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**Cover Photo: Panoramic view of Achanakmar-Amarkantak Biosphere Reserve**



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**From the Editor's desk**

*Bamboo is emerging as a powerful nature-based solution to climate change due to its rapid growth, high carbon sequestration capacity, and ability to restore degraded lands. Fast-growing species can absorb 5-12 tonnes of CO<sub>2</sub> per hectare annually and mature within 3-5 years, making bamboo ideal for quick ecosystem recovery and sustainable material production. Its versatility allows it to replace high-emission materials like steel, cement, plastics, and timber, significantly reducing the carbon footprint of construction and manufacturing. Beyond environmental benefits, bamboo strengthens rural economies, creates green jobs, and supports climate-resilient livelihoods. To fully harness its potential, bamboo must be integrated into climate policies, restoration programs, and green industry plans. Overall, bamboo offers a regenerative, low-carbon pathway toward sustainable development and a climate-secure future.*

*In line with the above this issue of Van Sangyan contains an article on Bamboo and climate change: A pathway to sustainability. There are also useful articles viz.. मिट्टी, मवेशी और किसान: भीमल का बहुमूल्य योगदान , Bay Laurel: The unique and special spice of kitchen, The remarkable world of scarabaeoidea: Ecological importance and biodiversity, Challenges and limitations in valuing ecosystem services in agroforestry, Role of forests in reducing the effects of global climate change, Agroforestry and fight against hunger, Role of dark septate endophytes in overcoming abiotic stress to combat climate change, Restoration forestry techniques: Healing our forests and Computational approaches for assessing genetic diversity*

*Looking forward to meet you all through forthcoming issues*

**Dr. Naseer Mohammad**

Chief Editor



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## Bamboo and climate change: A pathway to sustainability

Salma<sup>1</sup>, Venkatesh L<sup>2</sup>, Akunuri Supriya<sup>1</sup>, Syed Ali<sup>2</sup> and Pratap Toppo<sup>1</sup>

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### Introduction

Bamboo, a fast-growing grass from the Gramineae family, thrives in diverse tropical and subtropical climates across 31.5 million hectares worldwide. With over 1,300 species, it plays a critical role in forest ecosystems, offering numerous environmental services such as soil and water conservation, erosion control, and acting as windbreaks (Bahru and Ding, 2021).

One of bamboo's remarkable features is its extensive rhizome system, enabling rapid asexual reproduction and resilience against environmental changes. Well-managed bamboo forests can sequester more carbon than many fast-growing tree species, making them a potent ally in the fight against climate change. Studies have shown that regular harvesting can enhance their carbon storage potential, highlighting the importance of sustainable management practices.

In addition to carbon sequestration, bamboo serves as a valuable resource for local communities, providing food, materials for construction, and income. Its rapid growth and ability to thrive in poor soils make it an ideal candidate for bioengineering applications, particularly for soil stabilization on steep slopes. Bamboo stands out as a sustainable solution as global temperatures rise and the impacts of climate change intensify—such as rising sea levels and increased

natural disasters. It not only absorbs CO<sub>2</sub> more efficiently than traditional hardwoods but also contributes to restoring biodiversity and ecosystem balance.

Bamboo forests represent a multifaceted approach to mitigating climate change, providing ecological, economic, and social benefits. Their effective management is crucial for maximizing these benefits and ensuring a sustainable future.

### Properties of Bamboo

Bamboo exhibits a range of properties that vary among its numerous species, making it a versatile material for various applications. Key properties include:

#### Tensile and Compressive Strength

Bamboo's tensile strength is particularly high due to its vascular bundles concentrated in the outer zones. This strength varies along the height of the culms, allowing it to withstand significant loads.

#### Shrinkage

Bamboo typically exhibits minimal shrinkage compared to traditional wood, which contributes to its stability and durability as a construction material.

#### Resistibility

Certain bamboo species have natural resistance to pests and decay, making them suitable for long-lasting use in various environments.

#### Elasticity

Bamboo's remarkable elasticity allows it to absorb shocks, making it especially



advantageous in earthquake-prone areas. Its lightweight nature further enhances its suitability for sustainable building practices (Klaus, 2002).

### Potential of Bamboo for a Sustainable Environment

#### Rapid Growth

Bamboo is one of the fastest-growing plants, enabling quick regrowth after harvesting.

#### Soil Stabilization

Its extensive rooting system binds soil aggregates, reducing erosion and enhancing soil health.

#### Carbon Sequestration

Bamboo can sequester more carbon than many tree plantations, with estimates ranging from 200 to 400 tons of carbon per hectare.

#### Durable Carbon Storage

Bamboo stores carbon not only in its biomass but also in durable products made from it, maximizing carbon retention.

#### Climate Change Mitigation

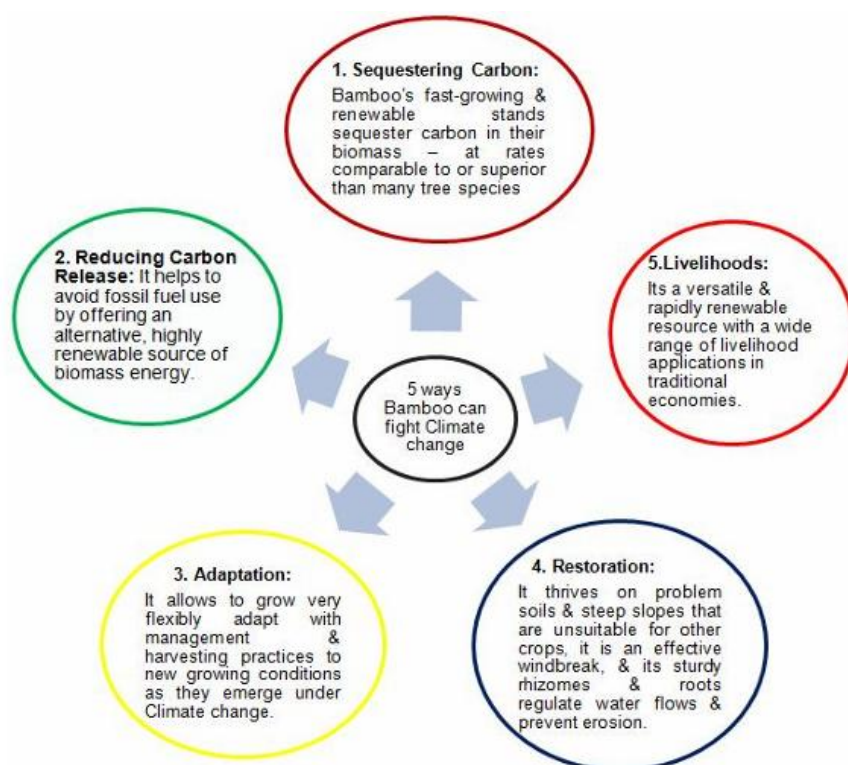
As bamboo proliferates in tropical regions across Africa, Asia, and the Americas, it offers significant potential to combat climate change, particularly in developing countries.

#### Sustainable Resource

Bamboo's ability to regenerate rapidly makes it a sustainable resource for various applications, from construction to bioenergy.

#### Environmental Benefits

Beyond carbon sequestration, bamboo contributes to biodiversity, water regulation, and ecosystem restoration (INBAR,2018).



**Fig.1: The five key functions of bamboo help to mitigate/adapt the impacts of climate change**



**Bamboo as a Carbon Sequester****Carbon Sequestration Process**

Bamboo absorbs atmospheric carbon dioxide through photosynthesis, transforming it into solid biomass, which is crucial for reducing overall carbon levels in the atmosphere (Yiping *et al.*, 2010).

