needs of increasing population by converting forests to pastures or agricultural lands causes' destruction.



(Source: Lapola *et al.*, 2023)

Tipping points are exacerbated due to increased deforestation, forest fires and other threats but lack of quantification pushing closer to a critical threshold level which might lead to global warming acceleration, extreme biodiversity loss, disruption of rainfall patterns, regional droughts, habitat fragmentation and impact on indigenous communities (Nobre and Borma, 2009). In recent decades, heightened climatic variability has led to the degradation of approximately 2.5 million square kilometers of forest area, primarily due to factors such as fire, edge effects, timber extraction, and extreme drought conditions (Lapola *et al.*, 2023).

Conservation strategies

The necessity for the preservation of Amazon is that this destruction has sparked outrage and concern across the globe and it would be affecting human lives. Currently, the Amazon has already lost about 17% of its original forest cover (Flores *et al.*, 2024). Researchers report that changes in the Amazon forest are being driven by anthropogenic actions than naturally occurring environmental changes of the past. To prevent it from reaching its catastrophic tipping point requires urgent global action to prevent collapsing.

Addressing deforestation and habitat destruction

Environmental activists and scientists have called for immediate action to halt deforestation and protect its vital resources. Amazon contains around 150-200 billion tons of carbon helping to stabilize regional and global climate by sustainable forest management, investment in reforestation efforts, rehabilitation and increased productivity of forested lands using improved technology by increasing awareness about sustainable consumption choices.

Mitigating climate change and fire hazards

Global climate action and international efforts to reduce greenhouse gas emissions can help in mitigation of climate change. Controlled burning, early detection of fire, preventing large scale wildfires and involving local communities in fire prevention and management can control fire hazards.

Combating illegal activities and protecting indigenous rights

Conservation projects aim to restore socio-natural relations, combat illegal activities and protect indigenous rights. Initiatives including expansion of protected areas, land reform policy and law enforcement could be taken to conserve the ecosystem (Butler, 2019). Displacement of indigenous communities leaves them vulnerable but they are the most knowledgeable conservationists, preserving the last remaining intact forests and addressing the climate crisis (Garnett *et al.*, 2018). They have nurtured their forests for millennia, preserving 80% of the world's biodiversity (Sobrevilia, 2008).

1. Overcoming resource exploitation: Promotion of sustainable resource management by sustainable fishing, hunting and gathering practices, community-based resource management reduces demand for over-exploitation and obtain ecosystem services. Besides this, sustainable agricultural and agroforestry practices and ecotourism could offer alternatives benefitting both the environment and local communities (Porro *et al.*, 2012).

Conclusion

Amazon’s faith is tied to our own fate as it is just more than a forest but it serves as the essential support system for the entire planet. So, its protection and conservation is a human need and not just an environmental issue. As climate change becomes an ever-growing threat, there is an urgent need to preserve and conserve wildlife.

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The agricultural significance of cow dung and urine: a scientific insight

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Abstract

Cow dung and urine are valuable by-products of livestock farming, playing a crucial role in sustainable agriculture and environmental conservation. Rich in diverse microorganisms, including bacteria, fungi, and actinomycetes, these organic materials contribute significantly to soil fertility, nutrient cycling, and plant growth. The microbial communities in cow dung facilitate the decomposition of organic matter, improve soil structure, and enhance water retention, while cow urine harbours nitrogen-fixing and antimicrobial organisms that promote plant health. Additionally, cow dung and urine serve as natural biofertilizers, biopesticides, and composting agents, supporting organic farming and eco-friendly agricultural practices. Beyond agriculture, these bio-resources possess medicinal properties, contributing to traditional therapies and disease management. The microbial potential of cow dung and urine also extends to bioremediation, helping degrade pollutants and restore soil health. This article highlights the microbial significance of cow dung and urine, emphasizing their multifaceted applications in sustainable agriculture, environmental sustainability, and therapeutic uses.

Keywords: Cow dung, Cow urine, Microbial diversity, Sustainable agriculture

Introduction

Cow dung and urine are essential by-products of livestock rearing, playing a crucial role in sustainable agriculture. These organic materials are rich in diverse microorganisms, including bacteria, fungi, actinomycetes, and protozoa, which significantly contribute to ecological and agricultural processes.

The microflora in cow dung and urine enhances soil fertility, facilitate nutrient cycling, composting, and suppress pathogen and making them essential components in organic farming and sustainable agroecosystems. The microbial composition of cow dung and urine varies depending on factors such as the animals' diet, health status, and management practices. Cow dung is known for its abundance of cellulose-degrading bacteria, which facilitate the decomposition of organic matter, while cow urine harbours nitrogen-fixing and antimicrobial organisms. Together, these microbial populations form a natural nutrient-recycling system essential for maintaining soil health and productivity.

Microorganisms isolated from cow dung are widely used in biofertilizers, biopesticides, and composting agents.

Similarly, cow urine is recognized for its therapeutic properties and is used in traditional practices for its antimicrobial and bioenhancing potential. Understanding the composition and functional roles of these microbial communities is crucial for optimizing their applications in agriculture and industry.

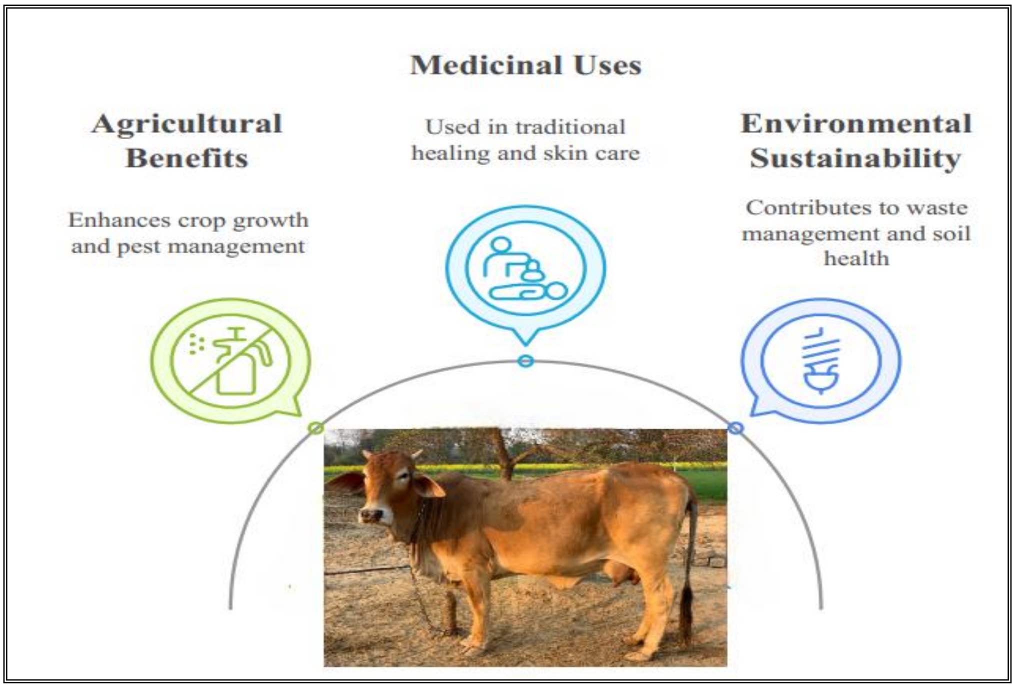

Fig.1: Benefits of Cow Dung and Urine

Cow Dung

Cow dung is an undigested residue excreted by herbivorous bovine animals. It's a mixture of faeces and urine in the ratio of 3:1 and mainly consists of lignin, cellulose and hemicellulose along with 24 different minerals including nitrogen, potassium, trace amounts of sulphur, iron, magnesium, copper, cobalt, and manganese (Gupta et al. 2016). In Ayurveda, cow dung is regarded as a natural purifier and is widely utilized in the field of agriculture, energy resources, environmental conservation, and therapeutic applications. The Cow dung-coated mud walls and floors act as natural disinfectants along with providing insulation during summer and winter months.

Cow dung is considered sacred in Hindu religion and is used in various religious ceremonies. As per Vedic scriptures cow dung from indigenous cow/ *Bos indicus*/ Zebu breed is considered better than that of other newer breeds (Randhawa and Kullar, 2011). The indigenous cow also contains higher amount of calcium, phosphorus, zinc and copper than the cross-breed cow (Garg and Mudgal, 2007). India has the largest livestock population in the World and the estimated total wet cow dung production in India is 562 million tonnes of which around 15 per cent is been utilized and the rest ends up being wasted or unutilized.

Microbial diversity and agricultural benefit

Cow dung harbours diverse microbial populations, including bacteria, fungi, and protozoa. These microorganisms contribute significantly to soil health by promoting nutrient mobilization and plant growth.

Phosphorus and Zinc Solubilization: Microbial genera such as *Bacillus subtilis*, Sphingomonas, Gemmatimonas, Pseudomonas, and Bradyrhizobium are utilized in phosphorus solubilisation (Fan et al. 2023; Swain et al. 2012). For zinc solubilization, species like *Bacillus megaterium* and *Pseudomonas kilonensis* play a vital role.

Sulfur Oxidation: Bacteria including Hydrogenophaga and *Bacillus subtilis* are effective in sulfur oxidation, aiding plant nutrient uptake (Mori et al. 2020; Swain and Ray, 2009).

Growth-Promoting Compounds: *Bacillus amyloliquefaciens*, *B. subtilis*, and *Lysinibacillus xylanilyticus* contribute to the production of indole-3-acetic acid (IAA), a critical plant hormone.

Traditional Practices: The practice of coating yam tubers with cow dung before planting is based on the belief that it enhances sprouting and seedling growth (Behera and Ray, 2021).

