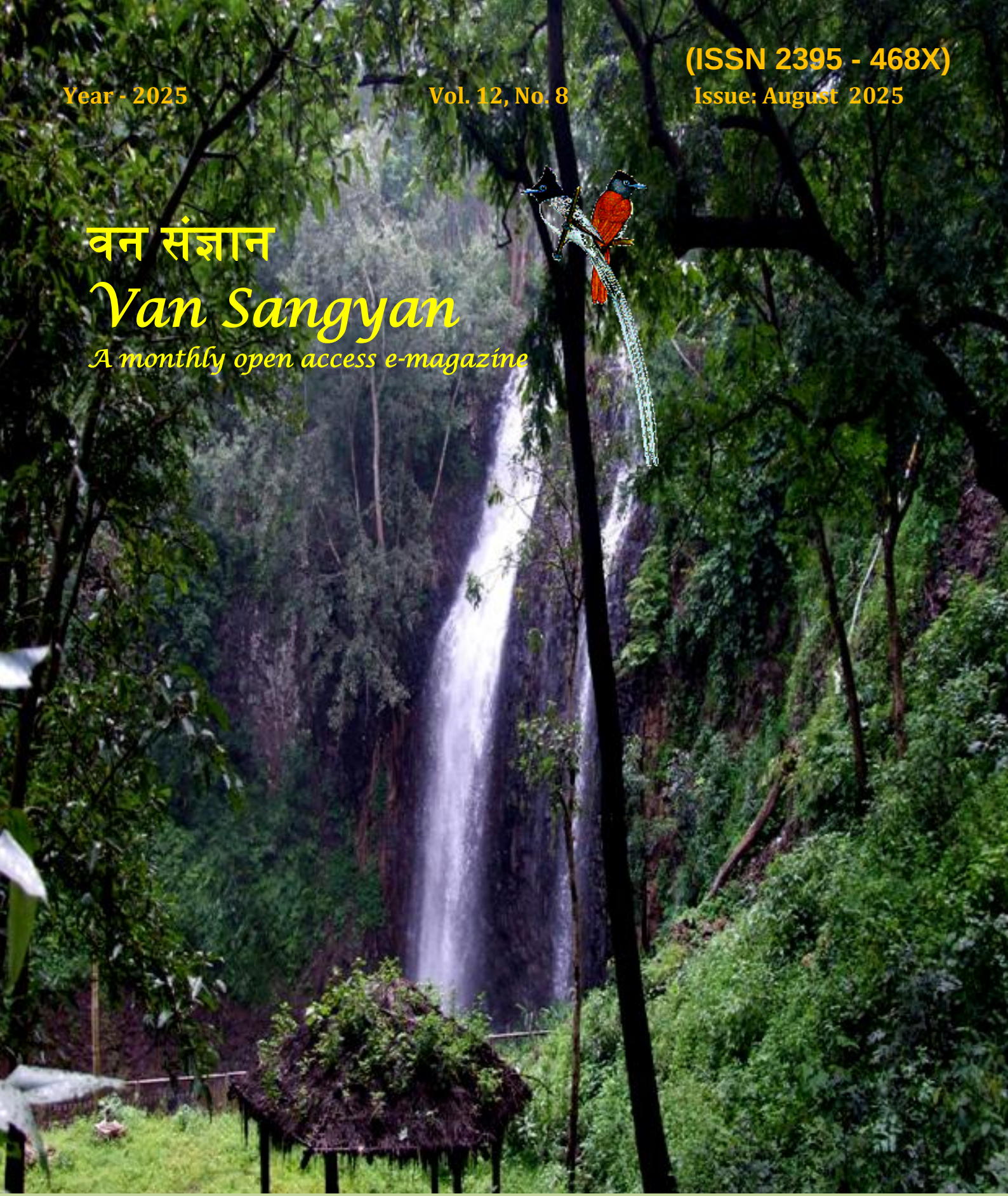
(ISSN 2395 - 468X)
Year - 2025 Vol. 12, No. 8 Issue: August 2025



वन संज्ञान
Van Sangyan
A monthly open access e-magazine

Indexed in:
COSMOS Foundation (Germany)
International Inst. of Org. Res. (Australia)
IIJIF

ICFRE-Tropical Forest Research Institute
(Indian Council of Forestry Research and Education)
Ministry of Environment, Forests and Climate Change (MoEFCC)
PO RFRC, Mandla Road, Jabalpur – 482021, India

Van Sangyan

Note to Authors:

We welcome the readers of Van Sangyan to write to us about their views and issues in forestry. Those who wish to share their knowledge and experiences can send them:

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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

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From the Editor's desk

Boswellia serrata – locally known as salai or "Indian frankincense" – is one of the dryland jewels of India's thorn and tropical dry deciduous forests. In Rajasthan it grows as scattered, often gnarled specimens across the Aravalli hills and other rocky outcrops where thin soils, low rainfall and a long dry season set the stage for xerophytic life. The species is simultaneously cultural (resin for ritual and traditional medicine), economic (raw material for pharmaceuticals, cosmetics and incense) and ecological (an element of dry forest structure and soil-holding communities). Yet that multi-role places Boswellia at the center of a stark dilemma: how to honour centuries of human use while halting population decline and restoring resilient populations on the ground.

In line with the above this issue of Van Sangyan contains an article on Boswellia serrata (Indian Frankincense) in Rajasthan Forests: A heritage terrain for Utilization and Conservation. There are also useful articles viz. The role of birds in agriculture, Climate resilient forest management, Green infrastructure: Trees as urban heat island solutions, महोगनी की खेती: एले क्रॉपिंग निवेश, लागत और लाभ, *From soil to canopy: Understanding the science of silviculture, Medicinal and Economic Value of Canarium strictum Roxb. (Black Dammar), Neem: Natural pest control and soil health booster and Monitoring forest resources to combat climate change using remote sensing and GIS technology.*

Looking forward to meet you all through forthcoming issues

Dr. Naseer Mohammad

Chief Editor

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Boswellia serrata (*Indian Frankincense)* in Rajasthan Forests: A heritage terrain for Utilization and Conservation

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Introduction

Boswellia serrata Roxb. Gum-resin has been used for hundreds of years to cure arthritis in Ayurvedic medicine. In recognition of its resin's rich flavour and perfume as a incense using the resin as a valuable incense, fumigant, and all-purpose aromatic, analgesic and anti-inflammatory qualities of salai-guggal, also a tree resin utilized in traditional Ayurvedic treatment. . Its application in the treatment of osteoarthritis and other inflammatory diseases is supported by recent studies The south-east, south Western Rajasthan, Madhya Pradesh, Gujarat, Orissa, Bihar and Maharashtra are among the regions in India where this tree is extensively found. After being tapped from the tree's trunk incision, the gum extract is consolidated and turned into a resin. *Boswellia serrata***,** commonly known as Indian frankincense, is a tree species that is native to dry and arid regions in India, as well as parts of Africa and the Arabian Peninsula. In India, it is found in various forest types, primarily in the western and central regions. It is renowned for its resin, which has been used in traditional medicine for thousands of years, particularly in Ayurvedic practices. *Boswellia serrata* is known for its resin, frankincense**,** which has been used in traditional medicine, particularly in Ayurvedic treatments for joint pain, inflammation, and other ailments. The tree plays a vital role in the ecosystem by providing habitat and food for various insects and animals. *Boswellia serrata's* distribution is mainly restricted to the above regions, where it can grow in dry conditions and rocky landscapes, making it well-suited to India's varied forest ecosystems.

Useful and Active medicinal compounds in *Boswelia serrata*

The resin from the tree has been used for centuries in Ayurvedic medicine for its therapeutic properties. The active compounds in Boswellia serrata are known as boswellic acids, which are believed to be responsible for the tree's anti-inflammatory and pain-relieving effects. It is a source of boswellic acids, particularly AKBA (acetyl-keto-boswellic acid), a potent anti- inflammatory compound. AKBA inhibits 5-lipoxygenase (5-LOX), an enzyme involved in the production of leukotrienes, key mediators of inflammation. Clinical studies support efficacy in treating osteoarthritis, rheumatoid arthritis, and ulcerative colitis. A meta-analysis of 7 randomized controlled trials showed significant pain reduction and improved function in osteoarthritis patients treated with Boswellia extract compared to placebo.

Threatened due to over-exploitation, habitat loss, and unsustainable harvesting practices. Conservation efforts are crucial.

Botanical Origin	Description and Distribution
Division : Spermatophyta Sub-division: Angiospermae Tribe: Rosopsida Sub-tribe: Rosidae S.Lat Over-class: Rutanae Class: Anacardiales Family: *Burseraceae* Genus: *Boswellia* Species: *serrata* *Common Trade Name:* Salai Guggal Vernacular Names: English: Indian Frankincense/ Indian Olibanum Hindi: Kundur, Salai, Gujarati: Dhup, Gugali Kannada: Chitta, Malayalam: Parangi Tamil: Sambraani, Telegu: Phirangi, Sanskrit: Shallki, Ashvamutri, Kundara	*Distribution: Boswellia serrata Roxb. is a species characteristic of the tropical dry deciduous forests and occurs in very dry teak forests or in dry mixed deciduous forests of India in association with species such as Terminalia spp., Anogeissus latifolia and Acacia leucophloea. It is resistant to drought and resists fire better than other species in its zone of occurrence. In Maharashtra and Rajasthan it is common throughout dry deciduous forests.* Height: *The tree typically grows to a height of 4-12 meters (13-39 feet).* Leaves: *The leaves are pinnate, meaning they have a feather-like appearance, and are bright green with an elongated shape.* Flowers: *The flowers of Boswellia serrata are small, yellowish, and typically clustered together.* Part used: *Thick, papery bark of Boswellia yields a gum containing natural sugars, essential oils, and several unique triterpene acids known as "boswellic acids." These acids appear to be the source ofboswellia's medicinal properties. Active Ingredients Boswellic acid and other pentacyclic triterpene acids are present. Beta-boswellic acid is the major constituent.* Resin: *The tree produces a resin called frankincense, which is harvested by making incisions in the bark. This resin is fragrant and has been valued for both its aromatic qualities and its medicinal properties. The resin is collected as tears or droplets after it oozes out of the tree.* Uses: *The resin has been used for its anti-inflammatory, analgesic, and antimicrobial properties, among others. It is often used in the treatment of conditions like arthritis, asthma, and digestive disorders. The resin is also used in incense and perfumes.*

Table.1. Details about description and distribution of *Boswelia serrata*

Forms of Consumption

- **Capsules/Tablets**: Often used as a supplement for joint health and inflammation.
- **Essential Oil**: Used in aromatherapy for its calming effects.
- **Resin**: Can be chewed or made into an ointment for topical use.

Key Benefits and Uses:

Anti-inflammatory Properties

Boswellia is best known for its potent anti-inflammatory effects. It has been traditionally used to treat conditions like

arthritis, including osteoarthritis and rheumatoid arthritis.

Pain Relief

It is often used to help alleviate pain, especially in conditions like joint pain and inflammation.

Digestive Health

Some studies suggest that Boswellia can help treat digestive disorders like inflammatory bowel disease (IBD), including Crohn's disease and ulcerative colitis.

Improved Mobility

It may help improve joint function and reduce stiffness in people with osteoarthritis.

Respiratory Benefits

The resin is sometimes used for its potential to improve symptoms of asthma and other respiratory issues due to its anti-inflammatory effects.

Habitat and Climatic Conditions

Native Regions

Boswellia serrata is primarily found in dry, mountainous regions of India, particularly in the states of Madhya Pradesh, Gujarat, Rajasthan, and Maharashtra. It is also found in parts of Pakistan, Nepal, and the Middle East.

Climate

The tree thrives in arid and semi-arid climates with rocky and well-drained soils. It is well-suited to areas that experience seasonal rainfall and can tolerate hot, dry conditions. It thrives in areas with a tropical and subtropical climate, where the annual rainfall is relatively low to moderate (typically less than 1,000 mm).

Altitude

Boswellia serrata prefers dry, rocky, and sandy soils and is typically found at elevations ranging from 300 meters to 1,200 meters above sea level.

Habitat and **Soil**

The tree prefers well-drained, loamy to sandy soils, often in hilly terrains or scrub forests. *Boswellia serrata* is typically found in hilly and dry forests, often at elevations ranging from 200 to 1,000 meters above sea level. It prefers areas with low to moderate rainfall and is typically found in open woodlands or dry deciduous forests.

The Indian Market: A Fertile Ground for *Boswellia serrata*

- India's Ayurvedic market size: Valued at $4.5 billion in 2023, projected to reach $10 billion by 2028 (CAGR of 17%).
- Growing consumer preference for natural and herbal remedies.
- Government support for the AYUSH sector (Ayurveda, Yoga & Naturopathy, Unani, Siddha, and Homeopathy).
- Rising awareness of preventive healthcare and wellness.
- Boswellia serrata offers significant marketing potential in India.
- Growing demand for natural and Ayurvedic products.
- Strategic marketing, product development, and regulatory compliance are crucial for success.
- Call to action: Explore partnership and investment opportunities to capitalize on this untapped market.