**Mitigating Climate Change**

Enhancing carbon sequestration through bamboo can help mitigate dangerous climate change scenarios by lowering carbon dioxide concentrations.

**Land Conversion Potential**

Converting low-carbon lands-such as shrublands, pastures, and degraded forests-into bamboo forests can significantly increase carbon storage in both vegetation and soil.

**Sustainable Forest Management**

Bamboo forests are less susceptible to deforestation compared to primary tropical forests, making them a viable option for sustainable land use and carbon capture.

**Research Importance**

The study of bamboo's carbon sequestration capabilities is increasingly relevant, given its role in sustainable production and environmental resilience.

**Ecosystem Benefits**

In addition to carbon storage, bamboo forests enhance biodiversity, improve soil quality, and regulate water cycles, further contributing to environmental health.

**Bamboo as a Source of Renewable Energy in India****Charcoal Production**

Research by INBAR indicates that bamboo charcoal has calorific values comparable to those of teak and eucalyptus while producing minimal smoke, smell, or sparks. This makes it an ideal substitute

for wood charcoal, where logging drives deforestation.

**Economic Benefits**

In India, producing bamboo charcoal can significantly enhance rural livelihoods, with households potentially earning over USD 1,000 annually. This economic incentive encourages sustainable practices and reduces pressure on existing forests.

**Land Restoration**

Bamboo is effective for restoring degraded lands, particularly in India, where 80,000 hectares of degraded land were revitalized using bamboo as a pioneer species. Its ability to thrive on poor soils and steep slopes makes it suitable for areas that are otherwise unproductive.

**Ecosystem Benefits**

Bamboo serves as an effective windbreak, helps regulate water flow, and prevents soil erosion due to its sturdy rhizomes and roots, making it beneficial for both natural and agricultural ecosystems.

**Community Empowerment**

INBAR has supported the establishment of community-based enterprises, promoting local businesses that utilize bamboo for sustainable practices. These initiatives can serve as models for other regions in India.

**Bamboo Gasification**

INBAR's work in Madagascar showcases the potential for bamboo gasification to provide off-grid electricity. A 25-kWh bamboo gasifier can power a training facility and approximately 250 households, offering a carbon-neutral alternative to fossil fuel-based energy.

**Future Prospects**

Expanding bamboo gasification projects in India could offer significant benefits, aligning with the country's renewable



energy goals while promoting economic development in rural communities.

### **Bamboo Forests and Water Regulation Services**

#### **Enhanced Water Percolation**

Bamboo's extensive root systems promote efficient water percolation and infiltration, improving soil moisture retention and groundwater recharge.

#### **Groundwater Recharge**

Studies, including those by INBAR and CIFOR, indicate that pure bamboo forests have a greater capacity for groundwater recharge compared to natural forests.

#### **Water Purification**

Bamboo forests contribute to local water purification, effectively filtering pollutants and improving water quality in surrounding areas.

#### **Lower Water Consumption**

Unlike dense natural forests with diverse vegetation, bamboo forests with intermediate canopy cover consume less water, allowing for more efficient water use in the ecosystem.

#### **Ecosystem Resilience**

By regulating water flow and enhancing groundwater recharge, bamboo forests play a crucial role in maintaining the resilience of local ecosystems, particularly in regions prone to drought or water scarcity.

#### **Conclusion**

Climate change is accelerating due to rising CO<sub>2</sub> emissions, but bamboo offers a promising solution for long-term carbon sequestration and is increasingly integral

to carbon offsetting initiatives. To effectively combat climate change, critical adaptation measures must be implemented at all levels-international, national, local, and community. Promoting bamboo plantations not only helps reduce greenhouse gases but also supports sustainable development through certification standards, as exemplified by China's leadership in bamboo forest management. By expanding bamboo cultivation, we can improve environmental health, enhance CO<sub>2</sub> removal, and contribute to a more sustainable future.

#### **References**

- Bahru, T. and Ding, Y. 2021. "A Review on Bamboo Resource in the African Region: A Call for Special Focus and Action", *International Journal of Forestry Research*. vol. 2021.
- INBAR (International Network for Bamboo and Rattan Organization), 2018. International Trade of Bamboo and Rattan in China in 2017. INBAR: Beijing, China.
- Klaus, D. 2002. Bamboo as a building Material, in: IL31 Bambus, Karl Kramer Verlag Stuttgart 1992. Contributions from seminar: design with bamboo, RWTH Aachen SS, 2001.
- Yiping, L., Yanxia, L., Buckingham, K., Henley, G., & Guomo, Z. 2010. Bamboo and Climate Change Mitigation: a comparative analysis of carbon sequestration.



## मिट्टी, मवेशी और किसान: भीमल का बहुमूल्य योगदान

रिपुल शर्मा एवं मुस्कान शर्मा\*

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### सारांश

भारत के उत्तर पश्चिमी हिमालय क्षेत्र में स्थित हिमाचल प्रदेश में भीमल एक महत्वपूर्ण कृषि वानिकी वृक्ष है जो पशुधन को सर्दियों के दौरान पोषक चारा उपलब्ध कराता है। स्थानीय किसान परंपरागत रूप से इसका उपयोग अपने मवेशियों के लिए चारे के स्रोत के रूप में करते आए हैं। भीमल की पत्तियाँ उच्च पोषक तत्वों, विशेषकर प्रोटीन, से भरपूर होती हैं, जिससे यह पशुधन के लिए एक उत्कृष्ट आहार विकल्प बन जाती है। यह पेड़ विशेष रूप से सर्दियों में चारे की कमी के दौरान मवेशियों को पोषण प्रदान करता है, जब अन्य चारा स्रोत उपलब्ध नहीं होते। भीमल की जड़ें मिट्टी के कटाव को रोकने में मदद करती हैं और इसके पत्ते जैविक खाद के रूप में कार्य करते हैं, जिससे मिट्टी की उर्वरता बढ़ती है। इसके अलावा, भीमल की लकड़ी और छाल का उपयोग विभिन्न हस्तशिल्प और औजार बनाने में किया जाता है, जो स्थानीय कारीगरों के लिए आय का स्रोत है। इस वृक्ष की विशेषताएँ इसे जलवायु परिवर्तन के प्रभावों को कम करने, ग्रामीण आजीविका को सुधारने और टिकाऊ कृषि प्रथाओं को बढ़ावा देने में सहायक बनाती हैं। भीमल का एकीकरण हिमाचल प्रदेश में स्थायी कृषि वानिकी प्रथाओं के लिए अत्यधिक लाभकारी है।

### प्रस्तावना

कृषि क्षेत्र भारत की अर्थव्यवस्था में एक महत्वपूर्ण भूमिका निभाता है और देश की कुल आबादी का लगभग 70 प्रतिशत सीधे कृषि क्षेत्र पर निर्भर है, कृषि के साथ पशुधन पालन एक आम प्रथा है जहां