Biocontrol and Disease Resistance

Microbial species present in cow dung exhibit strong biocontrol properties. Fungi like *Aspergillus niger* and *Trichoderma harzianum*, as well as bacteria such as *Bacillus cereus*, inhibit seedling blight in crops like cowpea and maize (Muhammad and Amusa, 2003). Additionally, *Bacillus subtilis* is effective against pathogens such as *Fusarium oxysporum* and *Botryodiplodia theobromae*.

Bioremediation Potential

Cow dung microflora exhibits the capacity to degrade both organic and inorganic pollutants, making it an eco-friendly solution for environmental restoration. Microbial species such as Pseudomonas, Bacillus, and Aspergillus are effective in breaking down petroleum derivatives, agricultural pesticides, and biomedical waste. Fungal species like Periconiella have shown remarkable efficiency in decomposing biomedical waste, while cow dung slurry aids in the remediation of harmful agrochemicals (Wokem and Akpila, 2021).

Therapeutic Applications

Cow dung is a crucial component of the traditional Panchgavya (urine, milk, ghee, curd and dung), which is reported to have beneficial effects against conditions such as cancer and diabetes (Dhama et al. 2005). *Mycobacterium vaccae*, isolated from cow dung, demonstrates antidepressant properties and shows promise in treating asthma, cancer, and leprosy. Additionally, cow dung serves as a substrate for the production of fibrinolytic enzymes used in cardiovascular treatments (Vijayaraghavan et al. 2016).

Biogas Production

Cow dung is a vital resource for biogas production, generating sufficient fuel to meet the cooking needs of an average family. The process involves four distinct microbial-mediated stages: hydrolysis, acidogenesis, acetogenesis, and methanogenesis. Microbes like Methanosarcina and Methanobrevibacter play pivotal roles in methane production, contributing to renewable energy solutions (Kusmiyati et al. 2023).

Food Preservation

Lactic acid bacteria (LAB) derived from cow dung, including *Bacillus smithii* and *Lactobacillus equigenerosi*, exhibit antimicrobial properties and potential as natural food preservatives. Bacteriocin production by these bacteria ensures safer, chemical-free food preservation (Dhiman et al. 2021).

Table1: Comparison of soil properties with addition of dung

Characteristics	Dung	Dung + Soil (1:3)
pH	5.1	6.5
OC (%)	37.1	40.2
N (ppm)	40.1	86.3
P (kg/ha)	121	135.3
K (g/kg)	0.276	0.997
Moisture (%)	68	71

(Dhiman et al. 2021)

Cow Urine

- Cow urine, or "Gomutra," has long been recognized in traditional Ayurvedic medicine for its germicidal, antibiotic, and antimicrobial properties. Scientific studies have highlighted its ability to inhibit harmful pathogens like *Salmonella typhi*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Staphylococcus epidermidis*, and *Streptococcus pyogenes*, among others.
- On average, a healthy cow produces about 6 to 10 liters of urine per day. For farmers who rear two cows will benefit approximately 4,380 liters of urine annually. This significant volume can provide around 65 kg of nitrogen, equivalent to about 136 kg of urea, making it a valuable resource for sustainable farming practices.
- Nutrient cycling through cow urine is noteworthy as cows consumed only 20% of their nitrogen intake. Approximately 52% of the dietary nitrogen is excreted in urine and 28% in dung. Cow urine primarily contains nitrogenous compounds, trace minerals, and has a pH level between 7.4 and 8.4. Due to its low carbon content and nutrient-rich composition, it can be an effective natural fertilizer for promoting crop health and productivity while reducing dependence on synthetic agrochemicals.
- It is a traditional component of Ayurvedic practices, consists of approximately 95% water, 2.5% urea, and 2.5% trace mineral salts, including beneficial plant enzymes and hormones. Its composition highlights its value not only in agriculture but also in germicidal applications.
- The major portion of nitrogenous materials in cow urine is urea (69%), but it also contains: Hippuric acid (5.8%), Allantoin (7.3%), Creatinine (3.7%), Uric acid (1.3%), Creatine (2.5%), Hypoxanthine (0.5%), Ammonia (2.8%) and Free amino acid nitrogen (1.3%). The presence of bioactive compounds such as creatinine, urea, phenols, calcium, and manganese impart potent germicidal properties to cow urine, making it an

effective agent against various pathogens.

Table 2: Physicochemical and Bioactive Properties of Cow Urine

S. No.	Constituents	Concentration
1.	pH	7.4–8.4
2.	Specific gravity	1.025–1.045
3.	EC	>23.7 mS/cm
4.	Urea nitrogen	23,000–28,000 mg/L per day
5.	Total nitrogen	6800–21,600 mg/L per day
6.	Ammonia nitrogen	1000–1700 mg/L per day
7.	Allantoin	770–3400 mg/L per day
8.	Calcium	100–140 mg/L per day
9.	Chloride	10–110 mg/L per day
10.	Creatinine	15–20 mg/L per day
11.	Phenols	4.7580 mg/100 mL
12.	Urea	440 mg/L
13.	Hippuric acid	5.96–8.93 mg/L
14.	Total phosphorus	305 mg/L
15.	Amylase	90.236 units
16.	Magnesium	3.7 mg/L per day
17.	Potassium	14.4–27 mg/L per day
18.	Sodium	4300–6100 mg/L per day
19.	Ammonia	20mg/L
20.	Sulfate	3-5 mg/L per day
21.	Uric acid	150-530 mg/L per day
22.	Leucocyte	<15 µL

(Devasena and Sangeetha, 2022)

Agricultural Benefits of Cow Urine

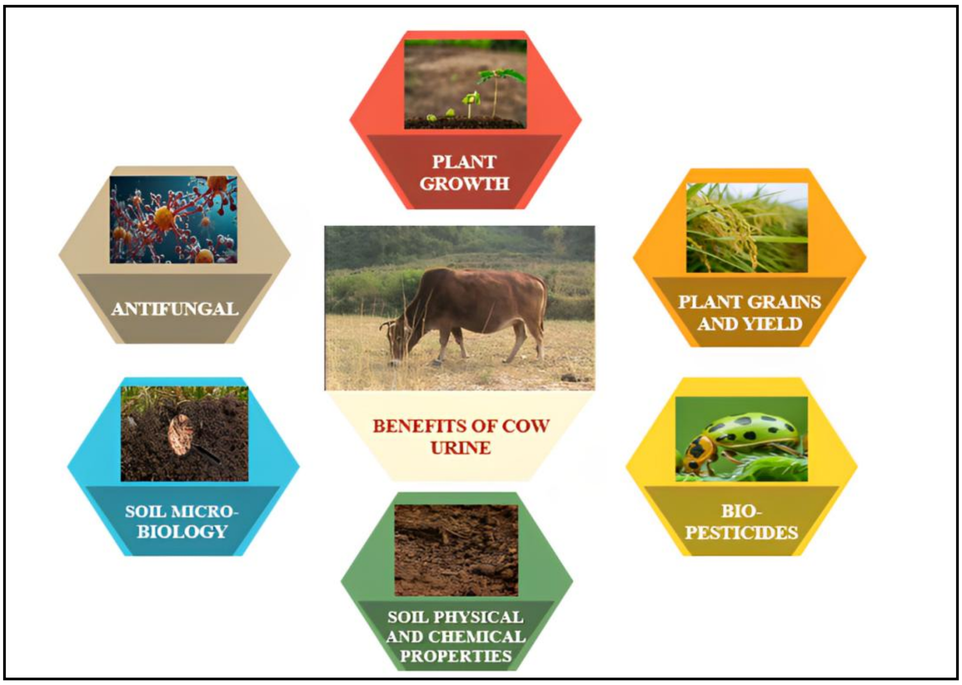

Fig.2: Benefits of Cow Urine

Plants growth

Cow urine could be a potent source to improve soil fertility, crop productivity and quality. A study was conducted at Sikkim which reported that the use of cow urine increased the growth parameters of buckwheat such as plant height, stem girth, leaves plant $^{-1}$, root length, seed plant $^{-1}$ and test weight was 116.2 cm, 0.64 cm, 13.5, 12.6 cm, 102 and 22.4g, respectively (Singh et al. 2015).

Plant grains and yield

The application of 1:1 (cow urine: water) reported the better yield from other treatment. Study reported the number of grains per panicle (grains) and yield per hectare (ton) in rice was 131.4 and 8.0, respectively (Polakitan et al. 2024).

Bio Pesticides

Cow urine, when enriched with neem leaves, serves as an effective biopesticide. These natural biopesticides are environmentally safe, do not persist in the food chain, and mitigate the adverse effects which are associated with synthetic chemical pesticides.

Soil Physical and Chemical Properties

A research experiment was conducted in Nepal and reported that the Foliar application of nitrogen at 150 kg/ha using cow urine resulted in the highest soil pH (6.0), organic matter content (5.43%), phosphorus (147 kg/ha), and nitrogen (0.31%), all of which were significantly higher than the control treatment (Sharma et al. 2016).

Soil Microbiology

Cow urine has a significant effect on soil microbial population. A study was conducted at Karnataka resulted that the application of FYM at 12.5 t/ha combined with cattle urine at 34,300 L/ha significantly increased the soil microbial population, including bacteria (47.0 × 10^5

cfu/g), fungi (34.6 × 10^4 cfu/g), and actinomycetes (40.0 × 10^3 cfu/g) (Veeresha et al.2014).

Antifungal Properties

The urine inhibits the growth of following fungi i.e. *Fusarium oxysporum*, *Rhizoctonia solani* and *Sclerotium rolfsii*.