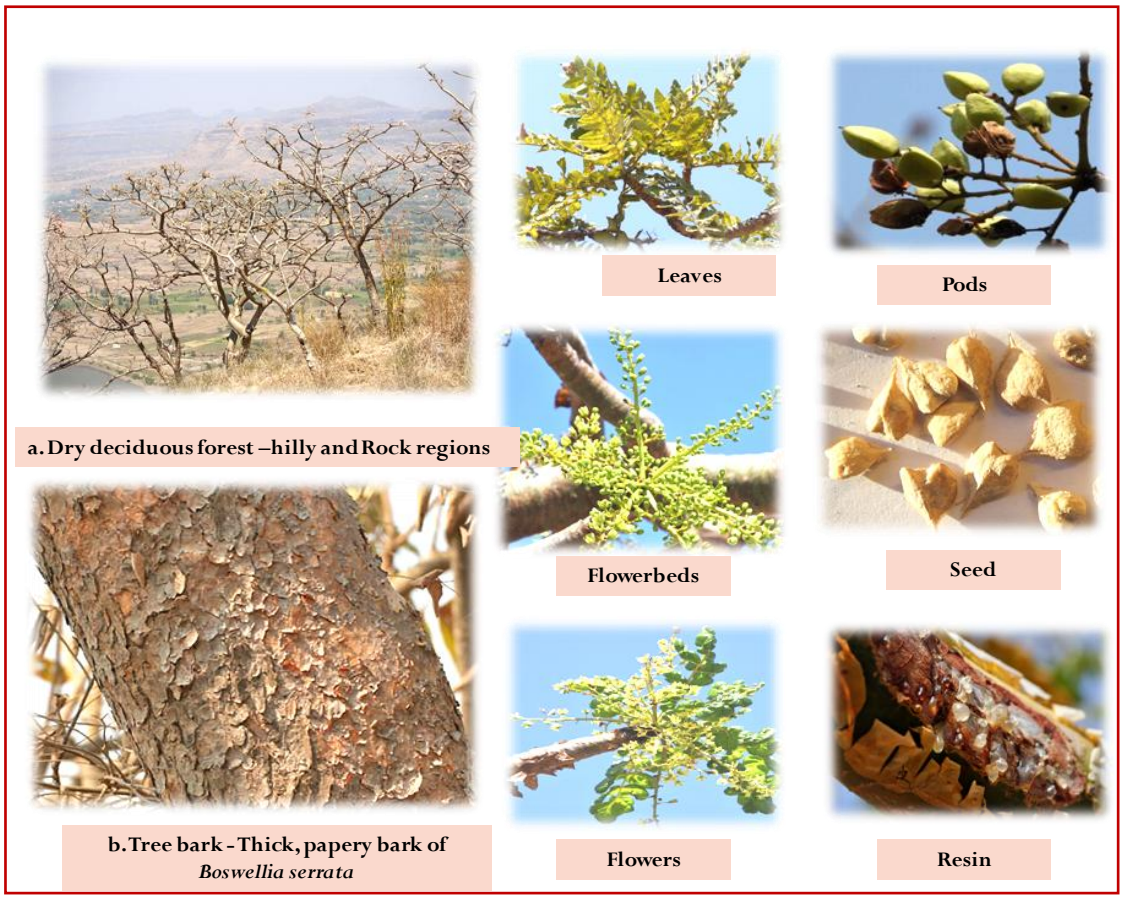

***Fig.1. Boswellia serrata - Gum-resin extracts* used in folk medicine for Centuries**

Ecological Habitat and Growing Conditions in Indian Forests:

Western India

Rajasthan

It is found in the arid and semi-arid regions of Rajasthan, particularly in the dry forests of the Aravalli Range.

Gujarat

Found in the dry forests of Gujarat, particularly in the Saurashtra region and the Kutch district.

Maharashtra

The tree also grows in the drier regions of Maharashtra, especially in areas such as the Vidarbha region.

Central India

Madhya Pradesh

It thrives in the dry forests of Madhya Pradesh, especially in areas like the Satpura Range, and parts of the Vindhya Range.

Chhattisgarh

The species is found in parts of Chhattisgarh as well, in the forested regions that have a semi-arid climate.

Southern India

Karnataka

It is found in the drier forests of Karnataka, including the northern part of the state.

Andhra Pradesh

Boswellia serrata is also present in the dry deciduous forests of Andhra Pradesh.

Problems in natural regeneration and conservation of *Boswellia serrata*

Natural regeneration of *Boswellia serrata*, also known as Indian frankincense, faces several challenges due

to a combination of ecological, environmental, and anthropogenic factors. Some of the key problems in the natural regeneration of this species include:

Deforestation and Habitat Loss

One of the major challenges is deforestation and land-use changes, which disrupt the natural habitat of *Boswellia serrata*. As forests are cleared for agricultural expansion, grazing, or urban development, the species' ability to regenerate naturally is diminished.

Overgrazing

In regions where livestock grazing is common, overgrazing can prevent the establishment of seedlings. Grazing animals often consume young plants, including the tender seedlings of *Boswellia serrata*, thereby hindering their growth and survival.

Climate Change

Changes in temperature and precipitation patterns due to climate change can adversely affect the growth of *Boswellia serrata*. This tree species is adapted to specific environmental conditions, and shifts in those conditions can limit its ability to regenerate naturally.

Soil Degradation

The degradation of soil quality, especially in arid and semi-arid regions, can be a limiting factor for regeneration. *Boswellia serrata* often grows in poor, rocky soils, but when these soils are degraded due to overuse, erosion, or lack of proper soil management, it becomes difficult for the species to regenerate successfully.

Fire and Disturbance

Frequent or uncontrolled fires can destroy young seedlings and saplings, preventing natural regeneration. While fire might sometimes play a role in some ecosystems by clearing underbrush and facilitating regeneration, excessive or uncontrolled fires can have the opposite effect, damaging the plant's habitat and reducing regeneration opportunities.

Poor Seed Dispersal

Boswellia serrata primarily regenerates through seeds, and poor seed dispersal mechanisms can limit its natural regeneration. If seeds do not reach suitable sites for germination or are not adequately dispersed by natural agents (like animals or wind), the seedling establishment will be low.

Invasive Species

The invasion of non-native plant species can out compete *Boswellia serrata* seedlings for resources such as water, nutrients, and sunlight. These invasive species often grow faster and are more resilient, making it hard for native plants to establish.

Slow Growth and Long Life Cycle

Boswellia serrata has a slow growth rate, especially in its early stages, and can take years to reach maturity. This long life cycle makes it more vulnerable to environmental stresses and slower to recover from disturbances.

Unsustainable Harvesting

In some areas, *Boswellia serrata* is overharvested for its resin, which is used in incense and medicinal products. Excessive tapping or harvesting of the tree can weaken the trees, reduce seed production, and limit regeneration efforts.

Seed Dormancy

Seeds of *Boswellia serrata* have dormancy mechanisms that may prevent immediate germination, requiring specific environmental conditions to break dormancy. This can limit the chances for

natural regeneration if those conditions are not met in the wild.

Steps for conservation *Boswellia serrata* in Indian forests

Conserving Indian Frankincense in Indian forests is crucial due to its ecological, medicinal, and economic value. *Boswellia serrata* is used for its resin, which has therapeutic benefits, but over-harvesting and habitat degradation have put pressure on its population. Here are steps for effective conservation:

Habitat Protection and Restoration

Identify and protect natural habitats

Focus on protecting existing forests and areas where Boswellia serrata is found. These forests should be free from encroachment and overgrazing.

Restore degraded habitats

Engage in afforestation and reforestation efforts in areas where Boswellia serrata populations have declined. This includes planting Boswellia serrata seeds or saplings in suitable areas.

Create conservation reserves or protected areas

Establish protected forest areas dedicated to preserving Boswellia serrata and its ecosystem.

Sustainable Harvesting Practices

Promote sustainable resin collection

Train local communities in sustainable resin tapping techniques. Resin should be harvested in a way that does not harm the tree's health, allowing it to regenerate naturally.

Set harvest limits

Define clear harvesting seasons and limits for resin extraction to avoid overharvesting.

Encourage alternative income sources for communities

Provide alternative livelihood options like eco-tourism, handicrafts, or agriculture to reduce dependency on overharvesting Boswellia.

Research and Monitoring

Conduct ecological studies

Regularly monitor the health of Boswellia serrata populations and assess the impacts of environmental changes, such as climate change or deforestation.

Genetic studies: Support research on the genetic diversity of Boswellia serrata to ensure the long-term health and resilience of the species.

Track resin yield data

Document resin yield trends and the economic impact of the resin trade, help to identify overharvesting or illegal trade activities.

Community Involvement

Empower local communities

Educate local communities about the importance of Boswellia serrata for their economy and ecology. Encourage community-based conservation efforts.

Participate in co-management programs

Work with forest departments and local communities to co-manage forests, ensuring that both conservation and livelihood needs are balanced.

Training programs

Offer training to local communities in the sustainable management of Boswellia trees and their resin collection.

Control Illegal Trade and Overharvesting

Strengthen enforcement of forest laws

Ensure strict law enforcement to combat illegal logging and resin extraction. Forest rangers should be trained to identify and stop illegal activities.

Promote certification schemes

Support certification of sustainably harvested Boswellia resin (such as Fair Trade or organic certifications) to ensure only ethically sourced products are sold.

Awareness Campaigns

Raise awareness

Conduct awareness campaigns in local communities, markets, and the general public about the importance of Boswellia serrata and the threats it faces.

Engage with global markets

Work with international markets to promote the use of sustainably sourced Boswellia resin, encouraging eco-friendly demand for the product.

Policy and Legislative Support

Lobby for better policies

Work with the government and non-governmental organizations to create policies that support the sustainable management of Boswellia serrata.

Support subsidies for conservation efforts

Advocate for subsidies or financial support for communities and organizations involved in Boswellia serrata conservation.

Incentivize Conservation Efforts

Create eco-tourism opportunities

Develop eco-tourism programs in areas where Boswellia serrata grows, providing economic incentives for conservation.

Develop value-added products

Promote the production of value-added products like Boswellia oil, which can provide more revenue and discourage over-harvesting of raw resin.

Promote Interdisciplinary Collaboration

Collaborate with NGOs and research institutions

Work together with environmental organizations, research institutions, and local government bodies to create a multi-faceted conservation plan.

Partnership with corporate sectors

Engage with companies that benefit from Boswellia resin (like pharmaceutical, cosmetic, and aromatherapy industries) to support sustainable practices.

Conservation Status, Future Directions and Research Needs

By combining these strategies, *Boswellia serrata* can be conserved effectively in Indian forests, ensuring that both ecological and community needs are met. Addressing these challenges requires a combination of conservation strategies, such as sustainable land management, habitat restoration, controlled grazing, and research into improving seedling survival and growth conditions for this valuable species. While ***Boswellia serrata*** is not currently listed as endangered, overharvesting of the resin and deforestation in some regions have led to concerns about the sustainability of its populations. Efforts are being made to protect and manage the species sustainably.

- Further research on seed physiology and dormancy mechanisms. RNA sequencing analysis of seeds during germination to identify key genes involved.
- Development of efficient and cost-effective tissue culture protocols for mass propagation.
- Field trials to evaluate the performance of propagated plants. Assessment of resin yield and boswellic acid content.

- Community involvement in propagation and conservation efforts.
- *Boswellia serrata* is a valuable medicinal plant facing propagation challenges.
- Integrated approaches combining seed germination enhancement, improved vegetative propagation techniques, and optimized tissue culture are needed.
- Successful propagation is essential for sustainable utilization and conservation of this important species.

Summary

In consequence of its poor natural seed germination rate, the species is susceptible to population decrease if improperly maintained. Regularize the sustainable harvesting techniques to guarantee the resin's long-term availability without endangering the trees. Repairing damaged ecosystems and planting new Salai guggal trees in its eco-habitats / native location of Rajasthan. More investigation on the biology, reproduction, and sustainable management strategies of the species is highly required on natural habitats**.** *Boswellia serrata* holds immense economic, medicinal, and cultural significance in India. While the species provides numerous benefits to local communities and the national economy, its future is threatened by over-harvesting, deforestation, and climate change. Through concerted conservation efforts, sustainable harvesting practices, and research, it is possible to secure the continued production of frankincense while preserving the ecological integrity of India's forests. Proper planting and management techniques are vital for successful cultivation. Sustainable harvesting ensures long-term productivity and conservation. Boswellia serrata offers significant economic and ecological benefits. Further research is needed to optimize cultivation practices. Researchers should give special focus on genetic improvements, quality planting stock production, disease resistance Urgent need for integrated conservation efforts, regulated extraction for economic benefits with ecological sustainability, collaborative approaches involving governments, communities, and industry, Future actions should focused to enhance the survival of Boswellia serrata in its natural habitat with support of Local communities. Sustainable practices, careful forest management, and community involvement are all crucial for its long-term conservation in dry deciduous forest in semi-arid regions of Rajasthan.

The role of birds in agriculture

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Birds, often celebrated for their melodious calls and vibrant plumage, play an indispensable role in sustaining ecological balance. Among the many sectors that benefit from avian activities, agriculture stands out prominently. Birds contribute significantly to pest control, pollination, seed dispersal, soil health, and even nutrient cycling. As agriculture continues to evolve in the face of climate change and increasing demand for sustainable practices, understanding and appreciating the role of birds becomes all the more critical.

Natural pest control agents

One of the most significant contributions birds make to agriculture is in the control of insect pests. Many bird species feed on insects, including those that are harmful to crops. For instance, swallows, flycatchers, and warblers consume large numbers of aphids, caterpillars, beetles, and grasshopperscommon pests that damage crops.