पेड़ किसानों की पशुधन को चारा प्रदान करते हैं। परंतु पहाड़ियों में वर्षा की स्थिति और किसानों के पास कम भूमि होने के कारण, उनके पास अपनी भूमि पर हरे चारे का उत्पादन करने की सीमित गुंजाइश है। इसलिए, उनके खेत में पेड़ लगाना, जो की चारा प्रदान करेगा, अत्यधिक पौष्टिक होना चाहिए और बेहतर पशुधन उत्पादन के लिए इष्टतम पोषण प्रदान करने के लिए सूखे भूसे के साथ मिश्रण के रूप में पशु आहार में शामिल किया जाना चाहिए। जिस पशुधन का हम उपयोग करते हैं, या तो मांस के लिए या अन्य सेवाओं के लिए, वह पोषण की कमी के खतरे में है। पूरी दुनिया में, पशुधन को आवश्यक पोषण प्रदान करके इस समस्या को दूर करने की आवश्यकता है। पशुओं में पोषण की कमी चारे की अनुपलब्धता के कारण हो रही है। विभिन्न मौसमों के दौरान, पशुधन के लिए चारे की उपलब्धता में उतार-चढ़ाव होता है, और कम चारे के मौसम में, किसान पोषण संबंधी आवश्यकताओं को पूरा करने के लिए अपने जानवरों को स्वदेशी प्रजातियों को खिलाते हैं। चारे की कमी की इस अवधि के दौरान जानवरों को पोषण संबंधी समस्याओं का सामना करना पड़ता है और उनका वजन कम होने लगता है। चारे के पेड़ चारे की अनुपलब्धता की ऐसी अवधि के दौरान पोषण चारा प्रदान करते हैं; जिस समय हरे चारे की जरूरत हो।

### हिमाचल में कृषि वानिकी

हिमाचल प्रदेश में किसान पौराणिक ज्ञान के आधार पर वैज्ञानिक हस्तक्षेप के अभाव के कारण



अपनी पारंपरिक कृषि वानिकी प्रणालियों के प्रबंधन में लगे हुए हैं। स्थान विशिष्ट प्रौद्योगिकियों का विकास पूर्व ज्ञान और स्पष्ट उद्देश्यों पर बहुत अधिक निर्भर करता है। जैसे-जैसे जनसंख्या वृद्धि, शहरीकरण और औद्योगीकरण में वृद्धि हो रही है, स्थायी विकास को बढ़ावा देने वाली वैकल्पिक भूमि उपयोग प्रथाओं की मांग बढ़ रही है। हिमाचल प्रदेश में खेतों में पेड़ों की निरंतर उपस्थिति इस क्षेत्र में कृषि वानिकी की स्थायी प्रथा को रेखांकित करती है। भौगोलिक विशेषताओं, सामाजिक-आर्थिक स्थितियों, सांस्कृतिक महत्व और सौंदर्य मूल्य जैसे विभिन्न कारक इस पर्यावरण के अनुकूल भूमि उपयोग दृष्टिकोण को निरंतर अपनाने में योगदान करते हैं। हालाँकि, अपनी लंबे समय से चली आ रही परंपरा के बावजूद, हिमालय में बसे हिमाचल प्रदेश को विकासात्मक गतिविधियों के कारण घटती जैव विविधता जैसी चुनौतियों का सामना करना पड़ता है।

### चारे की उपलब्धता

पशुधन क्षेत्र भारतीय अर्थव्यवस्था में कृषि का एक महत्वपूर्ण उपक्षेत्र है। यह 2014-15 से 2020-21 के दौरान 7.93 प्रतिशत की चक्रवृद्धि वार्षिक वृद्धि दर से बढ़ी। कुल कृषि और संबद्ध क्षेत्र सकल मूल्य वर्धन (स्थिर कीमतों पर) में पशुधन का योगदान 24.32 प्रतिशत (2014-15) से बढ़कर 30.13 प्रतिशत हो गया है (2020-21), वर्ष 2020-21 में पशुधन क्षेत्र ने कुल सकल मूल्य वर्धन में 4.90 प्रतिशत का योगदान दिया। हिमालयी क्षेत्र में पशुधन की संख्या में वृद्धि के कारण चारे की मांग और आपूर्ति के बीच के अंतर को तुरंत हल करना होगा और इसे कुशलता से करना होगा। पशुधन को चारा उपलब्ध कराना कृषि प्रथाओं का एक अनिवार्य हिस्सा है, विशेष रूप से सर्दियों के मौसम में पशुधन को हरा और पौष्टिक चारा प्रदान करना क्योंकि वर्ष के इस समय के

दौरान हरे चारे के कई विकल्प उपलब्ध नहीं हैं। इसलिए भीमल, इस क्षेत्र का एक महत्वपूर्ण कृषि वानिकी वृक्ष इस समस्या का अंतिम समाधान है।

### भीमल: एक बहुउद्देशीय वृक्ष

भीमल, जिसे आमतौर पर स्थानीय रूप से बेउल के रूप में जाना जाता है, पश्चिमी हिमालय के उप-उष्णकटिबंधीय क्षेत्रों में पनपता है। यह भारत, पाकिस्तान और नेपाल में ऊँचाई में 500 से 2500 मीटर तक फैली एक काफी व्यापक वितरण सीमा प्रदर्शित करता है। भारत के उत्तर-पश्चिमी क्षेत्र के भीतर, जम्मू और कश्मीर, हिमाचल प्रदेश और उत्तराखंड की तलहटी और मध्य-पहाड़ी क्षेत्रों में भीमल विशेष रूप से पनपता है। जंगली स्थानों तक सीमित होने के बजाय, यह आमतौर पर कृषि भूमि की मेड़ों पर फलता-फूलता है। मध्यम आकार के पर्णपाती पेड़ की प्रजाति, विमल 38 डिग्री सेल्सियस के अधिकतम तापमान और -2 डिग्री सेल्सियस के



न्यूनतम तापमान के साथ उपोष्णकटिबंधीय जलवायु की विशेषता वाले क्षेत्रों में पनपती है, जहाँ शरद ऋतु और सर्दियों के मौसम में अक्सर



पाला पड़ता है। यह आमतौर पर उन क्षेत्रों में पाया जाता है जहां वार्षिक वर्षा 1200 से 2500 मिमी तक होती है। विभिन्न प्रकार की मिट्टी के अनुकूल होने में सक्षम होने के बावजूद, यह पर्याप्त नमी के साथ रेतीली दोमट मिट्टी में इष्टतम वृद्धि प्राप्त करता है। जबकि पेड़ वर्षा-पोषित परिस्थितियों में विकास और जीवित रहने में सक्षम है, यह वर्षा-पोषित क्षेत्रों की तुलना में सिंचित भूमि की सीमाओं के साथ लगाए जाने पर उल्लेखनीय रूप से बेहतर वृद्धि दर्शाता है। भीमल की विशेषता सूर्य के प्रकाश की उच्च मांग है, जिससे इष्टतम विकास के लिए प्रकाश के पूर्ण संपर्क की आवश्यकता होती है। इस प्रजाति का प्रसार बीज या कटाई के माध्यम से आसानी से प्राप्त किया जा सकता है।

इसके अलावा, इसकी पूरी तरह से परिपक्व पत्तियां मवेशियों के लिए उत्कृष्ट चारे के रूप में काम करती हैं, विशेष रूप से सर्दियों के मौसम में। भीमल एक उल्लेखनीय वृक्ष है जो कई गुणों से संपन्न है जो स्थानीय समुदाय को अपना अमूल्य योगदान देता है। इसकी पत्तियां उत्कृष्ट चारे के रूप में काम करती हैं, जबकि इसकी नरम छाल में सैपोनिन होता है, जो शैम्पू और कंडीशनर जैसे बालों की देखभाल के उत्पादों में उपयोग किया जाने वाला एक प्रमुख घटक है। इसकी छाल से प्राप्त मजबूत फाइबर, सख्त होने के बाद, टिकाऊ रस्सियों, कुरना, कंडी (टोकरी) बैग, पर्स, चप्पल, चटाई और दीवार पर लटकाने के निर्माण में उपयोग किया जाता है। विशेष रूप से, नेपाल के मध्य और दूर पश्चिमी पहाड़ी क्षेत्र में किसानों के बीच बकरी उत्पादन के लिए उपयुक्त, टिकाऊ और फायदेमंद के रूप में भीम-आधारित भोजन पैकेजों की पहचान की गई है।