Summary

Cow dung and cow urine play a significant role in maintaining microbial diversity and promoting soil health. Their microbial composition aids in nutrient cycling, enhances soil fertility, and supports plant growth. The microorganisms present in cow dung and cow urine also contribute to the breakdown of organic matter, improving soil structure and enhancing its water retention capacity. Furthermore, the microbial properties of these substances have potential applications in sustainable agriculture, composting, and organic farming practices. Overall, understanding the microbial importance of cow dung and cow urine is crucial for advancing eco-friendly agricultural methods and fostering environmental sustainability.

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Sustainable harvesting of medicinal and aromatic plants – Indian perspective

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Introduction

Sustainability is a concept on which social and natural scientists, and philosophers have expressed views from time to time. It can be defined as the practice of reserving resources for future generations without any harm to native and other components of it. If any activity is said to be sustainable, it should be able to continue forever. The organizing principle of sustainability is the sustainable development, which includes the four interconnected domains: ecology, economics, politics and culture. Sustainable condition is an ecosystem condition in which biodiversity, renewability and resource productivity are maintained over time (Banerjee and Shukla 2010).

The forestry sector, perhaps more than any other, is well positioned to provide worldwide leadership in the practice of sustainable development. The forestry community is accustomed to a long term perspective; it is reasonably knowledgeable about the response of forest ecosystem to natural and human disturbances; it is comfortable with the sustained yield principle, and, in few instances, it has attempted to practice a multiple and integrated use of forests. As compared to many other industries sectors, it is relatively easier to the forest community to expand its scope from sustained yield to sustainable development, which requires a shift from forest management to forest ecosystem management (Mishra ans Banerjee 2012).

The AYUSH Ministry in Government of India has created an exclusive Organization called National Medicinal Plants Board (NMPB) to promote research and development of herbal resources in the country. The focus is on conservation and sustainable collection and use of natural biodiversity as well as domestication of wild flora used in herbal industry.Approximately 70 per cent of India's population uses plants for health care (Ved and Goraya 2008). A recent study commissioned by India's National Medicinal Plants Board (NMPB) has estimated that 177,000 metric tones of medicinal plants are used each year by India's domestic herbal industry that 86,000 metric tones are employed within rural Indian households, and that 56,500 metric tones are exported through international trade. The high level of domestic use of medicinal plants, coupled with increasing demand for exports, has resulted in rapidly dwindling natural supplies. The vast majority of medicinal plants used within theAyurvedic system of medicine are collected from the wild, a situation that has resulted in the over-exploitation of many botanical species in India. However, Government of India has recently initiated various projects aimed at conserving medicinal plants, and some

Ayurvedic companies have begun to increase their commitments to cultivation and to sustainable wild collection standards.

India and China are two of the largestcountries in Asia which have the richest arrays of registered and relatively well-known medicinal plants and since the Indian subcontinent is well known for its diversity of forest products and the age-old healthcare tradition, strengthening this sector may benefit and improve the living standards of poor people of India. A great deal of traditional knowledge of the use of various plant species is still intact with the indigenous people, and this fact is especially relevant with the mountainous areas such as the Himalaya due to less accessibility of terrain and comparatively slow rate of development (Kala 2002).

Being a part of tradition, there are many other social issues attached with medicinal plants sector. The indigenous knowledge on harvesting, storage and usage of medicinal and aromatic plants (MAPs) built over centuries needs to be taken into account for improving the sector and allocating scare resources among the competing demands. Development of medicinal plants farming, encouragement of traditional herbal use and herbal healers, establishing medicinal plants conservation areas, establishing the Social Capital Trust for herbal healers, establishment of linkages among various stakeholders, etc., are among some of the social issues that need to be honored and addressed properly. The folklore on several medicinal plants and the formulation developed by using them is well recognized in different ethnic communities living in northern India. These folklores should be brought into laboratory for validation.

MAP Trade

According to Iqbal (1993), about 4000 to 6000 botanicals are of commercial importance; another source refers to 5000 to 6000 botanicals entering the local market (SCBD 2001). A thorough investigation of the German medicinal plant trade identified a total of 1543 MAP being traded or offered on the German market (Lange and Schippmann 1997). An extension of this survey to Europe as a whole arrived at 2000 species in trade for medicinal purposes (Lange 1998). Recognizing the role of Europe as a sink for MAP traded from all regions of the world, it is a qualified guess that the total number of MAP in international trade will be around 3,000 species worldwide. Medicinal plants were assumed to be a free commodity in most parts of India and were mainly collected from wild since ancient past, which can be made a significant contribution to the livelihoods, health care and income for those people who are residing in forest and pasture fringes and in rural areas. Medicinal plants were collected as food, vegetables, and medicine in both domestic and commercial purposes. Some medicinal plants are used for home herbal remedy whilst the traditional healers (*Baidya*) use the species as major ingredients for their medicinal preparations. However, the commercial collections of the species, started about few decades ago, are already threatening the populations of many species.

India's export earnings in 2000-01 from the trade is estimated at Rs. 3.2 billion or about USD 70 million per annum. With increasing popular demand for medicinal plants, both in South Asia and internationally, the trade is expected to grow at an estimated rate of 10-15% per annum. Besides health benefits, MAPs also provide crucial livelihood options for millions of rural people in South Asia, particularly women, tribal people and the very poor. India is the centre of South Asia's export trade in medicinal plants, and in this country alone, it is estimated that the collection and processing of medicinal plants contribute to at least 35 million workdays of employment a year (GOI 2000). India exported raw herbs with USD 330.18 million during 2017-2018 (Table 1) with a growth rate of 14.22% over the previous year (MoC&I 2019). The export of value added extracts of medicinal herbs/herbal products from India during 2017-18 stood at USD 456.12 million recording a growth rate of 12.23 % over the year before (MoC & I 2019).

Table 1. Exports of Herbs and Herbal Products for the last three years and 2019 in value (USD million)

Commodity	2015 - 16	2016 - 17	2017 – 18	April – November 2019 (Provisional)
Plant & Plant portion (herbs)	274.14	289.07	330.18	205.45
Ayush and Herbal products	364.00	401.68	456.12	290.96

Source - Ministry of Commerce and Industry, GOI (MoC& I 2019)

Medicinal and Aromatic Plants: Limited Resource

An enumeration of the WHO from the late 1970s listed 21,000 medicinal species (Penso 1980) globally. However, in India alone about 3,000 of 15,000 native species are used as drugs in Indian traditional medicine. If this proportion is calculated for other well-known medicinal floras and then applied to the global total of 369000 flowering plant species (Dasgupta 2016), it can be estimated that the number of plant species used for medicinal purposes is more than 50000. According to the Report of Royal Botanic Garden, Kew, U.K. there are about 391000 species of vascular plants in the world of which about 369000 species (94 per cent) are flowering plants.In India, the rich plant diversity of the Himalayas over 8000 angiosperms, 44 gymnosperms, 600 pteridophytes, 1737 bryophytes, 1159 lichens etc. has been a source of medicine for millions of people in the country and elsewhere in the world. It is generally recognized, however, that certain plant families have higher proportions of medicinal plants than others. Good examples are the Apocynaceae, Araliaceae, Apiaceae, Asclepiadaceae, Canellaceae, Guttiferae and Menispermaceae. In addition, these families are not distributed uniformly across the country. As a consequence, not only do some floras have higher proportion of medicinal plants than others, but also have certain plant families a higher proportion of threatened species than others.

Ayurveda, the oldest medicinal system in Indian sub-continent, has alone reported approximately 2,000 medicinal plant species, followed by Siddha and Unani. The *Charak Samhita*, an age-old written document on herbal therapy, reports on the production of 340 herbal drugs and their indigenous uses (Prajapati *et al.* 2003). Currently, approximately 25% of drugs are derived from plants, and many others are synthetic analogues built on prototype compounds isolated from plant species in modern pharmacopoeia (Rao *et al*,2004).

Sustainable harvest and use practices

Sustainable harvest is increasingly seen to be the most important conservation strategy for most wild-harvested species and their habitats, given their current and potential contributions to local economies and their greater value to harvesters over the long term. The basic idea is that non-destructive harvests and local benefits will maintain population, species and ecosystem diversity. Besides poverty and the breakdown of traditional controls, the major challenges for sustainable wild-collection include: lack of knowledge about sustainable harvest rates and practices, undefined land use rights and lack of legislative and policy guidance.

Despite awareness of the importance of sustainable harvesting, many collectors adopt destructive harvesting practices. They are compelled to do so due to poor economic conditions, population pressure, consequent resource use competition and market demand for MAPs. Researchers and local agencies are working to systematize sustainable harvesting techniques and methods through field research and capacity building programmes for collectors, traders and forestry field staff, but their research findings are poorly disseminated and therefore not widely implemented (Prasad *et al.* 2002, Bhattacharya and Hyat 2004, Lawrence 2006). Although governmental and non-governmental organizations regularly conduct awareness and training workshops on sustainable harvesting of MAPs, these efforts do not appear to have translated into sustainable harvesting practices in the field. Collectors pay little attention to quality and continue to collect prematurely since the currently used grading system (mostly controlled by traders) and market demand put a price even on inferior material (Durst *et al.* 2006). Although chemical analysis of raw material is gaining wider acceptance, lack of local facilities restricts its implementation at the field level. Manuals or standardized rules for quality control are generally lacking. Lack of nearby storage facilities often compels primary collectors to sell their materials directly to local agents or traders, and an improper maintenance practice during storage shortens shelf-life and may diminish the quality of the material. However, in some areas of Chhattisgarh and Madhya Pradesh local MAP storage facilities have been established and have improved economic returns for the collectors. Documentation related to collection, storage and traceability of MAP materials is still rare.