The first known successful importationof a vertebrate predator occurred in1762 when the Indian Myna *Acridotheres tristes* was introduced fromIndia to Mauritius to control the red locust *Nomadacris septemtasciata*. The birds alone brought about 73 % control of the larval populationand thus improved the yield.Fixing of the perches @ 50/ha in chickpea improved the efficiency of predatory birds like Drongo, mynas, sparrow, etc. in searching. Eighteen species of birds fed on the white grub, which were exposed during ploughing operation.Birds reduced 45 to 65% of grub population when the field was ploughed using bullocks on three consecutive days.

Figure 1: Indian Myna

A single barn swallow, for example, can eat hundreds of insects a day. When these birds nest near agricultural fields, their daily foraging habits can dramatically reduce the pest population, thereby lowering the need for chemical pesticides. This natural form of pest control not only saves money for farmers but also reduces environmental pollution and the risk of chemical residues in food.

Moreover, birds like crows, jays, and magpies are known to prey on rodents and other small mammals that can damage crops or stored produce. Their presence in and around fields adds another layer of defence against potential agricultural threats.

Pollination assistance

While birds are not the primary pollinators in temperate regions, in tropical and subtropical zones, bird pollination is quite common and beneficial. Hummingbirds, sunbirds, lorikeets, and honeyeaters are among the notable avian pollinators. These birds feed on nectar and, in the process, transfer pollen from one flower to another, facilitating the reproduction of various fruiting and flowering plants.

In agricultural systems that include fruit trees, vegetables, and flowering crops, bird pollinators can complement the work of insects like bees and butterflies. This diversity of pollinators ensures that pollination can still occur even if one group faces threats or declines due to disease or habitat loss.

Seed dispersal and forest regeneration

Many bird species, particularly frugivores (fruit-eating birds), play a crucial role in seed dispersal. As they feed on fruits, they ingest the seeds and later excrete them at different locations. This behaviour aids in the natural propagation of many plant species.

In agroforestry systems or in areas practicing shifting cultivation, birds help in regenerating vegetation by dispersing seeds over wide areas. Their contribution is essential in maintaining plant diversity and improving soil quality over time. For farmers who rely on tree cover for shade crops like coffee or cocoa, the work of birds in forest regeneration is indirectly beneficial to their yield.

Nutrient cycling and soil fertility

Bird droppings, commonly referred to as guano, are rich in nitrogen, phosphorus, and potassiumnutrients vital for plant growth. In many traditional farming systems, bird droppings are collected and used as natural fertilizers. Even in natural settings, the regular deposition of droppings by birds foraging in the fields adds to the soil's organic content.Birds that feed on aquatic organisms also contribute indirectly to nutrient transfer between water bodies and farmlands. Species like herons and egrets often move between wetlands and fields, facilitating a form of natural nutrient exchange that enriches the agricultural landscape.

Weed control

Certain bird species feed on weed seeds, helping to reduce the spread of invasive plants. For example, finches and sparrows often consume seeds of common weeds found in crop fields. This reduces the competition for nutrients between weeds and cultivated plants, thereby enhancing crop productivity.

This ecological service, though often overlooked, is significant in integrated weed management practices, especially in organic farming systems where herbicide use is limited or avoided altogether.

Indicators of environmental health

Birds serve as excellent bioindicators of ecosystem health. Changes in bird population and diversity can reflect the impact of agricultural practices on the environment. A field with a diverse and healthy bird population is often indicative of a balanced and sustainable ecosystem.

Monitoring birds in agricultural landscapes can help farmers and ecologists assess the long-term impacts of pesticide use, habitat destruction, and other intensive farming practices. This insight can then guide the adoption of more bird-friendly and sustainable approaches.

Promoting bird-friendly farming

To maximize the benefits birds, offer, it is crucial to create and maintain habitats that attract and support avian populations. Some bird-friendly farming practices include:

- Maintaining hedgerows and tree lines: These provide nesting sites and safe corridors for birds to travel across fields.
- Leaving patches of natural vegetation: Native plants attract insects and provide food and shelter for birds.
- Reducing pesticide use: Avoiding harmful chemicals preserves the insects that birds feed on and reduces the risk of secondary poisoning.
- Installing nest boxes: Especially in orchard systems or near fields, nest boxes can encourage birds like owls and kestrels that prey on rodents.

Governments and agricultural organizations in several countries are recognizing the value of birds and are promoting "wildlife-friendly" or "bird-friendly" certifications that reward sustainable farming practices.

Challenges to avian contributions

Despite their importance, birds face several threats in agricultural landscapes:

- Habitat loss due to land clearing and monoculture farming reduces nesting and feeding grounds.
- Pesticide exposure can directly poison birds or eliminate their insect prey.
- Climate change alters migration patterns and breeding cycles, affecting their ecological roles.
- Light and noise pollution can interfere with bird behavior, especially nocturnal species.
- To continue reaping the benefits birds provide, these challenges must be addressed through policy, research, and community awareness.

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Climate resilient forest management

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Introduction

Climate resilient forest management is a type of forest management that aims to make forests more resistant to the negative effects of climate change.

This includes practices such as:

Reducing fragmentation

Fragmentation occurs when forests are broken up into smaller pieces, which can make them more vulnerable to pests, diseases, and other disturbances. Reducing fragmentation can help to make forests more resilient by providing them with a larger area to adapt to changing conditions.

Increasing connectivity

Connectivity refers to the ability of animals and plants to move freely through a landscape. Increasing connectivity can help to improve the resilience of forests by allowing species to disperse and find new habitat when their current habitat is degraded or destroyed.

Protecting old-growth forests

Old-growth forests are the most resilient type of forest, as they have been able to adapt to a wide range of environmental conditions over time. Protecting old-growth forests can help to ensure that there are healthy forests available to provide a variety of ecosystem services, such as carbon sequestration, biodiversity conservation, and water purification.

Using adaptive management: Adaptive management is a process of learning and adjusting management practices in response to new information. This approach can be used to help forest managers make decisions that are more likely to be successful in the face of climate change.

Why it is Important?

Climate resilient forest management is an important part of the effort to mitigate and adapt to climate change. By making forests more resilient, we can help to ensure that they continue to provide a variety of benefits for people and the environment.

Reduced risk of wildfires: Climate change is making wildfires more frequent and intense. By managing forests in a way that reduces fuel loads, we can help to reduce the risk of wildfires.

Improved water quality

Forests play an important role in filtering water and preventing pollution. By managing forests in a way that protects water quality, we can help to ensure that people may have access to clean water.

Enhanced biodiversity

Forests are home to a wide variety of plant and animal species. By managing forests in a way that enhances biodiversity, we can help to protect these species and the ecosystems they rely on.

Technological approaches for climate resilient forest management

Climate resilient forest management is crucial for mitigating the impacts of climate change on forest ecosystems. Here are some new technological approaches that can contribute to climate resilient forest management:

Remote Sensing and Earth Observation

Remote sensing technologies, such as satellite imagery and aerial surveys, provide valuable data on forest cover, vegetation health, and changes in land use. This information helps in monitoring and assessing the impacts of climate change on forests, identifying areas at risk, and informing management strategies.

Geographic Information Systems (GIS)

GIS technology enables the integration and analysis of various spatial data layers, such as climate data, forest inventory data, and ecological data. It helps forest managers make informed decisions by identifying suitable locations for reforestation, analyzing habitat connectivity, and assessing the vulnerability of forest ecosystems to climate change.

Climate Modeling and Forecasting

Climate models and forecasting systems help predict future climate scenarios and provide valuable information on temperature, precipitation, and extreme weather events. Forest managers can use this information to anticipate potential changes in forest ecosystems and develop adaptive management strategies.

Decision Support Systems (DSS)

DSS tools combine data, models, and expert knowledge to support decision-making in forest management. They assist in evaluating different management scenarios, assessing the potential impacts of management actions on forest resilience, and identifying optimal strategies for climate adaptation.

Mobile Applications and Sensor Technologies

Mobile applications and sensor technologies enable real-time data collection and monitoring in the field. Forest managers can use mobile apps to record forest inventory data, monitor tree health, and track invasive species. Sensor technologies, such as moisture sensors or weather stations, provide valuable data on soil moisture, temperature, and weather conditions, aiding in adaptive management practices.

Big Data Analytics and Machine Learning

Big data analytics and machine learning techniques can process large datasets and identify patterns or trends that may not be apparent through traditional analysis methods. These technologies can assist in predicting forest disturbances, identifying early signs of stress or disease, and optimizing forest management practices for climate resilience.

Precision Forestry

Precision forestry utilizes advanced technologies like LiDAR (Light Detection and Ranging), drones, and advanced sensors to collect detailed and accurate data about forest structure, composition, and health. This information helps in optimizing forest management activities, such as tree planting, harvesting, and restoration, to enhance resilience to climate change.

Implementing these technological approaches in forest management can improve our understanding of forest ecosystems, enhance adaptive capacity, and enable more effective responses to the challenges posed by climate change. However, it's important to note that technology should be used in conjunction with traditional knowledge and sustainable management practices for comprehensive and effective climate resilient forest management.

Remote Sensing and Earth Observation

Remote sensing technologies, such as satellite imagery and aerial surveys, provide valuable data on forest cover, vegetation health, and changes in land use. This information helps in monitoring and assessing the impacts of climate change on forests, identifying areas at risk, and informing management strategies.

Remote sensing, "as the practice of deriving information about the Earth's land and water surfaces using images acquired from an overhead perspective, using electromagnetic radiation in one or more regions of the electromagnetic spectrum, reflected or emitted from the Earth's surfaces" (Campbell and Wynne 2011), can contribute to quantifying CSF(Climate Smart Forestry) indicators. As a general consideration, the benefits of remote sensing to monitor the forests as a result of the application of CSF practices are related to full coverage of forested areas in a relatively short time, repeatability of measurements, and availability of data for remote or inaccessible terrestrial areas (Koch 2015).

Remote sensing plays an important role in mountain forest monitoring , i.e., forests at an elevation of 2500 m a.s.l. or higher, irrespective of the slope, or on land with an elevation of 300–2500 m and a slope with sharp changes in elevation within a short distance (Kapos et al. 2000). Because of their steep slopes and often-extreme climates and weather events, mountain forests are fragile ecosystems. Under a global change scenario, remote sensing technologies allow more complete spatial and temporal monitoring of climate-smart forests and forestry (e.g., to prevent and contrast illegal logging), including those in inaccessible mountain environments. Mountains are often data-scarce regions due to their remoteness and the harsh environment: in these contexts, remote sensing may provide one of the few methods for assessing the state of dynamic changes occurring in mountain forests (Weiss and Walsh 2009). Indeed, remote sensing overcomes the challenges of collecting field data in rugged terrain and the constraints imposed by the seasonality of access to many mountain environments.

Remote sensing products over mountain regions come with a larger measurement error than remote sensing products over flat terrain due to topographic effects (Li et al. 2014). In the case of satellite microwave radiometric data, for example, the error is particularly correlated to the mean values of the height and slope within the radiometric pixel, as well as to the standard deviation of the aspect and local incidence angle (Li et al. 2014). In optical images, corrections in pre-processing are in general required to reduce the spectral biases due to the topographic features that led to aspect-dependent illumination and reflectance differences, shadowing, and geometric distortion (Weiss and Walsh 2009). In other remote sensing data, such as the radio detection and ranging (RADAR), topography can result in distortions, such as foreshortening and layover on slopes and in areas of shadow that are not measured.

When assessing the CSF indicators in mountain forests by remote sensing, we have to consider that the temporal scale of monitoring needs to be adjusted for different indicators to ensure early detection of change is possible. Specific focus should be put on those indicators

sensitive to climate change. Forest-based climate change indicators should complement SFM indicators by capturing the effects of climate change on the forest environment and the forest sector (Lorente et al. 2018).

Geographic Information Systems (GIS)

GIS technology enables the integration and analysis of various spatial data layers, such as climate data, forest inventory data, and ecological data. It helps forest managers make informed decisions by identifying suitable locations for reforestation, analyzing habitat connectivity, and assessing the vulnerability of forest ecosystems to climate change.

The use of Geographical Information Systems (GIS) has flooded almost every field in the engineering, natural and social sciences, offering accurate, efficient, reproducible methods for collecting, viewing and analysing spatial data. Forests are important renewable natural resources and have a significant role in preserving an environment suitable for human life. In addition to timber, forests provide such resources as grazing land for animals, wildlife habitat, water resources and recreation areas. Forestry involves the management of a broad range of natural resources within a forested area. Forest resource management in today's ever-changing world is becoming more complex and demanding to forest managers.

Geographic Information Systems applications enable the storage, management, and analysis of large quantities of spatially distributed data. These data are associated with their particular geographic features. For example, water quality data would be linked with a sampling site, represented by a point. Data on crop yields might be associated with fields or experimental plots, represented on a map by polygons. A GIS can manage different datatypes occupying the same geographic space. For example, a biological control agent and its prey may be distributed in different abundances across a variety of plant types in an experimental plot. The power of a GIS lies in its ability to analyze relationships between features and their associated data.

GIS applications can be grouped into various categories depending on the level of integration with other forest management and financial systems. These categories include

- Data collection and maintenance.
- Map production.
- Data viewing and query.
- Decision support systems.

The forest atlas software:

The Forest Atlas is a dynamic tool that helps decision makers in the region to achieve sustainable management of forest resources through strengthened land use planning and monitoring. Through a combination of interactive mapping applications, posters, analytical reports, trainings, and outreach, the Atlases provide users with timely, accurate, and synchronized information about land use allocation within national forest estates. The goal of this work is to improve the quality and availability of information in the forest sector to support transparent and participatory decision making.