भीमल एक महत्वपूर्ण कृषि वानिकी प्रजाति के रूप में कार्य करता है जो मुख्य रूप से उत्तर-पश्चिम हिमालयी क्षेत्र में अपने हरे चारे, रेशे और

छोटी लकड़ी के लिए उगाई जाती है।

पश्चिमी हिमालय में, जहां लगभग 90% आबादी आय के लिए कृषि, बागवानी और पशुपालन पर निर्भर है, यह क्षेत्र प्रचुर मात्रा में जैव विविधता के साथ एक महत्वपूर्ण कृषि पारिस्थितिकी प्रणाली के रूप में कार्य करता है। इन प्रजातियों में, भीमल कृषि फसलों के साथ-साथ किसानों द्वारा बड़े पैमाने पर उगाए जाने वाले बहु-कार्यात्मक पेड़ों के रूप में सामने आता है। ये बहुउद्देशीय पेड़ प्रोटीन और आवश्यक पोषक तत्वों से भरपूर उच्च गुणवत्ता वाला चारा प्रदान करते हैं, इस प्रकार पशुधन के स्वास्थ्य को लाभ पहुंचाते हैं।

### वृक्ष के चारे का महत्व

चारे के पेड़ पशुधन के लिए एक महत्वपूर्ण चारा स्रोत हैं। पहाड़ी और पहाड़ी क्षेत्रों में चारे की मांग उनकी उपलब्धता से बहुत अधिक है। कम अवधि के दौरान, जब घास या तो अनुपलब्ध होती है और उनमें कम पोषण मूल्य होता है, तो चारे के पेड़ों में चारा की आपूर्ति करने की क्षमता होती है। पत्ते के चारे को फलीदार चारा फसलों की तरह पौष्टिक माना जाता है क्योंकि इसमें उच्च कच्चे प्रोटीन, खनिज होते हैं और पशुधन में उच्च स्तर की पाचन क्षमता प्रदर्शित करते हैं। पेड़ अपनी गहरी जड़ प्रणाली के कारण सूखे मौसम में भी अच्छा उत्पादन करना जारी रखते हैं। चारे के पेड़ तापमान और परिवर्तनशील मौसम की स्थितियों में भिन्नता के प्रति अधिक प्रतिरोधी होते हैं और गहरी मिट्टी की परतों से पानी खींच सकते हैं। इसलिए, वे शुष्क अवधि के दौरान उथले जड़ वाले पौधों की तुलना में लंबे समय तक चारा प्रदान कर सकते हैं। इस उद्देश्य के लिए, पारंपरिक कृषि वानिकी प्रणाली के तहत कृषि क्षेत्रों पर प्राकृतिक रूप से पुनर्जीवित होने वाले पेड़ों की प्रजातियों को संजोया जाता है।

### सर्दियों में सबसे अच्छा चारा



सर्दियों के दौरान चारे के स्रोत बहुत सीमित और दुर्लभ होते हैं क्योंकि चारे के कई प्राकृतिक स्रोत उपलब्ध नहीं होते हैं। अधिकतम पेड़ अपने पत्ते छोड़ देते हैं, घास के चारे उपलब्ध नहीं होते हैं और अगर किसी तरह कुछ चारा उपलब्ध हो तो उस चारे की गुणवत्ता मवेशियों के आवश्यक

पोषण मानकों को पूरा नहीं करेगी। यहाँ, भीमल चारा उपलब्ध कराने में महत्वपूर्ण भूमिका निभाता है जो सर्दियों के दौरान पर्याप्त रूप से उपलब्ध होगा और मवेशियों को अच्छा पोषण भी प्रदान करेगा। भीमल द्वारा प्रदान किए गए चारे के कुछ पोषण संबंधी गुण नीचे दिए गए हैं

| पोषण संबंधी विशेषताएँ    | सीमा        |
|--------------------------|-------------|
| शुष्क पदार्थ             | 27.3-59.6 % |
| कूड प्रोटीन              | 11.5-24.4 % |
| कूड फाइबर                | 14.1-21.5 % |
| ईथर एक्सट्रैक्ट          | 1.6-8.4 %   |
| राख                      | 7.4-14.9 %  |
| न्यूट्रल डिटर्जेंट फाइबर | 34.2-57.9 % |
| एसिड डिटर्जेंट फाइबर     | 24.2-47.8 % |

भीमल एक बहुमुखी और मूल्यवान पौधे की प्रजाति है जो मुख्य रूप से हिमालयी क्षेत्र में पाई जाती है। हिमाचल प्रदेश में खेतों में भीमल का पालन-पोषण ग्रामीण आजीविका में सुधार और स्थायी भूमि प्रबंधन प्रथाओं को बढ़ावा देने के लिए अपार गुंजाइश प्रदान करता है। भीमल के एकीकरण से मिट्टी का स्वास्थ्य बेहतर हो सकता है, कृषि उत्पादकता में वृद्धि हो सकती है और क्षरण और मिट्टी के क्षरण जैसे पर्यावरणीय तनावों के खिलाफ लचीलापन आ सकता है। इसके अलावा, भीमल किसानों के लिए आय के स्रोतों के विविधीकरण में योगदान कर सकते हैं, जिससे आर्थिक उतार-चढ़ाव और जलवायु परिवर्तन के प्रभावों के प्रति उनकी संवेदनशीलता कम हो सकती है।

इसने अपने कई सामाजिक-आर्थिक लाभों के लिए ध्यान आकर्षित किया है। समाज और अर्थव्यवस्था में इसके योगदान का विस्तृत अवलोकन यहां दिया गया है:

#### आर्थिक लाभ

- रोजगार सृजन: भीमल उत्पादों की खेती, प्रसंस्करण और बिक्री से खेती और कटाई से लेकर प्रसंस्करण और विपणन तक रोजगार पैदा होते हैं। यह विशेष रूप से ग्रामीण और आर्थिक रूप से वंचित क्षेत्रों में महत्वपूर्ण है।
- भीमल की लकड़ी का उपयोग कृषि उपकरण, छोटे फर्नीचर और निर्माण सामग्री बनाने के लिए किया जाता है। इसकी मध्यम कठोरता इसे विभिन्न अनुप्रयोगों के लिए उपयुक्त बनाती है।
- छाल से मजबूत रेशे मिलते हैं जिनका उपयोग रस्सियों, टोकरी, चटाई और अन्य हस्तशिल्प बनाने में किया जाता है। इससे स्थानीय कारीगरों और शिल्पकारों को अतिरिक्त आय प्राप्त होती है।

#### कृषि संबंधी लाभ



- भीमल की जड़ें मिट्टी को स्थिर करने, कटाव और भूस्खलन को रोकने में मदद करती हैं, जो पहाड़ी और पहाड़ी इलाकों में विशेष रूप से महत्वपूर्ण है।

- पत्तियां, जब विघटित होती हैं, तो मिट्टी के जैविक पदार्थ में योगदान करती हैं, मिट्टी की उर्वरता को बढ़ाती हैं और कृषि उत्पादकता का समर्थन करती हैं।