On many occasions, the collection of planting material, especially of rare and endangered medicinal plant species from natural habitats for various experimental purposes by researchers, also poses a threat on their natural populations in wild. The researchers must be aware on the germination potential, seedlings and rhizomes survival strategies of the desired species collected from wild for scientific experiments. Researchers must plant a similar number of individuals back in nature after completion of research work on the collected species (Dhyani and Kala 2005).

Local communities and their knowledge related to natural resources are being increasingly recognized globally. Participatory approach integrates people of different socio-economic and cultural status and helps to establish a need based and objective oriented local institution.Such an institution is aimed to facilitate coherent action and help the stakeholders to contribute in designing, implementation and appraisal of any methodology. It also helps the resource managers (in India they are the Forest Departments) to decentralize and broad base the conservation of valuable medicinal plants and other non-timber forest products, which provide livelihood support to many people.

There are certain traditional rules and regulations one has to follow while entering the Bughiyals (sacred groves) for vegetation collection in Uttaranchal. The persons who are protecting the Bughiyals will allow the inhabitants for collecting plant materials after thorough semi-structured interviews. They will allow the selected personfor a short period and it is believed that the selected persons are said to be selected by the Goddess herself and it is also believed that they act as a mediator between the supernatural powers and the protecting persons. People going for collection need to start early in the morning with an empty stomach wearing a white cotton dhuti. This mechanism ensures that they do not stay for long in the natural habitat of medicinal plants thereby preventing over-exploitation. Another example of efficiently managing the resources is revealed by the fact that the inhabitants are not allowed to visit the site during growing season with their shoes on. With shoes off, people would be cautious and careful to lace their steps, causing less damage to the sprouting vegetation. There is a common belief that wearing colourful clothes and making noises displease the goddess “Van Devi”, which could lead to serious punishment to the offender. Wearing colourful clothes and making noisedisturb the pollinators, which can adversely affect regeneration potential of such species. Another traditional mechanism for sustainable harvesting from the wild is that while returning from the forest, the inhabitants are required to leave a sample of produce as an offering to the goddess in a temple situated at the entrance of the village. Anyone found violating the rule is punished. This practice ensures sustainable harvesting of the resources from the wild.

The collection pressure on MAP varies among species owing to biological characters such as different growth rates (slow growing vs. fast growing), reproductive systems (vegetative or generative propagation; germination rates, dormancy, apomixes) and life forms (annual, perennial, tree). Species can be distinguished quite well in their susceptibility to over-collection if their life form and their plant parts collected are viewed together. Harvesting fruits from a long-lived tree presents a far lower threat to the long-term survival of the species than does collecting from an annual plant. Therefore, it may be stated that speciesmost susceptibleto over-harvest are habitat specific, slow growing and destructively harvested for their bark, roots or the whole plant. These species suffer most from harvesting and many of them have been seriously depleted. Within various communities across India there are certain sustainable extraction practices available only when the plant is used by traditional medicine practitioners. In case of plants where bulb or underground part (*Dioscorea*sp.) is used, a portion is left to allow the plant to grow in the next season. In case of species like (*Andrographissp*) the whole plant is never extracted rather a portion is kept to enable it to grow in the next season. But when the question of commercial extraction comes all such traditional norms are ignored making the process unsustainable.

Conclusion

Sustainable harvesting practice is the method of extraction of MAP from wild without causing any damage to its reproduction while avoiding any damage to its associates. Applying sustainable harvesting method in the wild is significant in conservation of resources and to fulfill the needs of forest fringe people and others who directly or indirectly get benefit from MAP. Medicinal and aromatic plants are globally valuable sources of herbal products, and they are disappearing at a high speed. Both conservation strategies (e.g. in-situ and ex-situ conservation and cultivation practices) and resource management (e.g. good agricultural practices and sustainable use solutions) should be adequately taken into account for the sustainable use of medicinal plant resources. The biotechnological approaches (e.g. tissue culture, micro-propagation, synthetic seed technology and molecular marker based approaches) should be applied to improve yield and modify the potency of medicinal plants.

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Deadwood: The hidden jewel of forest

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Introduction

The hidden treasure of forest carbon reserves,which although contributes significantly to it,but often neglectedis known as deadwood.Deadwood indicates all of the deadwood biomass including dead trunks, fallen branches and twigs, snags, stumps, either standing, lying or in soil. It can also be referred as 'Graveyard of Forest', a phase of transforming life unto death in the silvigeneticcycle of trees (Klamerus-Iwan *et al.*2023). It would be fair to state that deadwood and all the different forms exists in throughout the process of decomposition, gives shape to the forest ecosystem.Abundant deadwood proportion is the precursor of a stable and bounteous biodiversity as it provides much required nutrients to the soil for nurturing and protecting the living. Most of the times the deadwood present above ground is the subject to assessment for carbon estimation while the buried woods are metaphorically also buried at the time of investigation. In recent past, the positive aspects of deadwood have been raved about, discarding the negative aspects like deadwood being the origin of fire and insect pest outbreak.With the advancement in knowledge along with time, dissecting the presumptions, deadwood serves as a portal to life after itsdemise.The present need lies infocusing on determining the worth of deadwood, its contribution towards the ecosystem and ways to enhance its production and adoption of proper management practices.

Deadwood dynamics

The initiation of the process is always through onset of disruption in ecosystem equilibrium like an insect/disease outbreak, fire or wind etc. The death of a tree and its journey of transformation is a sequenceof interaction between disturbance course and productivity gradient. Among the components of deadwood, snag plays an important role. The fall of snag is dependent on events like cause of death, type of forest in question, the management practices adopted for the same.Often times the cause of emergence of deadwood remains a mystery as it's never one factor but an interaction of many which causes tree mortality. One of the many reasons rushing the time of fall is temperature; a higher temperature in a rather warmer climate tends to speed up the process of decomposition. Altitude also stands as a great booster of deadwood volume generation as it has shown favourable results in terms of increasing altitude. After the fall, it is subjected to degradation by effect of various intrinsic and extrinsic factors; gradual evolution of deadwood is marked. In Neotropical forest the degradation is highly controlled by intrinsic factors rather external environment.

Effects of precipitation on decomposition rates show sluggish results in lower temperature conditions and accelerate in warmer temperatures (Seibold et al. 2021). Open canopies help improve nutrient cycling and decomposition process in comparison to closed canopy. Rapid decay rates were substantiated by higher night time surface temperatures, high moisture and clay content along low pH values.

Deadwood volume and abundance is seen to be relatively higherin mixed forest than even- aged and thinned forest as it varies with affluent amount of trees ofdistinct size and age range. This particular reason is why a rapid decomposition is witnessed in regions of species diversification. Deadwood volume is seen to be three times higher in protected stands than shelter wood systems and two times higher than selection cutting system (Tavanker et al. 2022).The Deadwood generated by standing dead trees is comparatively higher than fallen dead trees, but the contribution of fallen ones to the total deadwood volume exceeds significantly.

Significance of deadwood

Deadwood ensures the sustenance of the different species associated with a particular tree or dead tree.The contribution of termites and microbes is (58-64)% and (36-42)% respectively, in terms of deadwood production. 50-70% of arthropod diversity linked to existence of deadwood. The Deadwood serves as a host for many organisms throughout its metamorphosis.Copious tree micro diversity can be spotted during true late stages of decay, in tree cavities, cracks, bark loss, although they account for no commercial value but serve as great contributor to the biodiversity. The primary fungal groups include ascomycota and basidiomycota which significantly associated with deadwood acts as a precursor to abundant bacterial population.

A healthy root growth is a result of decaying wood which indicates good air-water properties of soil. The release of organic matter from the decomposition process embarks thecourse by action as a substrate for microbial reaction, which in turn assures both carbon and nutrient cycling. Therefore, it also helps in formation of soil aggregates, improving the soil porosity in turn increasing the water holding capacity of soil.Stranding the deadwood by itself on soil affected by landslide helps microbial colonies build which then restores nutrient back to soil. The journey of deadwood down the slope covering different eco regions help strengthen the carbon network and water cycle, while broadening the biodiversity aspect. Deadwood also acts as a barrier to both rock slides and water runoff by acting as an effective water retainer. The water holding capacity of the deadwood is categorised by tree species concerned and time succeeded since death of tree. Deadwood if undergoes proper management can prove to be a great source of Dissolved Organic Carbon (DOC) production in soil. DOC induces microbial decomposition of organic matter leading to additional production of DOC. The CO2 emissions are moderated due to presence of organic extractives, lignin and sulphur content, fungal colonies.

Future prospectives

Deadwood being an important regulatory body of the ecosystem demands for adequate attention. The climatic variations over the past years, affecting the dynamics of the ecosystem pose a need for adoption of different models to optimise the process of decomposition, by accurately assessing the factors influencing decay rates. Estimations of deadwood decomposition through frequented decay paths can present the influential factors governing the same. Assessments surrounding tropical, subtropical, equatorial and subarctic forests for deadwood dynamics are negligible in comparison to temperate and boreal forests which need to addressed. This would help in knowing the similarity or contrasting patterns of decomposition of the different forest types. The inclusion of Deadwood inventories within the forest inventories can help in evaluation of deadwood production in an unbiased manner.

Conclusion

The ecosystem succession reveals deadwood as a highly influential factor in shaping the ecosystem. The progressive decay occurring provides different resources at each stage of it's transformation process.Deadwood although possess no life but nurtures and protects the living throughout its existence.The worsening of the climatic conditions and increasing concerns surrounding the possible catastrophe, deadwood has the potential to reduce the intensity of effects of climate change. In conclusion, deadwood dynamics is a vast sphere in need of exploration and attention.