Climate Modeling and Forecasting

Climate models and forecasting systems help predict future climate scenarios and provide valuable information on

temperature, precipitation, and extreme weather events. Forest managers can use this information to anticipate potential changes in forest ecosystems and develop adaptive management strategies.

Climate modeling and forecasting plays a crucial role in understanding and predicting climate patterns, trends, and future scenarios. By utilizing various mathematical and computational models, scientists can simulate the Earth's climate system and make projections about future climate conditions. These models integrate data on atmospheric dynamics, oceanic circulation, land surface processes, and other factors that influence the climate.

Climate modeling and forecasting help in climate resilient forestry by providing valuable information for decision-making and planning. Here are some key aspects of climate modeling and forecasting in the context of climate resilient forestry:

Projections of Future Climate

Climate models are used to simulate future climate conditions based on different greenhouse gas emission scenarios. These projections help forest managers assess the potential impacts of climate change on forests, such as changes in temperature, precipitation patterns, and the frequency of extreme weather events.

Understanding Climate Variability

Climate models can also capture natural climate variability, such as El Niño-Southern Oscillation (ENSO) and the North Atlantic Oscillation (NAO). Understanding these patterns and their influence on local climate conditions can assist in adaptive forest management strategies.

Assessing Climate Risks

Climate modeling allows for the identification and assessment of climate risks to forest ecosystems. For example, models can help estimate the vulnerability of specific tree species to changes in temperature or the potential spread of pests and diseases under different climate scenarios.

Development of Adaptation Strategies

Climate models provide insights into future climate conditions, enabling forest managers to develop adaptation strategies to enhance the resilience of forest ecosystems. These strategies may include adjusting tree species composition, altering forest management practices, and implementing measures to mitigate the impacts of climate change.

Improving Forest Management Decision-Making

By incorporating climate modeling and forecasting data into decision-support tools, forest managers can make more informed decisions regarding reforestation, forest restoration, fire management, and other forest management practices.

Uncertainty and Risk Assessment

Climate modeling acknowledges the inherent uncertainties associated with future climate projections. Forest managers can use ensemble modeling and probabilistic approaches to assess the range of possible climate outcomes and associated risks, enabling them to consider a broad range of scenarios in their planning processes.

It's important to note that climate modeling and forecasting are continually evolving fields, and the accuracy and resolution of models improve over time. They are used in combination with other sources of information, including on-the-ground

observations, to inform decision-making and support climate resilient forestry practices.

Decision Support Systems (DSS)

Decision support systems (DSS) are computer-based tools that help users make decisions. They can be used in a variety of fields, including forestry. In the context of climate resilient forestry, DSS can be used to help forest managers make decisions about how to manage their forests in a way that makes them more resistant to the negative effects of climate change.

DSS tools combine data, models, and expert knowledge to support decision-making in forest management. They assist in evaluating different management scenarios, assessing the potential impacts of management actions on forest resilience, and identifying optimal strategies for climate adaptation.

Decision Support Systems (DSS) are essential tools for forest management practitioners to help take account of the many environmental, economic, administrative, legal and social aspects in forest management. The most appropriate techniques to solve a particular instance usually depend on the characteristics of the decision problem. It is interesting to know the appropriate methods to answer specific problems, as well as the strengths and drawbacks of each method. We have also pointed out new approaches to deal with the newest trends and issues. The problem nature has been related to the temporal scale, spatial context, spatial scale, number of objectives and decision makers or stakeholders and goods and services involved. Some of these problem dimensions are inter-related, and we also found a significant relationship between various methods and problem dimensions, all of which have been analysed using contingency tables.

In the increasingly complex and diverse planning situation, science-based decision support is thus key for planning the sustainable management of multifunctional forests (Kangas et al., 2015).For this purpose, various decision support systems (DSS) have been developed in forestry across the globe (Vacik and Lexer, 2014; Nordström et al., 2019) and are increasingly used to explore synergies and trade-offs in BES (e.g., Biber et al., 2020).

Although a DSS can in principal be any system that aids decision makers, the term typically refers to model-based software systems which provide a user interface, a ‘knowledge system’ (database, models, etc.) and a ‘problem processing system’ (e.g., for calculating decision analyses) (Borges et al., 2014). Over time, DSS have been developed from systems for a single purpose (e.g., evaluation of sustainable timber production) to systems including multiple criteria (e.g., a wide variety of BES) and a modular construction (i.e., providing an integrative and flexible software framework) (Eriksson and Borges, 2014).

A particular challenge is to keep the system easy to handle and to provide results in a condensed and transparent way for the decision maker (Vacik and Lexer, 2014). DSS in forestry are therefore mostly developed for a specific region and particular environmental, social, economic situation at a specific spatial and temporal scale of interest (Eriksson and Borges, 2014). Despite the various DSS existing worldwide, such systems thus need to be tailored toward the specific needs of local

forest management and planning tasks (Nordström et al., 2019).

Mobile Applications and Sensor Technologies

Mobile applications and sensor technologies are playing an increasingly important role in climate resilient forestry. These technologies can be used to collect data on a variety of factors, such as forest health, climate change, and economic conditions. This data can then be used to make better decisions about how to manage forests in a way that makes them more resistant to the negative effects of climate change.

Here are some examples of how mobile applications and sensor technologies are being used in climate resilient forestry:

Forest health monitoring

Mobile applications and sensor technologies can be used to monitor the health of forests. This can be done by collecting data on factors such as tree growth, insect infestation, and disease. This data can then be used to identify areas that are at risk and to take steps to protect them.

Climate change monitoring

Mobile applications and sensor technologies can be used to monitor the effects of climate change on forests. This can be done by collecting data on factors such as temperature, precipitation, and drought. This data can then be used to understand how climate change is impacting forests and to develop management plans to adapt to these changes.

Economic monitoring

Mobile applications and sensor technologies can be used to monitor the economic conditions that affect forestry. This can be done by collecting data on factors such as timber prices, labor costs, and market demand. This data can then be used to make better decisions about how to manage forests in a way that is economically sustainable.

These are just a few examples of how mobile applications and sensor technologies are being used in climate resilient forestry. As climate change continues to pose a threat to forests, these technologies will become increasingly important tools for forest managers who are working to protect and restore these vital ecosystems.

Here are some of the benefits of using mobile applications and sensor technologies in climate resilient forestry:

Improved data collection

Mobile applications and sensor technologies can be used to collect data in a more efficient and accurate way than traditional methods. This can help forest managers to make better decisions about how to manage their forests.

Increased collaboration

Mobile applications and sensor technologies can be used to share data with other stakeholders, such as scientists, policymakers, and the public. This can help to build support for climate resilient forest management practices.

Reduced costs

Mobile applications and sensor technologies can help to reduce the costs of forest management. This is because they can be used to automate tasks that would otherwise be done manually.

Overall, mobile applications and sensor technologies are a valuable tool for forest managers who are looking to make their forests more resilient to climate change.

By using these technologies, forest managers can make better decisions, collaborate with others, and reduce costs.

Big Data Analytics and Machine Learning

Big data analytics and machine learning techniques can process large datasets and identify patterns or trends that may not be apparent through traditional analysis methods. These technologies can assist in predicting forest disturbances, identifying early signs of stress or disease, and optimizing forest management practices for climate resilience.

Big Data-based tools are already widespread in this new complex science, for example, to monitor seasonal changes in climate change (Manogaran et al., 2018), understand climate change as a theory-guided data science paradigm (Faghmous et al., 2014), learn how to manage the risks of climate change (Ford et al., 2016), explore soft data sources, e.g., Twitter (Jang et al., 2015), or demonstrate the potential of Systems of Systems (SoS), for instance, the exploration of the structure and relationships across institutions and disciplines of a global Big Earth Data cyber-infrastructure: the Global Earth Observation System of Systems (GEOSS) (Craglia et al., 2017).

Today, it is obvious that sustainability science is intertwined with data science, however, with the support of the business model of the circular economy (Jabbour et al., 2019), the complexity of the problem repository has further increased, so there is an urgent need to include data and analysis methods in the framework, whereas research results from different fields can be used in other fields. Furthermore, trends in climate and sustainability science are driving models toward higher resolution, greater complexity, and larger ensembles, which calls for multidisciplinary approaches in climate computational sciences (Balaji, 2015). This research provides a higher-level overview of the interconnectedness of disciplines, systems, data, and tools related to climate change, exploring further focal points concerning the need a deeper level of integration, because a disconnection between important industry initiatives and scientific research is still experienced (Nobre and Tavares, 2017).

Here are some examples of how big data analytics and machine learning are being used in climate resilient forestry:

Forest health monitoring: Big data analytics and machine learning can be used to monitor the health of forests. This can be done by collecting data on factors such as tree growth, insect infestation, and disease. This data can then be used to identify areas that are at risk and to take steps to protect them.

Climate change monitoring

Big data analytics and machine learning can be used to monitor the effects of climate change on forests. This can be done by collecting data on factors such as temperature, precipitation, and drought. This data can then be used to understand how climate change is impacting forests and to develop management plans to adapt to these changes.

Economic monitoring

Big data analytics and machine learning can be used to monitor the economic conditions that affect forestry. This can be done by collecting data on factors such as timber prices, labor costs, and market

demand. This data can then be used to make better decisions about how to manage forests in a way that is economically sustainable.

Precision Forestry

Precision forestry is the use of technology to collect and analyze data about forests in order to make better decisions about how to manage them. This data can be used to identify areas that are at risk, to track the health of forests, and to develop management plans that are tailored to the specific needs of each forest.

Precision forestry can be used to make forests more resilient to climate change in a number of ways. For example, it can be used to:

Identify areas that are at risk

By collecting data on factors such as tree health, climate change, and economic conditions, precision forestry can help forest managers to identify areas that are at risk from climate change. This information can then be used to take steps to protect these areas, such as planting more trees or thinning out stands of trees to reduce the risk of fire.

Track the health of forests

Precision forestry can be used to track the health of forests over time. This information can be used to identify changes in forest health that may be caused by climate change. For example, precision forestry can be used to track the growth of trees, the abundance of insects and diseases, and the occurrence of wildfires.

Develop management plans

Precision forestry can be used to develop management plans that are tailored to the specific needs of each forest. These plans can take into account the climate change risks that each forest faces, as well as the economic and social factors that are important to the people who live and work in the forest.

Precision forestry is a rapidly evolving field, and new technologies are being developed all the time. As these technologies become more widespread, they will play an increasingly important role in climate resilient forestry.

Here are some of the benefits of using precision forestry in climate resilient forestry:

Improved decision-making

Precision forestry can help forest managers to make better decisions about how to manage their forests. This is because it provides them with more data about the forests, which they can use to assess the risks posed by climate change and to develop management plans that are tailored to the specific needs of each forest.

Reduced costs

Precision forestry can help to reduce the costs of forest management. This is because it can be used to automate tasks that would otherwise be done manually, such as surveying and mapping.

Increased collaboration

Precision forestry can help to increase collaboration between forest managers, scientists, and other stakeholders. This is because it provides a common platform for sharing data and for developing solutions to the challenges posed by climate change.

Challenges of New technological approaches for climate resilient forest management

While new technological approaches hold promise for climate resilient forest management, there are several challenges

that need to be addressed. Here are some key challenges associated with the implementation of new technologies:

Cost: Adopting and implementing new technologies can often be costly, particularly for resource-constrained forest management organizations. The initial investment, ongoing maintenance, training, and infrastructure requirements can pose financial challenges, making it difficult for some stakeholders to fully embrace these approaches.

Accessibility and Capacity

Ensuring equitable access to technology and building the necessary capacity among forest managers and stakeholders can be a challenge. Some regions, especially in developing countries or remote areas, may lack the necessary infrastructure, internet connectivity, or technical expertise to effectively utilize and benefit from advanced technologies.

Data Quality and Integration

New technological approaches heavily rely on data collection, integration, and analysis. However, ensuring data quality, consistency, and compatibility across different sources can be a challenge. Integrating data from various platforms and sources, such as remote sensing, climate models, and field observations, requires robust data management systems and standardized protocols.

Privacy and Data Security

As technology involves data collection and sharing, privacy and data security become crucial concerns. Safeguarding sensitive forest-related data, ensuring compliance with privacy regulations, and preventing unauthorized access or data breaches are important considerations when implementing new technologies.

Stakeholder Engagement

Successfully integrating new technologies into forest management requires effective stakeholder engagement. Building trust, fostering collaboration, and involving local communities, indigenous peoples, and other relevant stakeholders in the decision-making processes related to technology adoption can help address potential social, cultural, and ethical concerns.

Technological Limitations and Reliability

While technological advancements offer great potential, some approaches may still have limitations or uncertainties. For example, certain remote sensing techniques may have limitations in accuracy or resolution, climate models may have uncertainties in long-term projections, and machine learning algorithms may require robust training datasets. Understanding the limitations and potential biases of new technologies is essential for their appropriate use and interpretation.

Adaptability and Scalability

Technological approaches need to be adaptable and scalable across different forest types, regions, and socio-economic contexts. Solutions that work in one specific setting may not be directly applicable or effective in another. Therefore, considering the local context and ensuring that technological approaches can be adapted and scaled up or down is crucial.