भीमल को फसलों के साथ-साथ उगाया जा सकता है, जो छाया प्रदान करता है और सूक्ष्म जलवायु स्थितियों में सुधार करता है, जो कृषि पारिस्थितिकी तंत्र के समग्र स्वास्थ्य के लिए फायदेमंद है।

- पेड़ एक पवन रोधक के रूप में कार्य करता है, जो तेज हवाओं के कारण फसलों को नुकसान से बचाता है और फसल के विकास के लिए अधिक अनुकूल वातावरण बनाता है।

#### पर्यावरणीय लाभ

- आवास प्रावधान। भीमल पक्षियों, कीड़ों और छोटे स्तनधारियों सहित विभिन्न वन्यजीव प्रजातियों के लिए आवास और भोजन प्रदान करके जैव विविधता का समर्थन करता है।

**जलवायु परिवर्तन शमन।** एक बारहमासी पौधे के रूप में, भीमल कार्बन डाइऑक्साइड को अलग करता है, जो वायुमंडल में ग्रीनहाउस गैसों की मात्रा को कम करके

जलवायु परिवर्तन के शमन में योगदान देता है।

#### सामाजिक लाभ

- पत्ते और फल पोषक तत्वों से भरपूर होते हैं और स्थानीय समुदायों के आहार सेवन में सुधार के लिए पूरक के रूप में उपयोग किए जा सकते हैं।
- पारंपरिक चिकित्सा। पौधे के विभिन्न हिस्सों का उपयोग पारंपरिक चिकित्सा में बीमारियों के इलाज के लिए किया जाता है, जो ग्रामीण आबादी के लिए एक सुलभ स्वास्थ्य संसाधन प्रदान करता है।
- भीमल कई समुदायों में सांस्कृतिक महत्व रखता है, जहां इसका उपयोग पारंपरिक अनुष्ठानों और प्रथाओं, सामुदायिक बंधनों को मजबूत करने और सांस्कृतिक विरासत को संरक्षित करने में किया जाता है।

#### शिक्षा और अनुसंधान के अवसर

- भीमल वनस्पति विज्ञान और कृषि अनुसंधान में अध्ययन का विषय है, जिससे स्थायी कृषि और वानिकी प्रथाओं में प्रगति हुई है।
- यह सतत विकास, कृषि वानिकी और पर्यावरण संरक्षण पर ध्यान केंद्रित करने वाले शैक्षिक कार्यक्रमों में एक व्यावहारिक उदाहरण के रूप में कार्य करता है।

#### निष्कर्ष

भीमल हिमालयी क्षेत्र की एक बहुउद्देशीय वृक्ष प्रजाति है, जो चारा, रेशे, औषधीय उपयोग, और पर्यावरणीय स्थिरता के लिए महत्वपूर्ण है। विशेष रूप से हिमाचल प्रदेश में, जहां कृषि और पशुपालन प्रमुख गतिविधियाँ हैं, भीमल न केवल



पशुधन के लिए पोषक चारा प्रदान करता है बल्कि मिट्टी की उर्वरता बढ़ाकर और कटाव को रोककर कृषि भूमि की गुणवत्ता भी सुधारता है। इसकी पत्तियाँ प्रोटीन और आवश्यक पोषक तत्वों से भरपूर होती हैं, जो सर्दियों के दौरान भी पशुधन के लिए पौष्टिक आहार का स्रोत बनती हैं। भीमल के उपयोग से स्थानीय समुदायों को आर्थिक, पर्यावरणीय और सामाजिक लाभ मिलता है, जैसे रोजगार सृजन, आय का स्रोत, जैव विविधता का संरक्षण और पारंपरिक ज्ञान का संरक्षण। यह वृक्ष सतत विकास के लिए एक महत्वपूर्ण संसाधन है, जो ग्रामीण आजीविका को सुधारने और पर्यावरणीय स्थिरता को बढ़ावा देने में महत्वपूर्ण भूमिका निभाता है।

#### स्रोत

भट, शीराज़ और अहमद, सुहेल . 2012. ग्रेविया ऑप्टिवा ड्रमंड में मॉर्फोमेट्रिक और चारा मापदंडों के लिए विचलन अध्ययन। रेंज प्रबंधन और कृषि वानिकी 33.  
सानख्यान, धीमान ज्योति, राणा नीरजा, चंद कृष्ण और प्राची . 2022. हिमाचल प्रदेश

के ग्रेविया ऑप्टिवा ड्रमंड की मिट्टी की भौतिक रासायनिक विशेषताएँ और पत्ते के चारे के साथ उनका सहसंबंध गुणवत्ता पैरामीटर। बायोलॉजिकल फोरम-एन इंटरनेशनल जर्नल 14 (2ए) 01-08.

हाशमी एम एम और वकार के. 2014. पाकिस्तान में चकवाल जिले के विभिन्न मौसमों और स्थलों में ग्रेविया ऑप्टिवा और ग्रेविया पॉपुलाइफोलिया का पोषण मूल्यांकन। यूरोपीय अकादमिक अनुसंधान 2:5048-57

पंत के. एस, विशिष्ट आर, शर्मा पी. पी और शर्मा एच. 2022. हिमाचल प्रदेश में कृषि वानिकी: स्थिति, चुनौतियाँ और भविष्य के दृष्टिकोण। इंडियन जर्नल ऑफ एग्रोफोरेस्ट्री 24(3).

प्रजापति डी आर, एन वी सरेश, गोपाल आर और खंडूरी वी. 2019. गढ़वाल हिमालय में ऊँचाई ढलान के साथ ग्रेविया ऑप्टिवा में समीपस्थ सिद्धांतों और सहसंबंध अध्ययनों में भिन्नता।



## Bay Laurel: The unique and special spice of kitchen

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When we hear bay leaf, it is common to think of cinnamon or tejpatta we regularly use in our Indian kitchens for flavouring various dishes. It is often confused with the European bay leaf (*Laurus nobilis*) commonly used in Mediterranean cuisine. The true bay leaf (*Laurus nobilis*) is an aromatic leaf that belongs to the family Lauraceae. Bay laurel is also known as sweet bay, true laurel, Roman laurel, noble laurel, daphne, laurel tree or Grecian laurel. It can be used whole or as dried and ground. Genuine bay leaf is often confused with Indian bay leaf obtained from *Cinnamomum tamala*. The leaves contain about 1.3% essential oils, consisting of 45% eucalyptol, 12% other terpenes, 8-12% terpinyl acetate, 3-4% sesquiterpenes, 3% methyleugenol, and other  $\alpha$ - and  $\beta$ -pinenes, phellandrene, linalool, geraniol, terpineol, and contain lauric acid also. If eaten whole, bay leaves are pungent and have a bitter taste. As with many spices and flavourings, the fragrance of the bay leaf is more noticeable than its taste. When dried, the fragrance is herbal, slightly floral, and somewhat similar to oregano and thyme. Both essential and fatty oils are present in the fruit. The fruit is pressed and water-extracted to obtain these products. The fruit contains up to 30% fatty oils and about 1% essential oils (terpenes, sesquiterpenes, alcohols, and ketones). The chemical

compound lauroside B has been isolated from *Laurus nobilis* (Batool et al., 2020)

### History

In Ancient Greece bay laurel was used to fashion the laurel wreath of ancient Greece, a symbol of the highest status. A wreath of bay laurels was given as the prize at the Pythian Games because the games were in honour of Apollo and the laurel was one of his symbols. In Rome culture, the laurel is a symbol of victory. It was also associated with immortality, ritual purification, prosperity and health. The leaves were used in diversified food, medicine and decoration purposes by Romans and Greeks (Nayak et al., 2006).