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Gene editing in forests: How CRISPR is transforming the future of trees

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Imagine a forest that can survive drought, resist pests, grow faster, and store more carbon—all thanks to tiny changes in its genes. This is not science fiction anymore. Thanks to a powerful new technology called CRISPR, scientists are now able to edit the DNA of trees with incredible precision. This could revolutionize how we protect and manage our forests in the age of climate change.

What is CRISPR?

CRISPR (pronounced "crisper") is short for Clustered Regularly Interspaced Short Palindromic Repeats—a mouthful that refers to a system originally found in bacteria(Jinek et al., 2012). These microbes use CRISPR as a kind of immune defense to destroy viruses. Scientists figured out how to turn this system into a tool to cut and modify DNA in any living thing(Doudna and Charpentier, 2014).

At the heart of CRISPR is an enzyme called Cas9. Think of Cas9 as a pair of molecular scissors. It's guided by a piece of RNA (called sgRNA) to find a specific DNA sequence (Jinek et al., 2012). When it finds the match, it snips the DNA at that exact spot (Fig.1). The cell then tries to repair the break—often introducing small

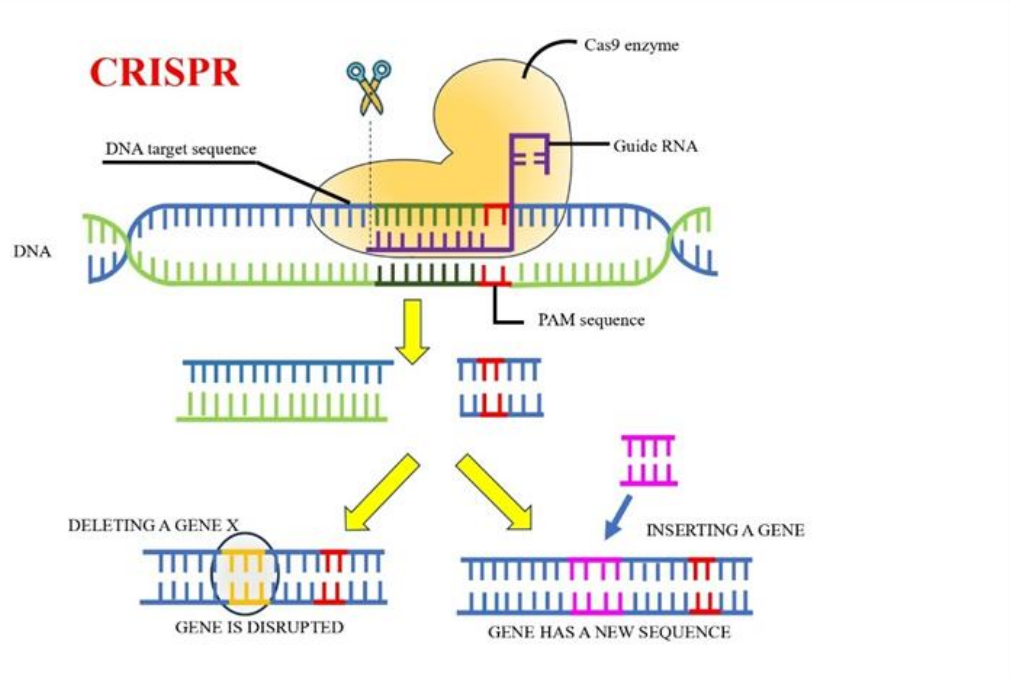

Fig.1.Workflow of the CRISPR/Cas9 system

changes or even new genetic instructions

Why Does This Matter for Forestry?

Trees are not like wheat or rice that grow in a few months. Many forest trees take **decades** to mature, which makes traditional breeding for improved traits slow and unpredictable (Tsai and Xue, 2015). CRISPR offers a game-changing alternative. It allows scientists to make precise changes to the tree's DNA, speeding up the process of developing better tree varieties (Bewg et al., 2018).

Here's what CRISPR could help us do in forests:

- Make trees more resistant to diseases and pests
- Improve wood quality and yield
- Enhance drought and heat tolerance
- Help forests adapt to changing climates
- Boost carbon sequestration for climate mitigation

Why Should Foresters Care?

Traditional tree breeding is slow. Trees often take 10, 20, or even 100 years to mature. Breeding them for better traits like disease resistance, drought tolerance, or improved wood quality can take generations (Neale and Kremer, 2011).

CRISPR flips that script. With this technology, we can:

Has It Been Tried on Trees?

Yes! In 2015, Chinese researchers successfully used CRISPR to edit the DNA of ***Populus tomentosa*** (Chinese white poplar), a common fast-growing tree. They targeted a specific gene (PtoPDS) using four guide RNAs. When the gene was turned off, the resulting plants turned albino—clear proof that the editing had worked (Fan, D. *et al.*, 2015). This was a major milestone, showing that that scientists provide (cong et al., 2013).

- Speed up trait development dramatically
- Directly edit genes linked to valuable characteristics
- Reduce reliance on pesticides and water
- Preserve genetic diversity while enhancing resilience

In a world grappling with climate change, forest fires, invasive species, and carbon emissions, CRISPR provides an urgently needed boost for forest conservation and productivity.

Real Progress: CRISPR in Action

In one pioneering study (Fan et al., 2015), scientists successfully edited the PtoPDS gene in *Populus tomentosa* (Chinese white poplar), a fast-growing tree widely used in plantations. Using four guide RNAs and **Agrobacterium-mediated transformation**, researchers induced genetic mutations that caused albino leaves—a visible sign of successful gene knockout.

This study proved that CRISPR can work in woody plants, not just crops like rice or maize. Since then, researchers have begun exploring how to use CRISPR to improve eucalyptus, pine, and other economically important tree species.

CRISPR can work in woody plants, not just in lab crops or animals.

CRISPR's Potential in Modern Forestry

Here's how CRISPR could reshape forest management:

Improved Wood Quality

Edit genes related to lignin content or fiber length to make stronger, more flexible wood.

Pest & Disease Resistance

Boost natural immunity to threats like bark beetles, fungal infections, and root rot.

Climate Adaptation

Tweak genes that help trees cope with drought, heatwaves, and salinity.

Carbon Capture and Growth Rate

Accelerate growth cycles while increasing carbon sequestration—key in fighting climate change.

Agroforestry and Mixed-Use Systems

Create trees suited to intercropping systems, enhancing food and timber production side by side.

But... What About the Ethics?

What's Next?

Even though CRISPR is widely used in medicine and agriculture, its use in forestry is still emerging. But with the growing availability of tree genome data, researchers can now identify genes linked to important traits like drought resistance or fast growth (Neale et al., 2017). CRISPR allows them to test these genes directly and figure out how they work.

This is especially important because climate change is stressing forest ecosystems worldwide. Trees can't move, and they take a long time to evolve naturally. CRISPR helps us **speed up the natural selection process**, while still working within the framework of a tree's own DNA (Bewg et al., 2018)

Looking Ahead

As climate change threatens ecosystems worldwide, forests must adapt faster than ever before. CRISPR gives us a chance to **accelerate natural solutions**, not replace them(Harfouche et al., 2019).Think of it as giving nature a nudge—helping trees survive, thrive, and support the planet.

As with any powerful technology, CRISPR raises important questions:

- Are genetically edited trees safe for wild ecosystems?
- Could edited genes spread to native forests?
- Will public trust accept

CRISPR-edited products?

Unlike genetically modified organisms (GMOs) that insert foreign DNA, **CRISPR often works within a species' existing genome**. Still, transparency, safety assessments, and inclusive public dialogue are essential to ensure ethical use in forestry(Zhang *et al.*, 2020).

For foresters, ecologists, and scientists alike, CRISPR represents a **new frontier in precision forestry**. Whether it's building climate-resilient forests or conserving endangered tree species, gene editing could become one of the most important tools in sustainable forest management (Jouanin *et al.*, 2020).

The forests of the future may not only be greener—they may also be smarter.

Final Thoughts

Forests are not just collections of trees—they're life-support systems for our planet. With CRISPR, we now have a tool to **make forests healthier, more productive, and more resilient**. Of course, ethical and environmental considerations must be addressed. But if used wisely, gene editing could help us protect these vital ecosystems for generations to come.

The future of forestry might just lie in its DNA.

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Wooden handicraft clusters/industries of southernmost part of Kerala- Products, problems, and possible solutions

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Abstract
The wooden handicraft industry plays a crucial role in the economy of Thiruvananthapuram district, Kerala, India. This study aimed to explore the current scenario of the wooden handicraft industry in the district and identify the challenges faced by the artisans and the industry. A sample of four industries/clusters was interviewed to gather the required data. The study highlighted the major challenges faced by the industry, including limited access to credit and the absence of proper marketing strategies. Based on these findings, it is recommended that the government and relevant organizations provide technical and financial support to the artisans and industry owners to improve the quality of their products and become more competitive in the market.

Keywords
Wooden Handicraft, Handicraft Industry, Raw Material, Thiruvananthapuram, Kerala

Introduction
Wooden handicraft industries play a vital role in the Indian economy, providing employment and income for many people. Kerala is well known for its articulate craftsmanship, which is an intimate part of her tradition. The local arts and crafts industry in Kerala is so strong that you can find handcrafted articles made of a wide range of materials, including wood, bell metal, brass, coconut shell, banana fibre, screw pine, straw, other natural fibres, papermache, textiles, cora grass, cane and bamboo, buffalo horn, and so on(Devaraj, 2021). Kerala handicrafts, due to their unique, original creative characteristics and an unsurpassed sense of colour, have earned a place on the Indian handicrafts map.