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Green infrastructure: Trees as urban heat island solutions

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Introduction to Urban Heat Islands

Urban Heat Islands (UHIs) are metropolitan areas that experience significantly higher temperatures than their surrounding rural regions. This phenomenon arises primarily from the replacement of natural landscapes, such as trees and vegetation, with built environments composed of materials like asphalt and concrete, which absorb and retain heat. Research indicates that cities can be up to 10°F-15°F hotter than their rural counterparts. The absence of vegetation exacerbates this issue, as green spaces play a crucial role in cooling the environment through shade and evapotranspiration.

Trees provide significant cooling benefits by offering shade, releasing water vapor through evapotranspiration, and enhancing air quality. The strategic planting of trees is essential to maximizing their cooling effects, with large-leaved and fast-growing species being particularly effective.

Causes of Urban Heat Islands

The primary driver of UHIs is the extensive alteration of natural landscapes into urban environments. Built surfaces have low albedo, meaning they absorb more solar energy than they reflect. In contrast, vegetation generally has high albedo, reflecting more sunlight. Furthermore, the "heat island effect" occurs when warm air is trapped by taller buildings, leading to increased temperatures, especially during calm weather when there is little air circulation.

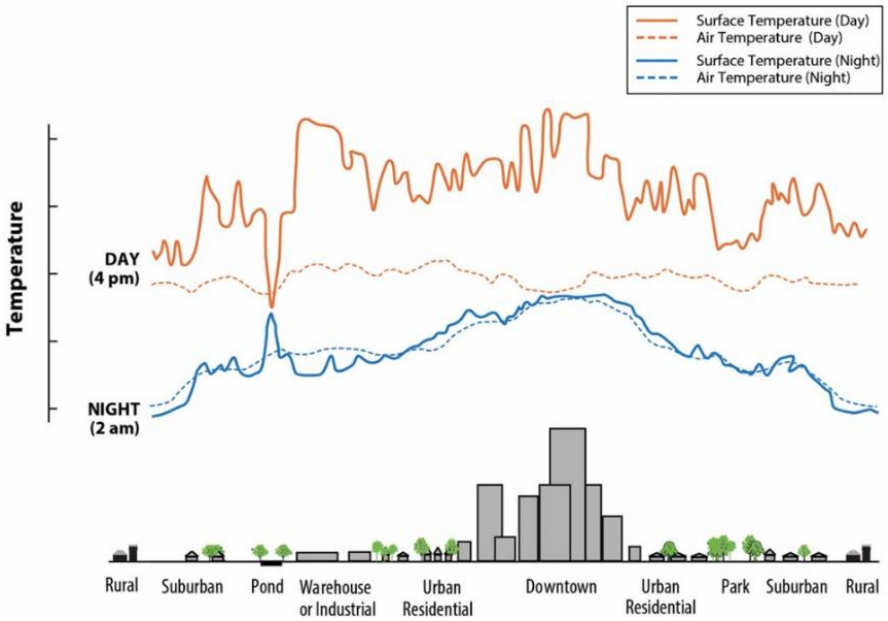

Figure 1: Temperature Variability in Urban Areas

During the day, surface temperatures are more variable than atmospheric air temperatures, but at night, they are often similar. Because water does not absorb the sun's energy in the same way that structures and paved surfaces do, it maintains a relatively constant temperature day and night. This is demonstrated by the dips and spikes in surface temperatures over the pond region. Cooler places can be created within a metropolis via parks, wide open spaces, and bodies of water. Borders between suburban and rural areas often see cooler temperatures than metropolitan centres.

There are several ways to mitigate urban heat islands, including planting trees and increasing vegetation cover, installing green roofs, and using reflective materials on surfaces such as roads and rooftops. Trees are particularly effective at mitigating heat islands because they provide shade and evaporative cooling, which help lower temperatures.

Effects of Urban Heat Islands

The ramifications of UHIs extend beyond just higher temperatures. They lead to increased energy consumption, heightened levels of smog, and detrimental health effects from heat stress. Urban areas with significant heat islands often experience poor air quality, leading to respiratory issues among residents.

Moreover, UHIs can have economic impacts, increasing energy costs for cooling systems and reducing overall liveability in cities. However, trees can effectively counter these issues by cooling the air, improving air quality, and reducing energy usage.

Mitigating the Effects of Urban Heat Islands

There are several strategies to mitigate the effects of UHIs, with tree planting being one of the most impactful. Trees contribute to cooling through:

Shading: By blocking sunlight, trees reduce the heat absorbed by surfaces like asphalt and concrete. Studies show that shaded areas can be up to 10°F cooler than unshaded areas.

Evaporative Cooling: As trees transpire, they release water vapor, cooling the air around them. This process can significantly lower local temperatures.

Windbreaks: Trees can act as barriers against hot winds, helping to maintain cooler temperatures within urban environments.

Urbanization and industrialization have led to increased heat reflectance from urban surfaces, resulting in higher temperatures in these areas compared to their rural surroundings. This phenomenon, known as the Urban Heat Island effect, necessitates adaptive strategies for mitigation (Kong *et al.*, 2016). Increasing vegetation cover is a key approach, as trees effectively control urban climates by moderating temperatures and enhancing humidity levels.

Research shows that trees can lower surface air temperatures by providing shade and facilitating evapotranspiration. Shaded surfaces can be 6°C to 7°C cooler than exposed materials, while evapotranspiration can reduce peak summer temperatures by 13°C to 17°C. In some urban areas, air temperature differences can reach up to 17°C to 15°C, highlighting the substantial impact of increased tree cover on urban climates.

Benefits of Trees in Mitigating Urban Heat Islands

The benefits of trees extend beyond mere temperature regulation. They contribute to:

- Improved Air Quality: Trees filter pollutants from the air, reducing smog and improving health outcomes for residents.
- Energy Conservation: By providing shade, trees lower the need for artificial cooling, thus reducing energy consumption.
- Economic Benefits: Enhanced property values, increased tourism, and job creation in landscaping and maintenance are additional advantages of urban greenery.
- Social Benefits: Trees enhance community well-being and promote outdoor activities.
- Aesthetic and Architectural Benefits: They improve the visual appeal of urban spaces and contribute to cultural identity.
- Ecological Benefits: They support biodiversity and provide habitat for various species.

Planting Trees to Combat Urban Heat Islands

To effectively combat UHIs, cities must prioritize tree planting initiatives. Strategies include:

- Green Infrastructure: Incorporating green roofs, living walls, and urban forests can enhance the cooling capacity of cities.
- Selecting Appropriate Species: Choosing fast-growing and large-leaved tree species maximizes the cooling effect.
- Community Engagement: Involving residents in planting and caring for trees fosters community pride ands responsibility.

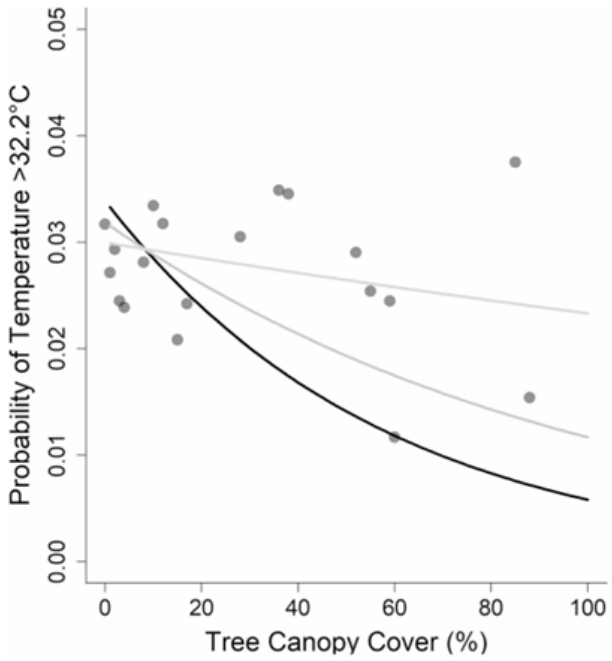

Figure 2: Impact of Tree Canopy on Urban Temperatures (Source: Ettinger *et al.*, 2024)

The graph shows that increasing tree canopy cover is associated with a decrease in the probability of high-heat events. This effect is more pronounced at lower elevations. The data points indicate the variability in heatwave risk across different locations within the study area. These findings suggest that urban greening initiatives can be a valuable tool in mitigating the impacts of climate change, particularly in cities experiencing rising temperatures.

Characteristics of Effective Cooling Trees

Key tree characteristics—such as canopy spread, leaf size and arrangement, tree height, and bole height—play essential roles in determining their cooling effectiveness (Lin *et al.*, 2017). Among these, heritage trees stand out as particularly valuable for urban cooling. Defined by their age, rarity, and significant aesthetic, ecological, and historical value (Coates and Peter, 2006), heritage trees are large, irreplaceable specimens that offer unique contributions to urban landscapes.

Heritage trees possess attributes that enhance their thermal cooling effects, including substantial canopy volume, high density coverage, and resilience to urban stressors. These features enable them to provide significant shade and contribute to microclimate regulation, thereby improving air quality and urban climate.

Conclusion

Urban Heat Islands represent a critical environmental challenge that affects city dwellers' health and well-being. However, through the strategic planting of trees and the promotion of green infrastructure, we can mitigate their adverse effects. Evidence suggests that increasing urban tree cover can lower temperatures, enhance air quality, and reduce energy consumption. By investing in tree planting programs and green initiatives, cities can create healthier, more sustainable environments for current and future generations.

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महोगनी की खेती: एले क्रॉपिंग निवेश, लागत और लाभ

विनोद कुमार एवं अंकित पाल

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परिचय

महोगनी, जिसका नाम डच चिकित्सक और वनस्पतिविद डॉ. जेरार्ड वॉन स्वीटेन के नाम पर रखा गया था, नकोलस जोसेफ वॉन जैक्विन द्वारा वर्गीकृत किया गया है। यह उष्णकटिबंधीय पेड़ों की एक अद्भुत जाति है जो मेलेसिएसी परिवार से संबंधित है। इन पेड़ों को उनकी पंखदार बीजों और अद्वितीय फूलों के लिए पहचाना जाता है, सबसे प्रसिद्ध प्रजातियों में से एक है महोगनी मैक्रोफिला, जिसे बड़े पत्ते के महोगनी या "स्काईफ्रूट" के नाम से जाना जाता है। यह एक तेज वृद्धि करने वाला सदाबहार पेड़ है जो उष्णकटिबंधीय और उप-उष्णकटिबंधीय क्षेत्रों में पाया जाता है। बड़े पत्ते का महोगनी सिर्फ जंगल में एक आकर्षक उपस्थिति नहीं है; यह एक वाणिज्यिक रूप से मूल्यवान प्रजाति भी है, जिसे इसके उच्च गुणवत्ता वाले लकड़ी के लिए सराहा जाता है, इसका उपयोग मुख्य रूप से उच्च गुणवत्ता वाले फर्नीचर, फर्श, दरवाजे, खिड़की के फ्रेम और सजावटी वस्तुएं बनाने में किया जाता है। जब हम इस पेड़ की प्रशंसा करते हैं, तो इसके पारिस्थितिकी महत्व को समझना और इसे भविष्य की पीढ़ियों के लिए संरक्षित करने के लिए स्थायी प्रथाओं की आवश्यकता पर ध्यान देना आवश्यक है।

विशेष रूप से इसे एशियाई-देशों में पारंपरिक चिकित्सा में कई चिकित्सीय महत्वपूर्ण गुणों के लिए भी जाना जाता है, इस अद्भुत पेड़ के विभिन्न भागों का उपयोग कई बीमारियों, जैसे मधुमेह, उच्च रक्तचाप, दर्द और मलेरिया के इलाज के लिए किया गया है। महोगनी के बीज विशेष रूप से महत्वपूर्ण हैं, क्योंकि इन्हें इसकी चिकित्सा विशेषताओं का मुख्य कारण माना जाता है। शोध मे यह पाया गया है कि इन बीजों में कई जैविक रूप से सक्रिय फाइटो कैमिकल्स होते हैं, जो उनके प्रभावशाली गुणों में योगदान करते हैं। ये बीज रक्त परिसंचरण को बढ़ावा देने, घावों के लिए एस्ट्रिंजेंट के रूप में कार्य करने, और यहां तक कि गर्भपात के औषधि के रूप में भी उपयोग किए जाते हैं। यह महत्वपूर्ण है कि हम इसके चिकित्सा संभावनाओं को भी पहचानें और संरक्षित करें, ताकि आने वाली पीढ़ियाँ इसके पारिस्थितिकी और चिकित्सा लाभों से लाभान्वित हो सकें।

महोगनी लकड़ी की मांग मुख्य रूप से इसकी स्थिरता, टिकाऊपन, कार्य करने में आसानी के कारण है। स्विटेनिया मैक्रोफिला, जो एकमात्र प्रजाति है जिसके प्राकृतिक आबादी का वाणिज्यिक दोहन संभव है, यह प्रकाश की मांग करने वाला वृक्ष है जो 70 मीटर की ऊंचाई तक और 3.5 मीटर व्यास तक बढ़ सकता है। यह आमतौर पर 0.1 से 3.0 पेड़ प्रति हेक्टेयर की कम घनत्व पर पाया जाता है, जिसकी दुर्लभता इसे लकड़ी उद्योगमें और भी अधिक मूल्यवान बनाती है।