### Uses of leaf

In Indian cuisine, bay laurel leaves are sometimes used instead of Indian bay leaf, although they have a different flavour. They are often used in rice dishes like biryani and as an ingredient in garam masala. Bay (laurel) leaves are frequently packaged as *tezpattā* (the Hindi term for Indian bay leaf), creating confusion between the two herbs. Dried bay laurel leaves are used in the Philippines and Filipino dishes such as Menudo, beef pares and adobo (Harisha and Singh, 2019).

### Uses of wood

Apart from the bay leaf, which is used as a spice in various cuisines and the preparation of curry powders, the wood of the tree has also been found helpful in the industry in the making of bowls, spoons,



furniture, jewellery boxes, etc. It is interesting to know that bay leaf plant is associated with music and the California Bayleaf wood is much preferred for making musical instruments such as violins and guitars.

#### Other uses

The bay leaf is an excellent insect repellent. Though safe for humans, its smell is toxic to insects and pests. Dried and powdered leaf can be sprinkled around the corners to repel cockroaches, ants and other household insects.

#### Plant description

The laurel is an evergreen shrub or small tree, variable in size and sometimes reaching 7–18 m (23–59 ft) tall. It is dioecious (unisexual), with male and female flowers on separate plants. The male and female flowers are formed on separate plants during the spring season. The flowers are whitish-green and developed into deep black-coloured fruit which are measuring 2 cm long (Ross, 2001).



Bay leaves come from several plants, such as:

**Bay laurel** (*Laurus nobilis*, Lauraceae). Fresh or dried bay leaves are used in cooking for their distinctive flavour and fragrance. The leaves are often used to flavour soups and stews in many countries. The fresh leaves are very mild and do not develop their full flavour until several weeks after picking and drying.

**California bay leaf** (*Umbellularia californica*, Lauraceae) known as California laurel, Oregon myrtle and pepperwood, is similar to the

Mediterranean bay laurel, but has a stronger flavour.

**Indian bay leaf** (*Cinnamomum tamala*, Lauraceae) also known as *astmalabathrum* differs from bay laurel leaves, which are shorter and light to medium green in colour. Indian bay leaves are about twice as long and wider. Indian bay leaves are quite different from laurel in flavour, having a fragrance and taste similar to cinnamon (cassia) bark with mild flavour.



**Indonesian bay leaf** (*Syzygium polyanthum*, Myrtaceae) Indonesian laurel is not commonly found outside Indonesia; this herb is applied to meat and, less often, to vegetables.

**West Indian bay leaf** (*Pimenta racemosa*, Myrtaceae)-leaf of the West Indian bay tree used culinarily (especially in Caribbean cuisine) and to produce the cologne called bay rum.

**Mexican bay leaf** (*Litsea glaucescens*, Lauraceae).

### Ecology

*Laurus nobilis* is a widespread relic of the laurel forests that originally covered much of the Mediterranean Basin when the climate of the region was more humid. With the drying of the Mediterranean during the Pliocene era, the laurel forests gradually retreated and were replaced by the more drought-tolerant sclerophyll plant communities (Eucalyptus, wattle etc) familiar today. Most of the remaining laurel forests around the Mediterranean are believed to have disappeared. However, some remnants persist in the mountains of southern Turkey, northern Syria, southern Spain, north-central Portugal, northern Morocco, and the Canary Islands and in Madeira. It is cultivated in India in Karnataka, Kerala, Uttar Pradesh, Bihar and North Eastern states.

### Soil and climatic requirements

Well-fertile soils rich in organic matter with a pH ranging from 6.0 to 8.0 are suitable. Soils in the backyard with more added manures with good soil moisture are favourable for leaf production.

Low lying area with water logging condition is unsuitable since it affects leaf quality and premature leaf fall due to poor respiration. Plants grow well in moist

tropical conditions. Plants need plenty of sunlight and are sensitive to cold winds and frost. The coastal climate of India and the northeastern hill climate are most suitable for growing the bay leaf.

### Propagation and planting

Bay leaf plants are propagated by stem cuttings and air layering. Side shoots growing upwards are used for propagation since it gives a straight growing habit and a good tree canopy can be maintained. The best time for cuttings or layering is from March to May when good sunlight is available. Air layers can root in 2 months on plants and be planted in the nursery for better growth before field planting. Plants can be planted in field or backyards at 5-6m spacing. Pits should be filled with farm yard manure and red soil for better establishment rate and root growth.

### Cultural practices

Pruning is important to induce more shoots-producing leaves and give the plants more sunlight. Hence thinning of branches affected by the disease and mechanical damage is removed from time to time. Mulching with dry leaf litter conserves moisture during dry periods and also maintains soil temperature, along with the additional benefit of adding organic matter to the soil.

Pests and disease are very low, and being in open conditions and high sunlight causes infestation with mealy bugs on tender leaves and shoots. This can be controlled by spraying neem oil with soap water.

### Harvesting and processing

When the leaves have more volatile oil and aroma, the leaves were picked from the base to the top of the plant. The leaves have a high aroma in the drier/hottest



months. Only matured green leaves are harvested and tender leaves are avoided. The harvested leaves are dried in shaded conditions to retain the green colour for 48-75 hours. One acre can accommodate 300 plants at 5 x 2.5 m spacing, yielding 2-5 quintals of dried leaves annually. A better and deeper flavour is observed in freshly dried leaves. Harvesting should be avoided when the plant is wet.

### References

- Batool S., Khera RA., HanifMA., Ayub MA. 2020. Bay Leaf. Medicinal Plants of South Asia. 63–74.
- Ross, I.A., 2001. Medicinal Plants of the World: Chemical Constituents, Traditional and Modern Medicinal Uses. Springer Science+Business Media, LLC, New York.
- Nayak, S., Nalabothu, P., Sandiford, S., Bhogadi, V., Adogwa, A., 2006. Evaluation of wound healing activity of *Allamandacathartica*L. and *Laurusnobilis*L. extracts on rats. BMC Complement. Altern. Med. 6, 12.
- Harisha, C.B. and Singh, N.P. 2019. Hand Book of Dry Land Medicinal Plants. Technical Bulletin No.31. ICAR- National Institute of Abiotic Stress Management, Malegaon, Baramati. 413 115. Pune, Maharashtra (India). p.70.



## The remarkable world of scarabaeoidea: Ecological importance and biodiversity

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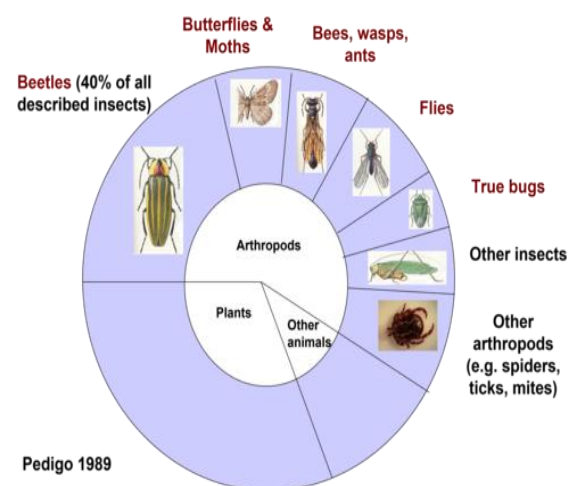
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### Introduction

The immense diversity of beetles has long captivated scientists and naturalists. J.B.S. Haldane once remarked that the Creator seemed to have "an inordinate fondness for beetles," a reflection of their extraordinary evolutionary success. Belonging to the order *Coleoptera*—the largest order in the animal kingdom—beetles comprise over 400,000 described species, with millions yet to be identified. Within this vast group, the superfamily *Scarabaeoidea*, commonly known as scarab beetles, stands out for its rich biodiversity, ecological significance, and widespread distribution.