Wooden handicrafts have been a traditional art form in the Thiruvananthapuram district of Kerala for centuries. The industry has been a vital source of livelihood for many artisans and has played a significant role in the economy of the region by producing high-quality wooden handicrafts, including furniture, toys, and decorative items (Mahgoub andAlsoud, 2015). However, in recent years, the industry has been facing numerous challenges, including declining demand and competition from other materials (Upadhyay and Jain, 2019; Radhika, 2018). In this research article, we aim to provide a comprehensive overview of the current state of the wooden handicraft industry in Thiruvananthapuram district, Kerala.

Our conclusions are based on in-depth interviews with artisans, industry leaders, and experts in the field; they also provide a critical evaluation of the challenges faced by the industry and suggest recommendations for its revival and sustained growth. The findings of this research can inform policymakers, industry stakeholders, and the broader public about the importance of preserving and promoting this traditional art form in the region.

Materials and methods

Study area

The present study was carried out in some handicraft industries located in the Thiruvananthapuram district of Kerala, India. Due to strict COVID protocols, we could only cover four industrial units within the district. We visited each enterprise and collected various details based on the questionnaire provided.

Data Collection

A structured questionnaire was used to collect data from the sample population. The questionnaire consisted of questions on the demographic profile, type of wooden handicrafts produced, production process, raw materials used, market demand, employment, sales, and challenges faced by the industries. Both primary and secondary data were collected for this study. Personal interviews with industry owners and managers were used to collect primary data, while secondary data was collected from government reports, academic journals, and websites.

Data Analysis

The collected data were analyzed using descriptive statistics such as frequency distributions and percentages. The findings were presented in the form of tables and charts.

Ethical Considerations

Ethical clearance was obtained from the Institutional Review Board before the commencement of the study. The purpose of the study was explained to the participants, and their informed consent was obtained. Confidentiality of the data was maintained, and the identities of the participants were not disclosed.

Results and discussion

Distribution

Due to strict COVID protocols, we could only cover four industrial units within the district (Table 1). They are Nambeesan's handicrafts, Rahul handicrafts, Handicrafts Development Corporation Kerala Govt. (HDCK), and Kerala Arts and Crafts Village.

Table 1. Table indicating the Wooden Handicrafts Industrial units surveyed in Thiruvananthapuram.

Sl. No.	Name of the Industry	Location	Year of establishment
1	Nambeesan's handicrafts	Karaali, Vallakkadavu PO	2014
2	Rahul handicrafts	Muttathara, Vallakkadavu PO	2013

3	Handicrafts Development Corporation Kerala Govt. (HDCK)	Press Club Rd, Puthenchantha	1969
4	Kerala Arts and Crafts Village	Vellar, Vazhamuttom	2021

Raw materials and Products

Most of the raw materials are bought locally and also from outside the district. Marayoor and Nilambur's depots are the major places from where timber species are collected. Species like rosewood and teak are mainly obtained from outside the district. In the case of teak, the main reasons for using it are the golden yellow colour as well as the resistance to termites.

Unlike other wood-based industries, raw materials are unlikely to be imported from outside sources, except for industries such as Rahul handicrafts, which imply countries such as Myanmar for Burmese teak. Government enterprises like HDCK acquire their raw materials only through government auctions, as there are rules and regulations governing such industries.

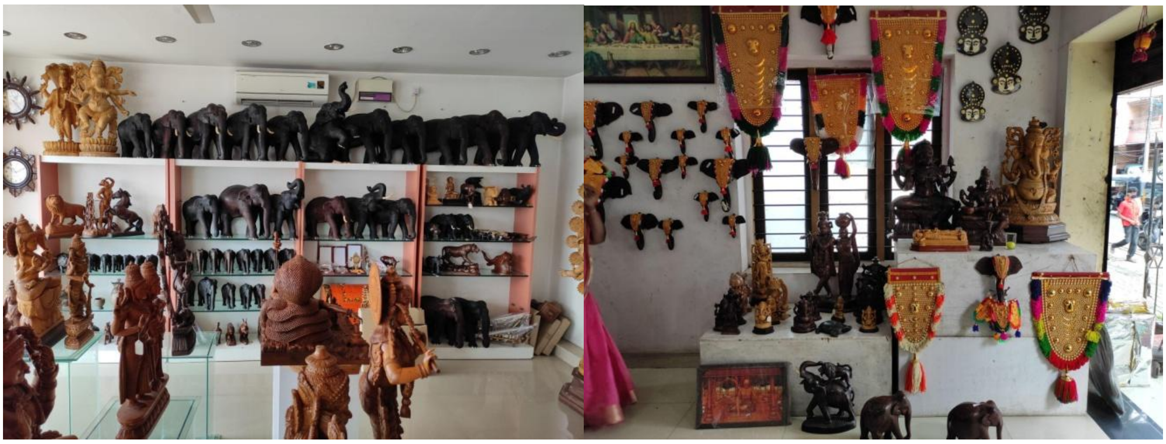

Fig No. 1 and 2: Wooden Handicrafts products

Table 2. Table indicating the principal product and subsidiary product and the major wood species used in industries.

Sl. No.	Name of the Industry	Major wood species used	Principal Product	Subsidiary Product
1	Nambeesan’s handicrafts	• *Dalbergia sissoo*	• Nettur petti (Amadapetti)	• Snake boat (Chundanvallam)

2	Rahul handicrafts	• *Tectona grandis* • *Thuja occidentalis*	• Wooden sculptures • Statues	• Kerala traditional mural painting • Coconut shell products
3	Handicrafts Development Corporation Kerala Govt. (HDCK)	• *Tectona grandis* • *Dalbergia sissoo* • *Santalum album* • *Thuja occidentalis*	• Wooden sculptures	• Mementos • Ice-cream bowl • Teacup • Spoon • Utensils • Mobile stand
4	Kerala Arts and Crafts Village	• *Tectona grandis* • *Pandanus utilis* • *Santalum album* • *Dalbergia sissoo* • *Liriodendron tulipifera* • *Saccharum officinarum*	• Handicrafts products	

Consumer category

The handicraft industry serves a diverse range of consumers, including individuals, private institutions, government institutions, and other firms. According to the scientific findings, individuals represent the largest consumer category at 34%, followed by government institutions at 33% and private institutions at 22%. The remaining 11% of the market is made up of other types of firms (Fig No. 3). It is worth noting that in most of these industries, the final products are purchased by individuals and government institutions. Only a few handicraft industries have purchase agreements with private institutions and other firms.

This diversity of consumers highlights the importance of producing a range of handicraft products that meet the needs and preferences of different types of buyers. It also suggests that the market for handicrafts is relatively stable, as government institutions and individuals are likely to continue to be reliable consumers of these products. This information may be useful for policymakers and industry stakeholders who are interested in supporting the growth and development of the handicraft industry.

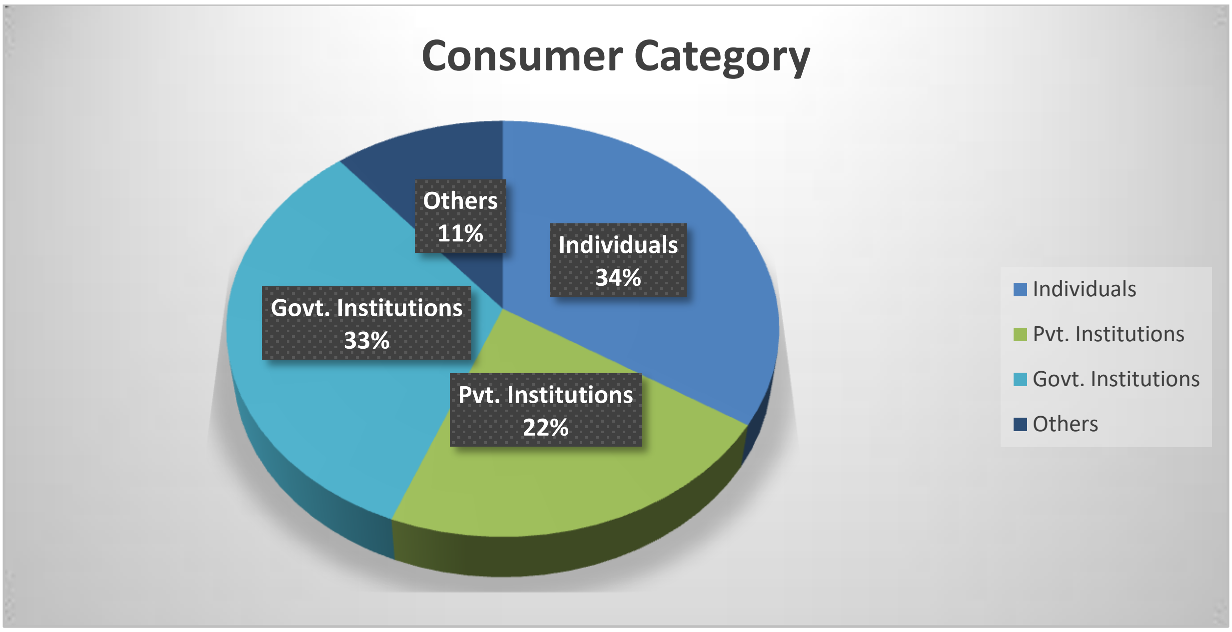

Fig No. 3: Consumer Category

Nature of Production and Competitors

In all these surveyed industries, the nature of production is continuous, and products are mainly sold wholesale or retail. It has been inferred that the entire market structure is competitive and is heavily influenced by the competitors within it. In the case ofNambeesan's handicrafts, small scale industries are the major competitors. This suggests that the industry is fragmented and characterized by numerous small players. Rahul handicrafts, on the other hand, faces competition from both small scale industries and public enterprises, indicating a more diverse market structure. Similarly, Handicrafts Development Corporation Kerala Govt. (HDCK) competes with small scale industries and public enterprises.Finally, Kerala Arts and Crafts Village faces competition from individuals, suggesting that the industry is more decentralized and characterized by independent craftsmen rather than organized entities. Overall, understanding the competitive landscape is crucial for firms to develop effective strategies and succeed in their respective industries.