महोगनी की खेती

महोगनी पेड़ की स्वस्थ वृद्धि सुनिश्चित करने के लिए, सही रोपण, स्थान का चयन करना बेहद महत्वपूर्ण है। पेड़ को किसी भी घर, दीवार और कारखाना से कम से कम 15 फीट और फुटपाथ से 8 फीट की दूरी पर लगाएं, ताकि इसके पूर्ण आकार के लिए पर्याप्त स्थान मिले। रोपण क्षेत्र को तैयार करने के लिए सबसे पहले एक गड्ढा खोदें जो 1.5 x 1.5 x 1.5 फीट का हो, और सुनिश्चित करें कि यह घास, पॉलिथीन, कंक्रीट और मलबे से मुक्त हो। मिट्टी की उर्वरकता बढ़ाने के लिए इसमें जैविक सामग्री जैसे कि खाद और गोबर कीखाद मिलानेके बादगड्ढे मे भर दे,गड्ढे को लगभग 1.5 सप्ताह तक बैठने दें। इस चरण में जैविक मिश्रण को शामिल करने से पोषक तत्वों की उपलब्धता बढ़ेगी। यदि आपको लगता है कि मिट्टी बहुत अधिक पानी रोक रही है, तो जल निकासी और वायु संचार में सुधार के लिए बालू मिलाने पर विचार करें। महोगनी पेड़ों के लिए, 6.0 x 6.5 फीट की दूरी बनाए रखें ताकि उन्हें बढ़ने के लिए बिना प्रतिस्पर्धा का स्थान मिले। वैकल्पिक रूप से, घास की वृद्धि को रोकने के लिए हर्बिसाइड लगाने से मदद मिल सकती है,

जिससे आपकी पौध को आवश्यक पोषक तत्व मिलते रहें। जब पौधे को गड्ढे में रखें, तो सुनिश्चित करें कि जड़ें पूरी तरह से ढकी हों और पेड़ सीधा और केंद्र में खड़ा हो। इस सावधानीपूर्वक तैयारी से स्वस्थ वृद्धि को बढ़ावा मिलेगा और एक फलदायी महोगनी पेड़ की नींव रखी जाएगी।

एले क्रॉपिंग के अंतर्गत महोगनी की खेती

महोगनी की खेती एले क्रॉपिंग पद्धति के अंतर्गत एक प्रभावी और लाभकारी कृषि रणनीति के रूप में उभर रही है। एले क्रॉपिंग का तात्पर्य है मुख्य फसल के साथ सहायक फसलों का संयोजन, जिससे भूमि का अधिकतम उपयोग किया जा सकता है। इसकी आर्थिक वैल्यू इसे किसानों के लिए एक आकर्षक विकल्प बनाती है। महोगनी का पौधरोपण करते समय, सहायक फसलों का चयन सोच-समझकर करना आवश्यक है। ऐसे फसलों का चयन करें जो महोगनी के पेड़ों के साथ तालमेल बिठा सकें, जैसे फल, सब्जियाँ, और औषधीय पौधे। यह प्रणाली न केवल खाद्य उत्पादन को बढ़ाती है, बल्कि कृषि विविधता को भी बढ़ावा देती है। महोगनी के पेड़ मिट्टी की गुणवत्ता में सुधार करते हैं और पोषक तत्वों को बढ़ाते हैं, जिससे अन्य फसलों की वृद्धि के लिए अनुकूल परिस्थितियाँ बनती हैं। आर्थिक दृष्टि से, महोगनी की खेती एले क्रॉपिंग के साथ एक स्थिर आय का स्रोत प्रदान करती है। महोगनी की लकड़ी की बिक्री से मिलने वाला लाभ सहायक फसलों से होने वाली आय के साथ मिलकर एक मजबूत वित्तीय आधार बनाता है। इसके अलावा, महोगनी के पेड़ कार्बन डाइऑक्साइड को अवशोषित करके जलवायु परिवर्तन के खिलाफ मदद करते हैं। यह प्रणाली न केवल किसानों को आर्थिक लाभ देती है, बल्कि पर्यावरण के संरक्षण में भी महत्वपूर्ण भूमिका निभाती है।

खेती में निवेश, लागत और लाभ

महोगनी की खेती में यदि आप 10-12 वर्षों के लिए 500 महोगनी पौधों का रोपण करते हैं, तो यह आपको महत्वपूर्ण लाभ दे सकता है। प्रत्येक पौधे की कीमत लगभग 25 से 30 रुपये है, जिससे 500 पौधों की कुल लागत लगभग 15,000 रुपये बनती है। इसके अलावा, एक एकड़ में खाद की लागत 20,000 रुपये, श्रम शुल्क 15,000 रुपये, और अन्य विविध खर्चों का अनुमान 25,000 रुपये है। इस प्रकार, कुल उत्पादन लागत लगभग 80,000 रुपये है, जो महोगनी लकड़ी की बिक्री से अच्छे आय की संभावना को दर्शाती है। महोगनी के पेड़, विशेषकर स्विटेनिया मैक्रोफिला, 10 वर्षों में औसतन 75 फीट ऊँचे और 0.95 फीट व्यास के हो सकते हैं। यदि आप प्रत्येक पेड़ के बीच 6.0 x

6.5 फीट की दूरी रखते हैं, तो आप एक एकड़ में लगभग 1200 से 1500 पेड़ लगा सकते हैं। ये पेड़ लगभग 32,000 घन फीट लकड़ी का उत्पादन कर सकते हैं। यदि इनका उचित प्रबंधन किया जाए, तो प्रत्येक पेड़ 10 वर्षों में लगभग 20 घन फीट लकड़ी दे सकता है, जिससे प्रति एकड़ कुल 10,000 घन फीट लकड़ी का उत्पादन होता है।500 पौधों की रोपाई की कुल लागत लगभग 80,000 रुपये होगी, जिसमें पौधे, खाद, श्रम, और अन्य खर्च शामिल हैं। लकड़ी की बिक्री से शुद्ध आय का अनुमान 600 रुपये प्रति घन फीट है, जिससे प्रति एकड़ कुल 6,000,000 रुपये की आय हो सकती है। महोगनी की खेती न केवल आर्थिक दृष्टि से लाभदायक है, बल्कि यह पर्यावरण के लिए भी महत्वपूर्ण है। यह पेड़ न केवल वायु को शुद्ध करते हैं, बल्कि मिट्टी के कटाव को रोकने में भी मदद करते हैं। इस प्रकार, महोगनी की खेती एक अल्पकालिक निवेश है जो सही प्रबंधन और देखभाल के साथ आपको उच्च लाभ दे सकता है। इसकी खेती के लिए शुरूआती लागत भले ही अधिक हो, लेकिन आने वाले वर्षों में मिलने वाले लाभ इसे एक आकर्षक विकल्प बनाते हैं। इस प्रकार, महोगनी की खेती एक लाभदायक उद्यम हो सकती है, जो न केवल आर्थिक लाभ देती है, बल्कि पर्यावरण संरक्षण में भी योगदान करती है। उचित योजना सेआप महोगनी के पेड़ लगाने के इस तकनीक से अच्छा लाभ प्राप्त कर सकते हैं।

From soil to canopy: Understanding the science of silviculture

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Introduction

Forests are essential elements of the Earth's ecosystem (Ahmad *et al.*, 2023). They play a key role in absorbing carbon dioxide, generating oxygen, and maintaining global climate stability (Nunes *et al.*, 2020). Moreover, forests provide crucial habitats for a wide array of terrestrial biodiversity, including various plant, animal, fungal, and microbial species (Rawat & Agarwal, 2015). They are also significant for water cycles, aiding in groundwater replenishment and minimizing soil erosion (Van *et al.*, 2021). However, urban development, agricultural practices, and climate change have significantly impacted these ecosystems (Upadhyay, 2020). This is where silviculture is important, as it provides a systematic approach to sustainably manage forest resources, ensuring that they continue to deliver ecological, economic, and social advantages (Fujimori, 2001). Silviculture includes a diverse array of practices aimed at effectively managing forest growth and structure. It merges ecological concepts with practical management strategies to fulfill multiple goals, such as timber production, habitat preservation, and recreational opportunities (Ashton &Kelty, 2018). This field requires a solid understanding of tree biology, forest ecology, soil science, and the effects of human actions on forest ecosystems. Fundamentally, silviculture seeks to develop and sustain healthy, productive forests that can satisfy the needs of both present and future generations. This encompasses not just the care of individual trees, but also the management of the forest as an integrated ecosystem (Wilson, 2023).

The Foundation: Soil Health

The foundation of silviculture lies in the health of the soil. Healthy soil is a vibrant ecosystem, filled with microorganisms, nutrients, and organic matter that foster tree growth and enhance the forest's overall vitality. Soil health is influenced by various factors, including texture, structure, pH levels, and the availability of vital nutrients (Chauhan *et al.*, 2007). Silviculturists perform soil evaluations to grasp the specific characteristics of a site, which is crucial for selecting appropriate tree species, as different species have distinct soil needs. For example, pines thrive in sandy, well-drained soils, whereas oaks prefer more nutrient-rich environments. By choosing species that align with the soil conditions, silviculturists can encourage robust growth and enhance biodiversity (Nyland, 2016).

Choice of Species

Selecting the right tree species is a crucial element of silviculture (Nyland, 2016). Each species exhibits distinct growth habits, ecological functions, and varying

levels of vulnerability to pests and diseases. A knowledgeable silviculturist must consider several factors, including the local climate, soil characteristics, and the surrounding ecosystem when determining which trees to grow (Savill*et al.*, 1997; Matthews, 1991). For instance, fast-growing species like poplar may be preferred for timber production due to their economic advantages, while native species such as oak, hickory, and maple could be prioritized to boost biodiversity and support wildlife habitats (Daugaviete*et al.*, 2022; Webster *et al.*, 2018). This meticulous selection process fosters a resilient forest ecosystem where diverse species can flourish and adapt to evolving environmental conditions.

Planting: Laying the Groundwork for Growth

After selecting the appropriate species, the planting phase becomes critical. Silvicultural practices determine the ideal spacing and arrangement of trees, which can greatly influence their growth and health (Ashton &Kelty, 2018). Various techniques are used depending on the desired outcomes (Nyland, 2016):

Clear-Cutting

This method involves removing all trees in a specific area, facilitating rapid regeneration of certain species. While effective for timber production, it necessitates careful planning to minimize ecological consequences.

Selective Cutting

This technique involves harvesting only certain trees while leaving others intact, which helps preserve the forest canopy and provides habitats for wildlife. It supports biodiversity and maintains the integrity of the forest ecosystem.

Shelterwood Cutting

This method entails removing trees in stages, allowing seedlings to grow under the protection of mature trees. It promotes new tree growth while sustaining the forest structure.

The choice of planting technique will depend on the specific management goals of the forest and relevant ecological factors.

Cultivating: The Importance of Effective Management

As trees grow, continuous management is essential for maintaining their health and productivity (Fujimori, 2001). Silviculture focuses on monitoring tree development, managing invasive species, and applying pest control measures. Regular evaluations enable silviculturists to detect potential problems early and implement corrective measures. Thinning is a common management technique that involves the selective removal of certain trees to lessen competition for vital resources such as light, water, and nutrients. This practice not only fosters the growth of the remaining trees but also improves overall forest health by boosting biodiversity and lowering the risk of disease (Nyland, 2016).

The Canopy: A Vital Layer

The canopy forms the highest part of the forest, where sunlight filters through the leaves, creating a distinctive habitat that supports numerous species. This layer plays a key role in carbon storage, aiding in the fight against climate change. Silviculture emphasizes the importance of maintaining a robust canopy, which supports biodiversity, prevents soil erosion, and helps regulate forest microclimates (Nadkarni *et al.*, 2004). By

using sustainable methods, silviculturists ensure that the canopy remains preserved, allowing essential ecosystem services to continue while permitting the selective harvesting of both timber and non-timber products (Ashton &Kelty, 2018).

Connecting Canopy to Community

Silviculture's influence goes beyond just trees. Healthy forests offer significant benefits to nearby communities, such as recreation, tourism, and economic resources (Winter *et al.*, 2009). Sustainable forestry practices aim to balance ecological health with economic sustainability; ensuring forests will continue to meet the needs of future generations (Knudsen, 1996). Community involvement plays a crucial role in successful forest management. Engaging local stakeholders in the decision-making process helps foster a sense of ownership and encourages sustainable practices that support both environmental and community well-being (Wilson, 2023).

The Next Generation of Silviculture

In light of growing challenges like climate change, deforestation, and habitat destruction, silviculture's role is increasingly important. Innovative methods, such as agroforestry, which incorporates trees into agricultural settings, are becoming more popular as they improve food security and support biodiversity (Nair, 2007). Additionally, technological advancements such as remote sensing and data analysis are allowing silviculturists to monitor forest health more efficiently and make informed management decisions. These tools provide accurate tracking of ecological changes, enabling adaptive strategies that address emerging issues (Jain, 2019).

Conclusion

From the soil that sustains life to the canopy that offers shelter, silviculture integrates science, ecology, and community. By understanding its principles, we can better appreciate the intricacies of forest management and the importance of sustainable practices. As caretakers of our natural resources, it is crucial that we embrace silviculture to ensure that our forests continue to flourish for future generations. Recognizing silviculture's role is essential to moving toward a sustainable future, where healthy forests are not only preserved but celebrated as integral parts of our planet's ecosystem.