With approximately 40,000 species identified globally, *Scarabaeoidea* includes ecologically diverse families such as dung beetles (*Scarabaeinae*), rhinoceros beetles (*Dynastinae*), and flower chafers (*Cetoniinae*). These beetles are present in nearly all terrestrial ecosystems, from tropical forests and savannas to temperate woodlands and arid zones. Their adaptability is a testament to their evolutionary resilience and ecological versatility.

Beyond their diversity, scarabs play indispensable roles in ecosystems. Dung beetles contribute to nutrient recycling and soil aeration, while others serve as pollinators or decomposers, supporting plant reproduction and organic matter breakdown. Their ecological services are



critical not only to natural ecosystems but also to agriculture, where they enhance soil fertility and help manage pest populations.

Scarabs also hold cultural significance, most notably in ancient Egypt, where they were revered as symbols of renewal and protection. These beetles thus bridge the gap between ecological importance and cultural heritage, highlighting their enduring relevance.

### Scarabaeoidea: A Superfamily of Rich Diversity

The super family *Scarabaeoidea* encompasses one of the most speciose groups within *Coleoptera*, characterized by a wide array of forms, sizes, and ecological functions. This group includes both plant-feeding (phytophagous) and non-phytophagous beetles, many of which are crucial to ecosystem health. While they represent a relatively small fraction of



global insect diversity, their ecological impact is disproportionately large.

In India, over 2,500 species of the family *Scarabaeidae* have been documented, contributing to an estimated 4,000 scarab species across six families nationwide. Globally, scarabs are among the most widely distributed and ecologically active beetles, making them an essential focus for biodiversity studies.

### **Ecological Roles of Scarabaeoidea**

Scarab beetles fulfil a variety of ecological functions that support ecosystem stability and productivity:

#### **Scavenging**

Dung beetles and other scavenging scarabs decompose animal waste and organic material, aiding nutrient cycling and waste removal.

#### **Soil Aeration**

By burying dung and organic matter, many scarabs improve soil structure and fertility.

#### **Pollination**

Certain scarabs act as pollinators, particularly in tropical regions, facilitating the reproduction of various plant species, including crops.

#### **Phytophagy**

While some scarabs help regulate plant populations, others—such as chafer beetles—can be serious agricultural pests.

#### **Predation**

Some species are carnivorous, preying on other insects and contributing to natural pest control.

### **Scarabaeoidea in India: Diversity and Ecological Insights**

India's ecological variety makes it a hotspot for scarab beetle diversity. The family *Scarabaeidae* is particularly well-represented, thriving in forests, grasslands, agricultural fields, and semi-urban

environments. Despite this diversity, much of the research in India has historically focused on pest control, especially in agroecosystems where phytophagous scarabs cause crop damage.

The ecological functions of scarabs, however, are underexplored. While early taxonomic work by researchers like G.J. Arrow laid foundational knowledge, modern studies have been limited in scope—often focusing on specific taxa or regions. Recent research efforts, such as those by Chandra and Gupta (2012a, 2012d) and Thakare et al. (2011), have begun documenting regional faunal compositions, but broader ecological studies remain scarce.

### **Need for Comprehensive Ecological Studies**

Despite their ecological relevance, scarabs are understudied in terms of community structure, seasonal variation, and habitat-specific diversity. Understanding these dynamics is essential for monitoring ecosystem health and developing conservation strategies.

Research into the spatial and temporal diversity of scarabs can serve as a bioindicator for environmental change. Such studies would help illuminate how scarab populations respond to habitat alterations, climate variability, and human impacts, offering valuable insights for biodiversity management.

### **Conclusion: Scarabaeoidea as Indicators of Ecosystem Health**

The *Scarabaeoidea* superfamily exemplifies the intricate relationships within ecosystems. Through nutrient recycling, pollination, pest regulation, and soil enrichment, scarabs play foundational roles in ecosystem functioning. Yet, many



aspects of their biology and ecology remain poorly understood, particularly in biodiverse countries like India.

A multidisciplinary research approach: integrating taxonomy, ecology, and conservation biology: is urgently needed. By deepening our understanding of scarab beetles, we not only protect a key insect group but also gain a broader perspective on ecosystem health and resilience. As Haldane insightfully observed, the extraordinary diversity of beetles is no accident; it reflects their ecological importance and evolutionary success, making them deserving of our focused attention and study.

## References

- Philips, T. K. (2011). Systematics and phylogeny of the Scarabaeidae. In *Encyclopedia of Life Sciences (ELS)*. Wiley.
- Schoolmeesters, P. (2024). *Scarabs: World Scarabaeidae Database*. Ratcliffe, B. C., & Jameson, M. L. (2005). Scarabaeidae Latreille, 1802. In R. H. Arnett, Jr., M. C. Thomas, P. E. Skelley, & J. H. Frank (Eds.), *American Beetles, Volume II: Polyphaga: Scarabaeoidea through Curculionoidea* (pp. 1–78). CRC Press.



## Challenges and limitations in valuing ecosystem services in agroforestry

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### Introduction

Agroforestry practices integrate trees and shrubs into agricultural landscapes and have received a lot of interest as a sustainable land-use practice that accords many ecological, economic, and social benefits (Jose et al., 2021). Agroforestry systems, properly designed, can address some of the most urgent environmental challenges of climate change, land degradation, and food insecurity, thus providing a pathway for sustainable land-use practices by linking agricultural production and ecosystem services such as carbon sequestration, soil fertility enhancement, biodiversity conservation, and water regulation (Notaro et al., 2022). Despite its promise, the valuation of ecosystem services within agroforestry systems is still prone to major complications and challenges. Any accrual of benefits through the valuation of ecosystem services would be helpful to show the real value of agroforestry, lead policy-making, and offer benefits for the adoption of sustainable practices to the farmers, and yet this whole process faces challenges and profound limitations. Ecosystem services are mostly intangible, and measuring and marketizing them is fraught with difficulty. Adding to this complex knot of factors is the very

fact that these services are interdependent: altering one may have cascading effects on others. Furthermore, the site-specific and time-dependent feasibility of agroforestry systems imposes a system of complexities wherein they vary with ever-changing socio-economic and cultural contexts.

### Conceptual Challenges

#### Complexity of Ecosystem Services

Agroforestry systems deliver a range of ecosystem services, including provisioning (e.g., food, timber), regulating (e.g., climate control, water purification), cultural (e.g., recreation, aesthetics), and supporting services (e.g., nutrient cycling, soil formation) (Nangula et al., 2024). These services are often interlinked and synergistic, making it challenging to isolate and assess their individual contributions. For example, the biodiversity within agroforestry systems enhances soil health, which then influences crop yields and water quality. Existing valuation methods often cater to simpler, more isolated systems, which limits their applicability to agroforestry's complex dynamics (Udawatta & Jose, 2021).