Annual Production

It can be observed that annual production for the past 5 years has been almost unaffected till 2018, and thereafter there is a slight decline in the production unit due to the invasion of COVID-19, especially in the case of the Rahul handicrafts industry. The production is continuous and as per the needs of the customer. The graphical representation of annual production in the wood-based industry is mentioned in Fig No. 4.

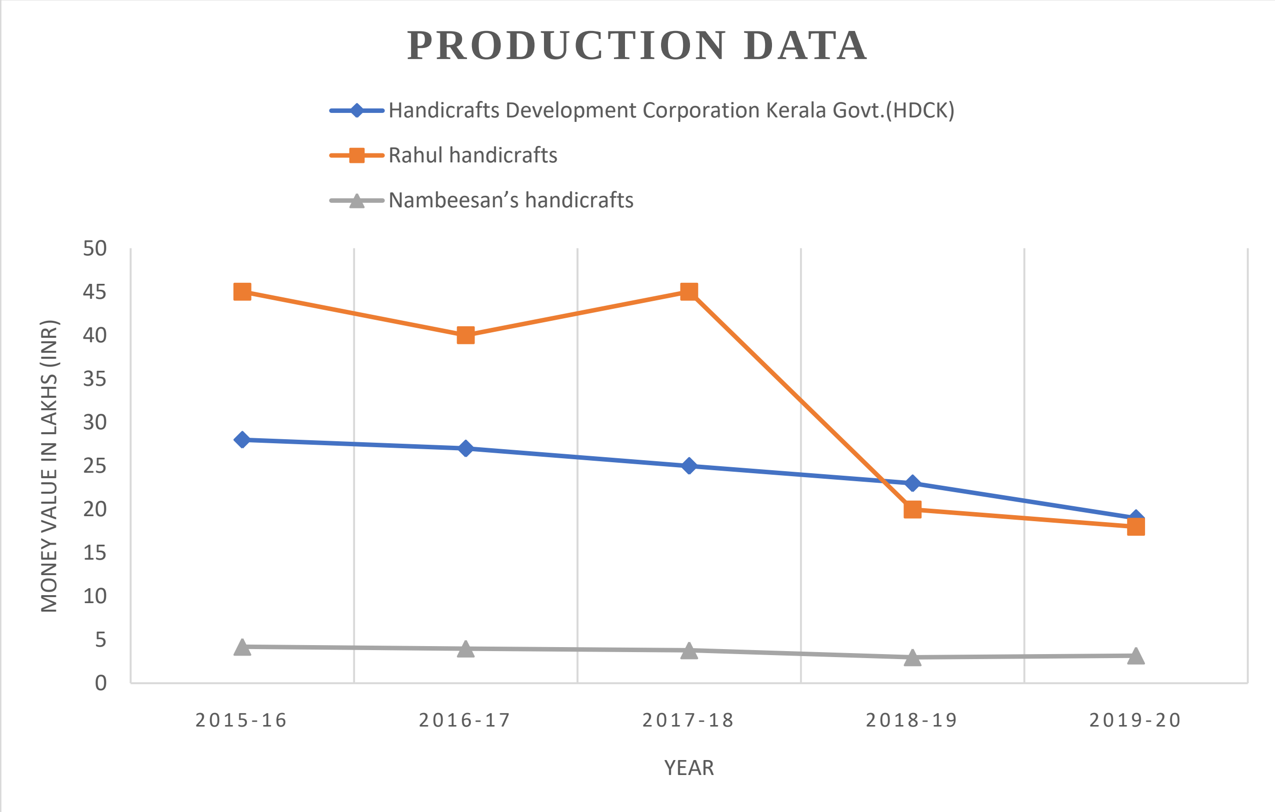

Fig No. 4: Production data of studied clusters or industries

Other industrial parameters (Workforce, Organizational pattern, and Machinery)

Workforce in industries

The industry employs both skilled and unskilled workers who assemble wooden pieces and then convert them. The casual workforce also includes migrant workers from other states too. The workforce in the handicraft industries varies significantly, with some having a higher proportion of skilled workers than others.

For instance, Nambeesan's Handicrafts employs 8 skilled workers and 4 unskilled workers, while Rahul Handicrafts employs 17 skilled workers and no unskilled workers. HDCK has 20 skilled workers and no unskilled workers, whereas Kerala Arts & Crafts Village employs 60 skilled workers and 38 unskilled workers (Fig No. 5). It is worth noting that these industries involve both skilled and unskilled workers, and the casual workforce also includes migrant labourers from other states. The workers are involved in setting up wooden pieces and converting them into finished handicraft products.

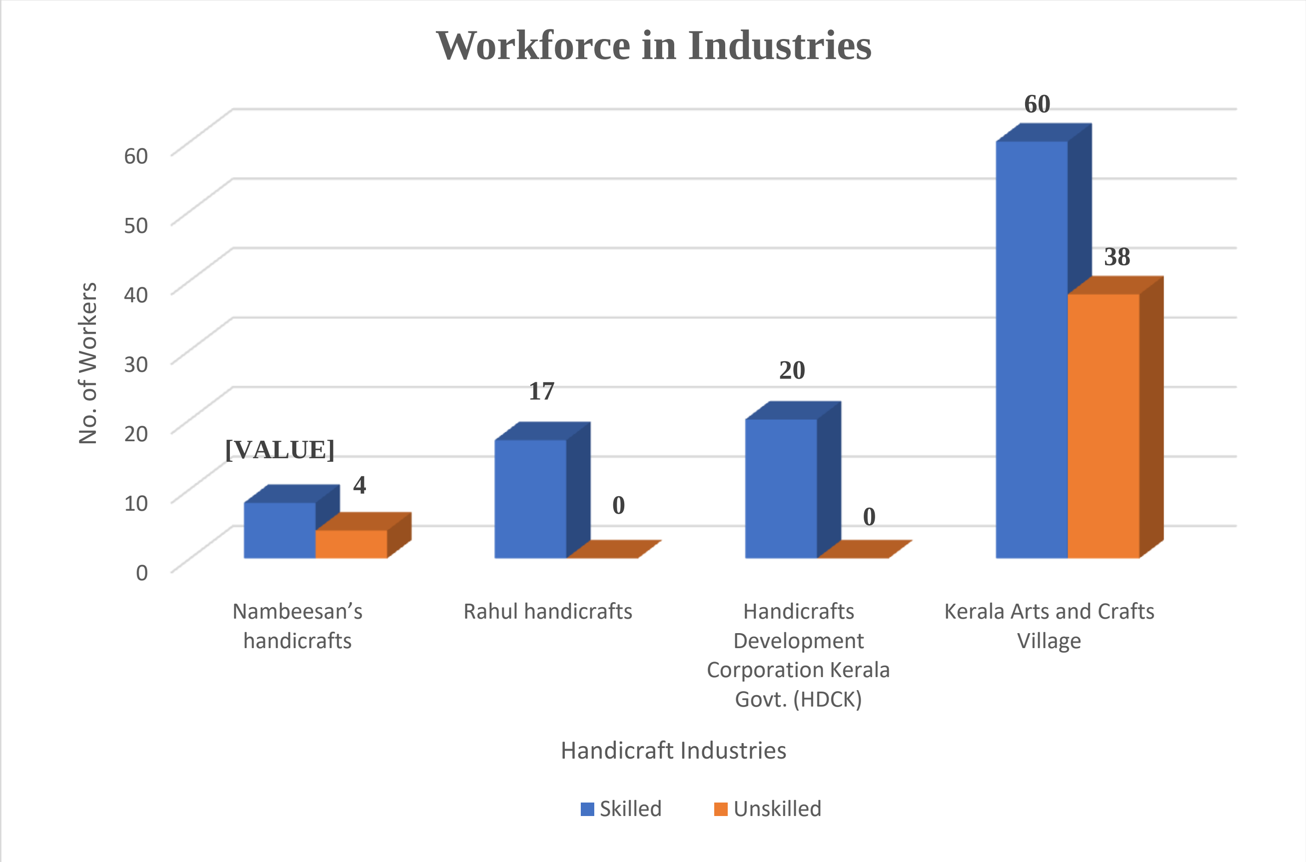

Fig No. 5: Workforce in industries

Organizational pattern

The organizational pattern of handicraft industries varies, with some being owned by private individuals and others being run by the government. Nambeesan's Handicrafts and Rahul Handicrafts are both proprietorships, while HDCK and Kerala Arts & Crafts Village are government-owned enterprises (Fig No. 6). Interestingly, none of the industries studied fall under the category of the cooperative or public sectors. It is worth noting that the major shares of these industries belong to either the proprietorship or government categories. This suggests that the organizational pattern of handicraft industries is diverse and that different types of ownership structures can be successful in this sector.

Machinery

Machinery plays a crucial role in the production of wooden handicrafts, and the scientific findings indicate that the major types of machinery and tools used in the handicrafts industries include band saw, planer, mitre saw, circular saw, and wood router. Interestingly, most of the industries studied are still using the machinery that was initially used, suggesting that there has been relatively little investment in upgrading or modernizing production processes.

In contrast to machinery, many of the tools used in handicrafts do not require any maintenance and are used lifelong without sustaining damage. The findings also suggest that most industries are still using traditional techniques for crafting wooden handicrafts, with only a few using modern techniques such as CNC cutting. This information highlights the importance of traditional craftsmanship in the handicraft industry and suggests that there may be opportunities to integrate modern techniques and machinery to improve production efficiency and quality.