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Medicinal and Economic Value of *Canarium strictum* Roxb. (Black Dammar)

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Introduction

Canarium strictum Roxb., commonly known as black dammar, is a polygamodioecious tree belonging to the Burseraceae family. It is of significant ecological, cultural, and economic importance. Traditionally, the resin of *C. strictum*, known as "dhoop," is extracted and used in ceremonial rituals. The species is also noted for its antimicrobial properties, with leaf extracts demonstrating varying levels of activity

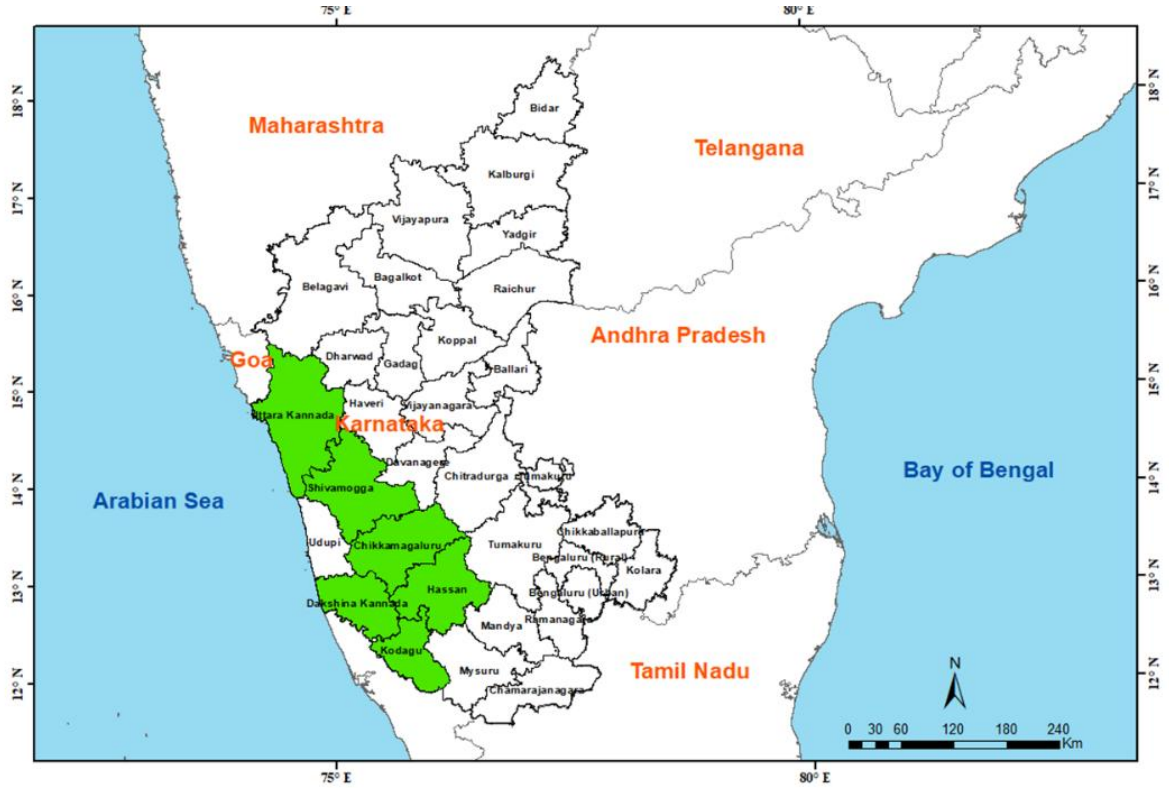

Fig.1 Distribution of *Canarium strictum* across the Western Ghats of Karnataka

against different bacteria and fungi, particularly with methanolic extracts showing notable efficacy. Given its status in sacred groves and the integration of traditional ecological knowledge with modern scientific approaches, the conservation of *C. strictum* is crucial for sustainable management.

Distribution and Habitat

C. strictum is predominantly found in tropical moist evergreen forests and moist mixed deciduous forests. In India, it is distributed across states such as Sikkim,

Arunachal Pradesh, Assam, Meghalaya, Odisha, Maharashtra, Karnataka, Kerala, Tamil Nadu, and the Andaman Islands, typically at altitudes up to 1600 meters. The species is listed as vulnerable on the IUCN Red List in regions like Kerala and Karnataka due to overexploitation. However, detailed information on harvesting and trade practices in certain areas remains scarce, necessitating further research and conservation efforts.

Canarium strictum is a large tree species identifiable by its rounded crown and a straight, unbranched trunk that can extend up to 30-45 meters in height. This species is polygamodioecious, meaning it has both male and hermaphroditic individuals. The compound leaves are arranged alternately and spirally and are covered with rust-colored hairs. The flowers are trimerous and exhibit polygamy, with distinct morphologies for male and bisexual flowers. The fruits are drupaceous, oblong, and pointed at the ends, featuring a fleshy mesocarp and a hard, aromatic stone.

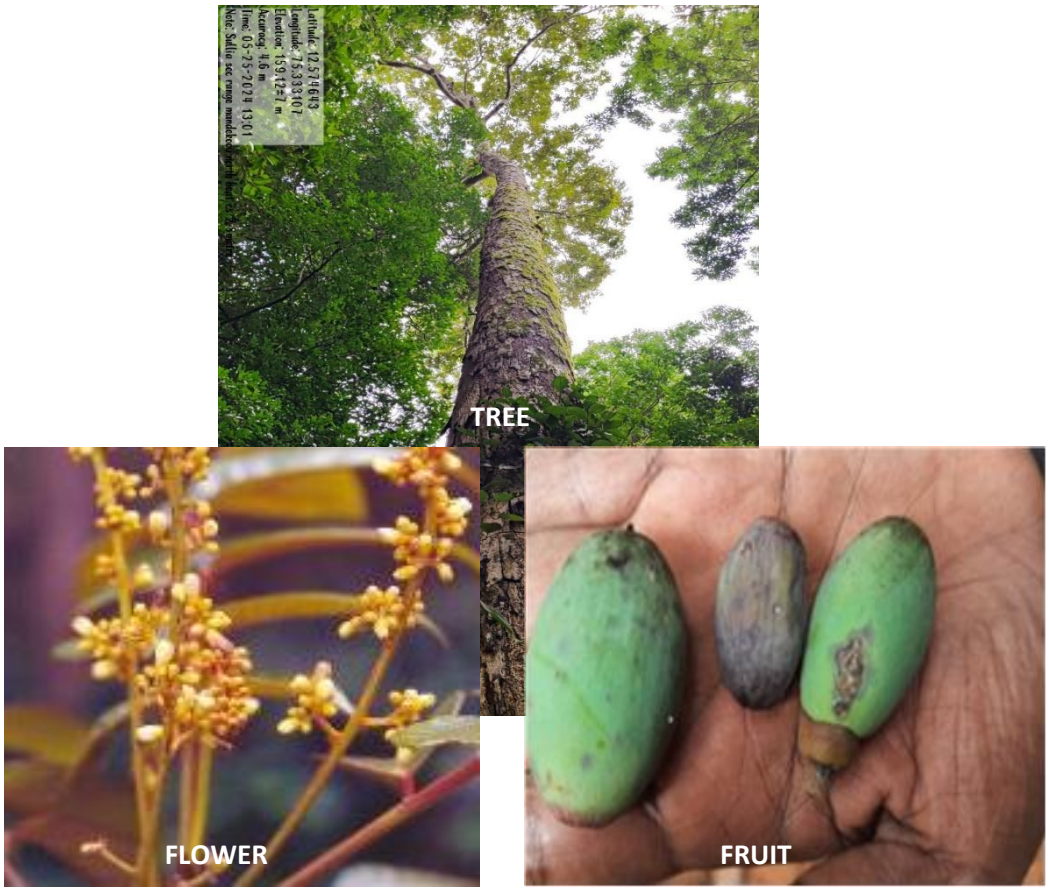

Fig.2 Morphological characteristics of *Canarium strictum*

Economic Importance

Resin (Sambrani or Dammar)

Canarium strictum produces a resin known locally as ‘Sambrani’ or ‘Dammar’, which is both medicinal and commercially valuable. The resin has a long history of use among tribal and folk communities in India for treating various ailments. It is a key ingredient in traditional medicine, including the Siddha system, and is

commonly used in incense production and varnish industries. Additionally, the resin serves as a substitute for burgundy pitch in the creation of medicinal plasters.

Medicinal Uses of Resin

The resin is renowned for its therapeutic properties. It is commonly used to treat a variety of conditions, including bronchial ailments such as asthma and cough, as well as chronic skin disorders, fever, rheumatism, epilepsy, syphilis, and hernia. Oral consumption of resin powder is also believed to improve complexion and skin health.

Timber Uses

The wood is characterized by its grayish-white color with a pinkish hue in the heartwood, has various practical applications. It is primarily used for making ceiling boards, flooring, and partitions from well-seasoned timber. The wood is also employed in the production of packing cases, low-cost utility furniture, and plywood tea boxes, owing to its good glue-holding capacity.

Seed and Oil Uses

The seeds are edible, and their oil is used in confectionery production. This highlights the plant's economic importance beyond its resin and timber.

Domestic Markets for Black Dammar

Market Trends and Usage

In India, the trade of Black Dammar is largely concentrated in Kerala due to restrictions on resin collection in Tamil Nadu. Between 2004 and 2008, approximately 150 tons of Black Dammar were sold through auctions in Kerala. The rising domestic prices of Dammar have reduced its demand in matchstick and fireworks industries by about 50% in recent years.

The agarbatti industry, a major consumer of Dammar, produces an estimated 4,200 million incense sticks annually, with 1,100 to 1,200 tons of gum Dammar used as a binding agent. High-quality incense manufacturers prefer Indian Dammar due to its superior fragrance.

Additional Uses

In Kerala, the boat-building industry utilizes Dammar gum for waterproofing wooden boat parts and caulking, consuming approximately 50–60 tons annually. Overall, nearly 60% of Dammar consumption in India is attributed to the incense industry, with the domestic usage estimated at 18,000 tons annually. Major procurement hubs, such as Virudhnagar, supply Dammar to both local industries and importers.

Ecological Impacts of Tapping Practices

Sustainability Concerns

The sustainability of resin extraction from *Canarium strictum* is closely linked to the frequency and intensity of tapping. Increased commercial demand, forest encroachment, and a decline in traditional land tenure systems have led to unsustainable harvesting practices. Frequent tapping not only reduces the quality of resin but also negatively impacts the tree's health by increasing adult mortality and lowering reproductive output.

Impact on Reproductive Success

Excessive resin tapping decreases the fruit-to-flower ratio and results in higher production of non-viable seeds. This decline in reproductive success also disrupts the ecological balance, as the tree supports various fauna, including pollinators and frugivores such as hornbills and imperial pigeons.

Population Decline and Genetic Fitness

Ecological surveys indicate a shrinking population of *Canarium strictum*, which may result in long-term population declines. Research has shown higher seedling mortality when seeds are collected from smaller groves compared to larger groves. Reduced grove sizes increase the likelihood of inbreeding, leading to lower seedling fitness and accumulation of deleterious genetic traits.

Threats and Conservation Status

Canarium strictum faces significant threats to its survival, primarily due to habitat driving the decline of its populations in the wild, especially in South India, where it is listed as a vulnerable species. As a result, urgent measures are required to promote its cultivation, ensuring a sustainable supply for trade and local subsistence needs while protecting the species from extinction.

Regeneration and Viability

Regeneration Potential

Canarium strictum demonstrates a relatively high potential for regeneration under proper conditions. The species can recover rapidly if areas are protected from further clearance and degradation. The tree's seeds, which typically fall near the parent tree, are easy to germinate and can be propagated artificially by sowing seeds in shaded mother beds. Seeds should be soaked for 24 hours, drained, and planted at a depth of 1.5 to 2.0 cm, with the micropyle facing upwards. Germination is epigeal, and it typically begins three weeks after sowing, continuing for up to 120 days, especially when seeds are sown during the winter months. Germination rates of up to 95% have been observed when using sand substratum.

fragmentation and human activities. A reduction of 20% in its population has been observed over the past decade, with particular concerns arising from habitat destruction in regions like the Kolli Hills in the Eastern Ghats and Silent Valley in the Western Ghats. The decline in pollination and seed dispersal, coupled with the overexploitation of resin and wood, has contributed to the species' endangered status.

Unsustainable tapping practices for resin extraction have been identified as a major factor

Seedling Growth and Transplanting

Once the seeds have germinated, the seedlings grow quickly and can be transplanted into polythene bags when they reach the three-leaf stage. After about two months, these seedlings are ready for plantation. *Canarium strictum* can also be successfully grown by direct sowing in the fields at the onset of the monsoon season, with high germination rates observed under controlled conditions. Establishing a nursery at the study site could enhance seedling survival rates and improve the seed-to-seedling ratio.

By promoting the cultivation and regeneration of *C. strictum* through these methods, there is potential to stabilize its population, ensuring its continued availability for medicinal and economic purposes.

Conservation Implications

To mitigate these impacts, sustainable tapping practices and habitat restoration efforts are crucial. Protecting larger groves and promoting traditional knowledge can enhance genetic diversity, improve reproductive success, and ensure the long-

term viability of *Canarium strictum* populations.

Conclusion

Canarium strictum holds significant medicinal and economic value but is now endangered due to overexploitation and habitat loss. The erosion of indigenous knowledge, coupled with unsustainable harvesting, exacerbates its decline. Comprehensive studies on its population, ecology, and reproductive biology are needed to ensure its survival. Preserving this species is vital for both biodiversity conservation and the livelihoods of local communities.However, the species' ability to regenerate and its medicinal and economic significance offer hope for conservation. Collaboration between forest departments, conservationists, and NGOs is essential to protect this endangered species and ensure its sustainable use for future generations.

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Neem: Natural pest control and soil health booster

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Introduction

For centuries, Neem (*Azadirachta indica*) has been celebrated in traditional medicine, but its benefits extend far beyond personal health. In agriculture, Neem has become indispensable for farmers aiming to adopt sustainable, eco-friendly practices that enhance crop health and productivity.As farmers face challenges like soil degradation and pesticide resistance, there's a growing need for sustainable agricultural practices. Neem (Azadirachta indica), often called the "miracle tree," offers a natural solution to these issues. As a natural pesticide, soil enhancer, and resilience booster, Neem offers an impressive array of solutions that reduce dependence on synthetic chemicals, safeguard the environment, and promote long-term agricultural sustainability.

Natural Pest Control with Neem

Neem is renowned for its natural pest-repellent properties, making it a key ally in reducing crop damage without harmful chemicals. The secret lies in azadirachtin, a compound in Neem oil that disrupts the life cycle of many common pests. When applied to crops, azadirachtin interferes with pest feeding, growth, and reproduction, effectively controlling pest populations over time.Neem's impact extends to a variety of harmful pests, including aphids, caterpillars, whiteflies, mites, and even root-knot nematodes. Unlike synthetic pesticides, Neem doesn't kill insects on contact but works gradually, which helps protect beneficial insects like bees, ladybugs, and other pollinators. This targeted, environmentally friendly approach makes Neem an invaluable tool for organic and conventional farmers alike, as it reduces pesticide residue in crops and limits pollution in water and soil systems.

Enhancing Soil Health and Fertility

Beyond pest control, Neem contributes significantly to soil health. Neem cake, a residue left after Neem oil extraction, is rich in essential nutrients, including nitrogen, phosphorus, and potassium, which plants require for healthy growth. Neem cake also contains secondary nutrients and trace elements that enrich the soil, promoting microbial diversity and enhancing soil structure. As an organic fertilizer, Neem cake adds organic matter to the soil, which improves its moisture retention, aeration, and texture, all of which contribute to healthier root development and increased crop yields.Moreover, Neem cake is a natural biopesticide against soil-borne pests like nematodes, fungi, and other harmful

pathogens. By incorporating Neem cake into soil management practices, farmers not only feed their crops but also protect them from underground pests that are often resistant to chemical treatments. The use of Neem cake can lead to healthier soil ecosystems, which are vital for sustaining agricultural productivity over multiple seasons.

Neem in Integrated Pest Management (IPM)

In the context of Integrated Pest Management (IPM), Neem offers a critical advantage. IPM combines biological, mechanical, and chemical methods to manage pests in an environmentally balanced way. Neem-based products fit seamlessly into this approach, reducing the need for chemical pesticides and fostering a balanced farm ecosystem. When used in combination with other organic treatments, Neem contributes to a more comprehensive and sustainable pest management strategy.Unlike chemical pesticides, which often cause pest resistance over time, Neem works slowly and disrupts pest breeding cycles without killing outright. This significantly reduces the risk of resistant pest populations, extending the effectiveness of Neem products across multiple seasons. Additionally, Neem's selective action allows beneficial insects to thrive, further supporting natural pest control and crop pollination.Neem's slower action on pests also reduces the risk of resistance, offering a long-term solution for pest management that supports sustainable farming goals.

Economic and Environmental Benefits of Neem

For farmers, Neem offers both economic and environmental benefits. By providing a natural and effective alternative to chemical fertilizers and pesticides, Neem reduces the costs associated with synthetic inputs. Farmers, particularly those with small or organic farms, benefit from Neem's affordability and accessibility. The use of Neem-based products can increase crop yield and quality, enhancing market value and profitability.Neem's resilience to adverse climate conditions, like drought, is an added advantage in an era of climate unpredictability. Neem trees are naturally drought-resistant, and their byproducts help improve soil moisture retention, making crops more resilient to dry spells. Environmentally, Neem minimizes chemical runoff, supports biodiversity, and contributes to healthier ecosystems, as it doesn't pollute water sources or degrade soil quality.By incorporating Neem, farmers are investing in practices that support both immediate and long-term agricultural productivity, without compromising environmental health.

Conclusion

Neem is more than just a tree; it's a multifunctional, sustainable resource that's making a powerful impact in agriculture worldwide. Its ability to enhance soil health, provide natural pest control, and reduce dependence on synthetic chemicals underscores its role as a vital tool in sustainable farming. With Neem, farmers are empowered to cultivate healthy crops, improve soil fertility, and protect natural ecosystemsbenefiting both their livelihoods and the planet. In every sense, Neem truly is the farmer's friend in the quest for sustainable agriculture.With Neem, farmers are empowered to cultivate healthier crops and protect the land for generations to come.

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Monitoring forest resources to combat climate change using remote sensing and GIS technology

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Introduction

Forests are crucial in countering climate change as carbon sinks and regulators of global temperatures. These ecosystems absorb enormous amounts of carbon dioxide (CO_2), maintain biodiversity, and regulate hydrological cycles. However, deforestation and forest degradation pose severe threats to these critical functions. Studies indicate that forest degradation accounts for a significant fraction of the carbon emissions globally. Deforestation annually accounts for as much as 20% of the total emission. The increasing scale and complexity of such challenges require new approaches to the management of forest resources. Advanced technologies, such as Remote Sensing (RS) and Geographic Information Systems (GIS), serve as necessary tools for monitoring forest resources and developing sustainable management strategies. This article discusses the applications, challenges, and opportunities of RS and GIS technologies in the fight against climate change through effective forest monitoring.

The Role of Forests in Climate Change Mitigation

Forests are critical carbon sinks, absorbing about one-third of the CO_2 released by fossil fuel combustion annually. This function is lost when forests are degraded or destroyed, and the stored carbon is released back into the atmosphere. In addition to carbon sequestration, forests offer a wide range of ecosystem services, such as biodiversity conservation, water regulation, and soil protection. However, forest degradation through illegal logging, forest fires, agricultural expansion, and unsustainable land-use practices reduces these services. Monitoring forest degradation is quite a challenging process because it incorporates assessing changes in forest structure, composition, and biomass over time. To abate this problem, remote sensing technologies have improved significantly, allowing for accurate and very complete observations of forest dynamics and offering crucial data for climate change research and policy-making.

Remote Sensing and GIS - Transformative Technologies

RS and GIS technology have transformed forest monitoring by giving precise, real-time data at large geographical and temporal scales. Here are some of their major applications and advantages:

Deforestation and Degradation Monitoring

- Satellite imagery from satellites such as Landsat, MODIS, and

Sentinel enables one to detect and monitor deforestation and forest degradation. The imagery is high resolution, thus helpful in identifying the activities such as selective logging, land-use change, and forest fires

- Biomass change monitoring and assessment of carbon stock loss in degraded forests are made through techniques like spectral mixture analysis and time-series analysis. This method helps to quantify the degree of degradation and provide data required for effective intervention strategies.

Biodiversity and Habitat Assessment

- GIS tools enable the mapping of biodiversity hotspots and vulnerable ecosystems to support conservation planning and resource allocation. By overlaying data on forest cover, topography, and species distribution, GIS helps identify areas of critical ecological importance.
- LiDAR, and synthetic aperture radar (SAR), both provide detailed views on forest canopy structure and species distributions. These tools offer the possibility to measure tree height, canopy density, and habitat quality with some precision.

Carbon Stock Accounting

- RS and GIS technologies play a critical role in measuring above-ground biomass and monitoring carbon stock changes over time. These measurements are essential for international frameworks such as REDD+ (Reducing Emissions from Deforestation and Forest Degradation).
- Improved technological advancements with the use of drone-based RS enhance the precision and efficiency in carbon accounting efforts. These devices can collect data of high resolutions in remote and inaccessible areas.

Disaster Response and Risk Mitigation

- Forest fires, hurricanes, and other natural disasters greatly affect the health of forests and contribute to carbon emissions. Thermal sensors on satellites can detect active fires, while post-event imagery helps assess damage and supports recovery planning.
- Using RS and GIS for monitoring and predicting the impact of extreme weather conditions helps in effective proactive disaster risk management.

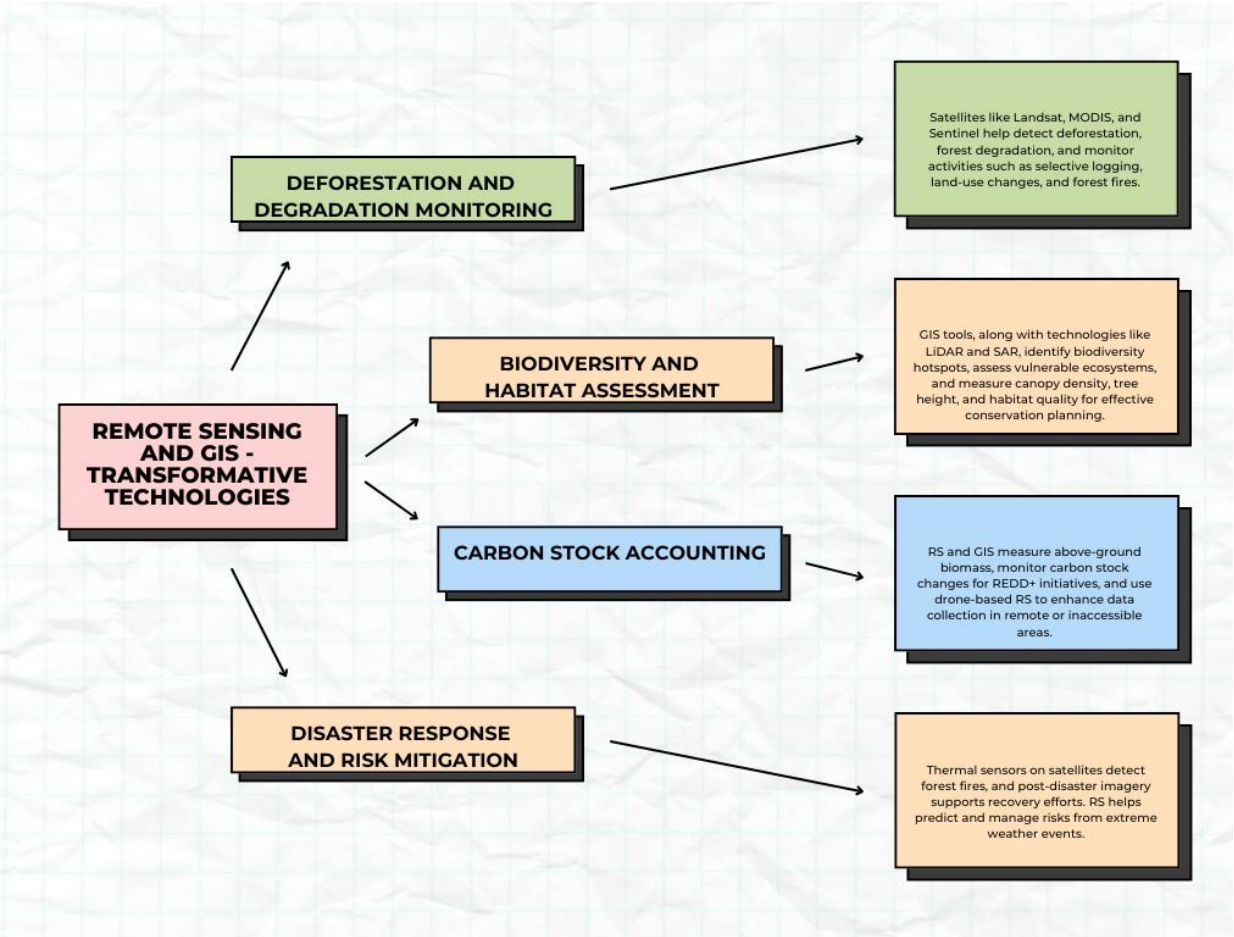

Fig 1. Remote Sensing and GIS - Transformative Technologies

Challenges and Opportunities

While tremendous potential exists with RS and GIS technologies, challenges still abound:

Sensor Limitations

Sensor Limitations: Certain sensors' spatial and temporal resolution may be insufficient to detect small-scale or minor forest changes. High-resolution imagery, while useful, can be expensive and data-intensive.

Data Interpretation

RS and GIS data demand expertise and must often be grounded validated to produce accurate results. The only way forward is through co-operation between the field researchers and technology specialists.

Data Accessibility

While platforms such as Google Earth Engine and Copernicus Sentinel have significantly reduced barriers, there is still a need for more open access to high-resolution datasets and analytical tools.

Despite these challenges, advancements in RS and GIS technologies, coupled with global collaborations, present significant opportunities. Initiatives such as the UN's Sustainable Development Goals (SDGs) and international climate agreements provide a strong impetus for the adoption of these technologies. The increasing availability of open-source RS software and cloud-based platforms has democratized access to data and analytical

tools, enabling wider participation in forest monitoring efforts.

Conclusion

The incorporation of RS and GIS technology into forest monitoring is a transformational strategy to solving climate change challenges. These technologies help politicians, conservationists, and scientists develop successful plans for sustainable forest management by delivering accurate, timely, and actionable data. As threats to global forests rise, it will be crucial to harness the power of RS and GIS technologies to protect these vital ecosystems and prevent climate change. Collaborative efforts, technology breakthroughs, and policy support will be critical to maximizing the impact of these tools for a sustainable future.

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Published by:

Impact Factor

SJIF: 2022-6.071

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