Major problems faced by the industries/clusters

The handicraft industry is facing several major constraints that are affecting its growth and profitability. One of the main challenges faced by the industry is a decrease in sales during the COVID-19 pandemic, which has led to a downturn in the economy. Nambeesan's Handicrafts and HDCK both face challenges in accessing markets for their products, which can limit their sales and revenue. Also, private industries like Rahul Handicrafts face challenges in accessing financial resources to invest in their businesses and expand their operations. The lack of financial support from the government for private industries has further compounded the situation.

Proprietorship enterprises are particularly affected by the increase in workload, as the owner must manage investment, manufacture, and sale, leading to burnout. The unavailability of skilled labourers and the labour shortage in some industries have also posed a challenge. Rahul Handicrafts, HDCK, and Kerala Arts & Crafts Village faced challenges in attracting and retaining skilled labour, which can limit their production capacity and quality. The depreciation of the tourism sector has had a significant impact on the demand for handicraft products.

Another major constraint faced by the industry is the lack of use of the latest technology in government enterprises, leading to lower efficiency and competitiveness. HDCK faces challenges in maintaining and upgrading its machinery, which can limit its production efficiency and quality. The inconsistent market conditions and lack of support for individual artisans have made it difficult for the industry to grow. Moreover, the younger generation is not interested in pursuing traditional sectors like handicrafts, leading to a shortage of skilled workers in the future (Arif *et al.,* 2018). Customers are mainly focused on variability, looks, and price rather than quality, which is a major concern for the industry. The introduction of GST has led to a sudden drop in demand due to the hike in price. Finally, the handicraft industry is also facing competition from plastic and metal products, which are cheaper and more readily available.

Possible solutions for the improvement of Clusters/Industries

The survey was done to understand the demand and marketing trends of handicraft industries. From the survey conducted in Thiruvananthapuram, the handicraft industries in the district need enough support from the government in the form of subsidies, grants, etc. Increased wood technology research and development efforts should be initiated to screen out more industrially potential "lesser known" indigenous timber species useful for different manufacturing units. Electronics and computer-assisted machines for greater precision and better-quality sharpening can be used in industries. Lack of awareness of new wood application technology is the major problem faced by artisans. So, artisans need to be made aware of the new wood technologies.

Wood waste in terms of oversizing and planning appears to be rather low because the wood is cut according to the specific requirements of the specific handicraft product. The upliftment of these types of wood-based industries is necessary for the development of the industrial sector. For this reason, authorities should promote these types of industries by helping them with easier licensing procedures, grants, funds, power subsidies, etc. The government should take appropriate steps to bring small-scale industries together. Encouraging industries to raise plantations would help them meet their raw material requirements. Controlling plastic-made crafts through legislation not only reduces environmental pollution but also boosts the handicraft industry.

New generations should be encouraged to come up with innovative startups in the field and made aware of the prospects of online marketing and online sales. They should be made aware of the new experiments in the market and the scope of coconut wood processing, along with government support. Coconut wood is a raw material that is available in plenty in our state. So, the conversion and processing of coconut could give a larger profit to the sawmill owners and the small-scale wood industries. Another inference is that small-scale industries should join as a consortium for a bigger market, and this could increase the demand for their products (Ghouse, 2012). They should be made aware of the prospects of forest certification.

Conclusion

Decentralized, unorganized, and labour-intensive are three characteristics of the wooden handicraft industries/clusters found in the Thiruvananthapuram district. The industry has the best potential to provide rural areas with a significant number of jobs. However, the sector is currently confronted with a variety of problems, such as a shortage of loan options, problems with raw materials, fierce competition from mechanized items, technical improvements, etc. Proper legislative changes, awareness campaigns, market facilities, the reinforcement of wooden handicraft clusters through increased financial support, etc. are essential solutions to solve several issues in the industry, and an integrated stakeholder-specific strategy is the need of the hour.

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Advancing Indian forestry: The role of electrophysiology techniques

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Abstract

Insect infestations pose significant threats to forest plantations, leading to substantial economic losses. The private sector invests approximately USD 1.5–2 billion annually in plantations and USD 6.5 billion in the wood processing industry across Africa, Asia, and Latin America. Despite technological progress, conventional control methods such as trap-tree deployment, felling, and debarking remain predominant. Electrophysiological techniques — specifically electroantennography (EAG) and electro ovipositorgraphy (EOG)—in conjunction with gas chromatography-mass spectrometry (GC-MS), offer promising alternatives for identifying insect attractants or repellents. These advanced methods enable targeted pest control strategies that preserve beneficial insect populations.

Keywords

Electroantennography, Electroovipositorgraphy, Gas chromatography, Mass spectrometry, Timber, Volatile organic compounds

Introduction

According to the India State of Forest Report (ISFR) 2023, India's forest cover spans 715,342 km², representing 21.76% of the country's geographical area. An additional 112,014.34 km² is under tree cover. Between 2011 and 2021, tree cover increased by 4,904 km². Trees outside forests (TOF) account for 30.70 million hectares, or 37.11% of the combined forest and tree cover. Forests serve as critical ecosystems that support biodiversity, stabilize climates, and bolster national economies.

Forests are vital carbon sinks. In 2023, CO_2 levels reached 420 ppm—151% above pre-industrial levels—according to the World Meteorological Organization (WMO). Forest expansion is a key strategy to combat climate change. Globally, forests hold approximately 662 billion tonnes of carbon. India alone has an estimated forest carbon stock of 7,285.5 million tonnes (ISFR 2023).

Wood and timber, among the key forest products, are extensively used in industries such as construction, furniture, handicrafts, paper production, and plywood. India's wood stock is estimated at 6,429.64 million m³, of which 4,478.89 million m³ is within forests and 1,950.75 million m³ from TOF. Key timber species include *Shorea robusta*, *Tectona grandis*, *Pinus roxburghii*, and *Terminalia tomentosa*. In TOF, dominant contributors are *Mangifera indica*, *Azadirachta indica*, *Madhuca sp.*, and *Cocos nucifera*. The nation also has 154,670 km² of bamboo-bearing area.

The timber industry is poised for growth following the 2020 Central Public Works Department (CPWD) decision to lift the 1993 ban on wood use in construction. Demand for roundwood equivalents is projected to increase by 37% by 2050 (Global Forest Outlook Report).

India plants approximately 500,000 hectares of timber species annually, with teak being the flagship species.

Insect-Plant Interactions in Forests

Insects and plants interact in complex ways. While plants offer food, shelter, and oviposition sites, insects contribute to pollination, nutrient cycling, and biological control. However, several insects act as forest pests, causing severe damage to valuable timber species. Common forest pests in India include sal heartwood borer, bark beetles, woodwasps, and teak defoliators, among others. Traditional pest management practices remain limited in efficacy.

Electrophysiological techniques present a modern solution for managing insect pests. These methods can provide insights into insect behavior and host-plant interactions, which are crucial for forest and agricultural pest management.

Applications of electrophysiology in forest entomology

Understanding insect chemical ecology is essential for sustainable forest protection. Olfactory cues guide insects in host selection, mate finding, feeding, and oviposition (Hartlieb & Anderson, 1999). These sensory functions are mediated by olfactory receptors primarily located on the antennal flagellum (Keil, 1999). These receptors reside in sensilla—hair-like structures that vary morphologically and functionally.

Electrophysiology, a key neurobiological tool, is used to record insect sensory responses. Electroantennography (EAG) and single-sensillum recording (SSR) are widely used to evaluate antennal sensitivity to volatiles. Electroovipositorgraphy (EOG), an analogous technique, assesses ovipositor sensitivity in species that use these structures for chemosensation during oviposition.

Electroantennography (EAG)

Herbivorous insects rely on specific host plants for survival and reproduction. Volatile organic compounds (VOCs) play a critical role in host recognition. EAG is a technique that measures the summed electrical response of multiple olfactory sensory neurons (OSNs) to VOCs (Kaissling, 1971; Roelofs, 1984).

EAG Setup

- For excised antennae: Mount the antenna on a glass slide. Use two electrodes—one at the tip (recording) and one at the base (ground)—to measure responses to presented volatiles.
- For whole insects: Immobilize the insect, mount its antenna, and insert electrodes as above (tip and eye, respectively).

This method helps determine the sensitivity of insect antennae to various plant-derived volatiles.

Electroovipositorgraphy (EOG)

Many insects use ovipositors for chemosensation to identify optimal oviposition sites. Woodwasps and fig wasps are notable examples, with some species engaging in parasitism or hyper-parasitism. EOG allows researchers to study these behaviors.

EOG Procedure

1. Dissect the ovipositor in insect saline, removing the protective covering.
2. Mount the ovipositor on a slide with the ground electrode at the base and the recording electrode (≥10 MΩ) at the tip.
3. Stimulate the ovipositor with VOCs and record the responses. Use conductive gel if electrode contact is insufficient.

Integration with GC-MS

To identify the compounds eliciting significant EAG or EOG responses, use GC-MS to analyze VOC extracts from host plants. Subsequent behavioral assays with insects help confirm the biological relevance of these compounds. VOCs that induce strong electrophysiological responses may serve as attractants for traps, while non-responsive compounds may function as repellents.

Conclusion

Combining electrophysiological techniques like EAG and EOG with GC-MS provides a powerful toolkit for identifying insect attractants and repellents. These approaches have broad applications in forest and agricultural pest management. Furthermore, they enhance our understanding of complex interactions such as hyper-parasitism in species like fig wasps (Yadav & Borges, 2017), contributing to more targeted and sustainable pest control strategies.

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