#### Trade-offs and Synergies

Agroforestry inherently involves trade-offs between ecosystem services (Arya et al., 2023). For instance, increased timber



production may reduce biodiversity or degrade soil quality due to intensive land use (Sistla *et al.*, 2016). Similarly, prioritizing agricultural output can lead to water quality degradation from fertilizer runoff (Meena *et al.*, 2024). Balancing these trade-offs and maximizing synergies, such as enhancing pollinator habitats while reducing soil erosion, requires sophisticated tools and integrated models, which are still underdeveloped (Morizet *et al.*, 2023).

#### **Lack of standardized frameworks**

Despite the recognition of agroforestry's benefits, a universal framework for valuing its ecosystem services comprehensively has yet to be established (Felipe *et al.*, 2015). Current approaches tend to focus on easily measurable services like timber and crop yields, while non-market services such as cultural identity, aesthetic appeal, and long-term climate benefits often remain underrepresented. This imbalance results in a limited understanding of the overall value of agroforestry systems (Barbier *et al.*, 2009).

#### **Methodological limitations**

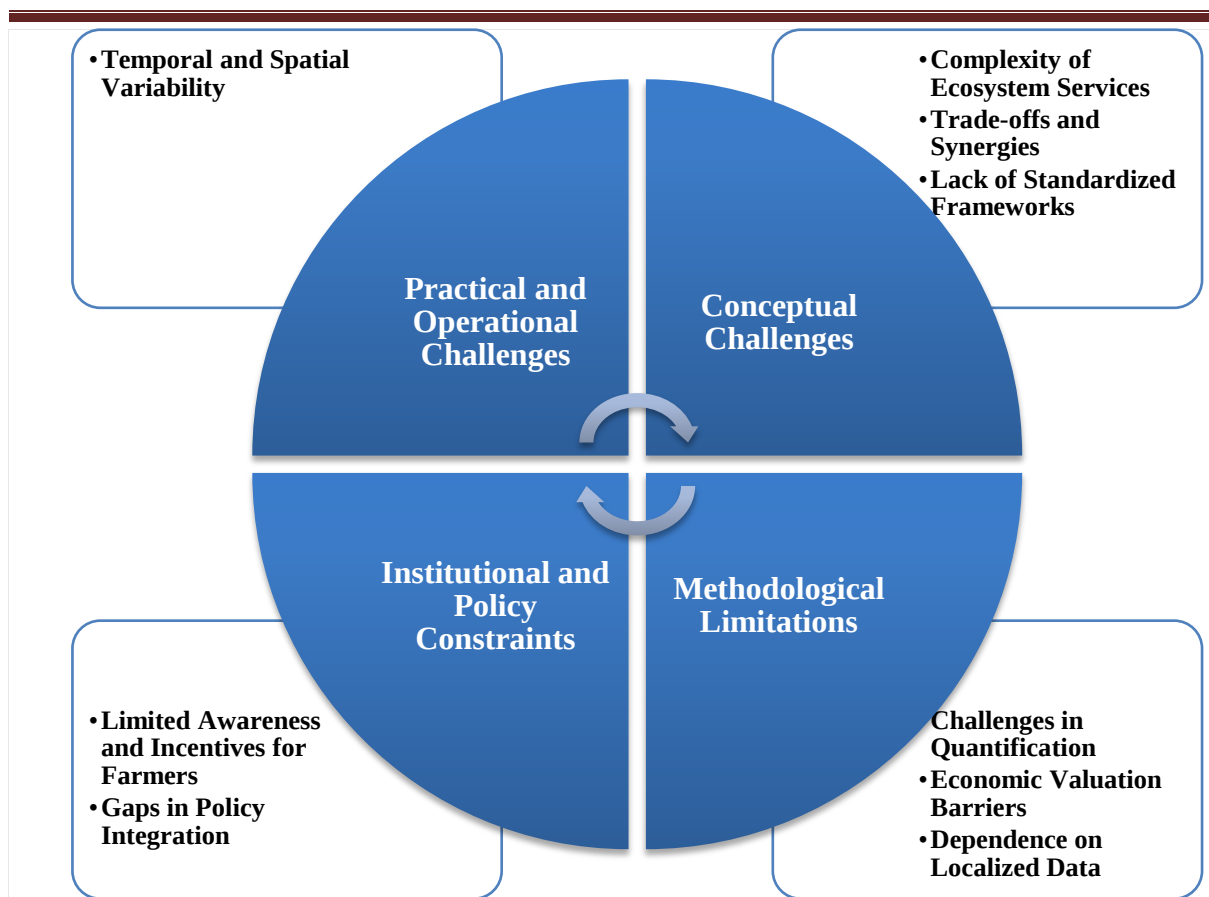
#### **Challenges in quantification**

The quantification of ecosystem services in agroforestry requires precise biophysical data, such as rates of carbon sequestration, water filtration efficiency, and nutrient cycling (Stewart *et al.*, 2022). However, the tools and methods available for measuring these parameters are either inadequate or not well-validated. For example, while biomass measurements can estimate carbon sequestration, the benefits of biodiversity conservation or cultural ecosystem services often lack standardized measurement approaches (Sukhdev *et al.*, 2012; Daniel *et al.*, 2012).

#### **Economic valuation barriers**

Economic valuation methods like contingent valuation, hedonic pricing, and cost-benefit analysis are insufficient for capturing the complete range of ecosystem services provided by agroforestry. Non-market benefits such as cultural significance or biodiversity's intrinsic value are especially difficult to monetize. Furthermore, inconsistencies between valuation methods make it challenging to establish a reliable economic representation of agroforestry's contributions (Cai & Aguilar, 2021; Mercer *et al.*, 2017).





**Figure 1. Challenges and Limitations in Valuing Ecosystem Services in Agroforestry**

#### **Dependence on localized data**

Valuation studies often depend on specific local data, including soil types, climate conditions, and regional biodiversity. These factors are not always transferable to other regions, which limits the generalization of findings and hinders the development of global or national valuation frameworks. Additionally, the scarcity of long-term studies means temporal changes in ecosystem service delivery are frequently overlooked (Alamet *al.*, 2014).

#### **Institutional and policy constraints**

##### **Limited awareness and incentives for farmers**

Farmers tend to prioritize immediate financial returns over long-term societal benefits due to a lack of awareness or

direct incentives. While agroforestry provides public goods such as improved water quality and carbon sequestration, farmers mainly benefit from marketable outputs like crops and timber. Without financial mechanisms, such as subsidies or payments for ecosystem services (PES), it is unlikely that farmers will adopt ecosystem service-driven practices (Udawatta & Jose, 2021; Alamet *al.*, 2014).

##### **Gaps in policy integration**

Even though global frameworks like the Millennium Ecosystem Assessment emphasize ecosystem services, many national and regional policies fail to incorporate these concepts effectively. Contributions from agroforestry are often excluded from accounting systems, land-use strategies, or climate policies,



weakening its promotion as a sustainable land-use practice (Barbieret *al.*, 2009).

### **Practical and operational challenges**

#### **Temporal and spatial variability**

The delivery of ecosystem services in agroforestry is highly variable, depending on factors such as tree species, climate, soil conditions, and management practices (Kuyahet *al.*, 2017). For example, older agroforestry systems generally sequester more carbon than newer ones, making temporal dynamics critical for valuation. Additionally, the benefits of agroforestry can differ across geographic regions, complicating uniform valuation efforts (Jose, 2009; Montagnini & Nair, 2004; Albrecht & Kandji, 2003).

### **Conclusion**

The valuation of ecosystem services originating from agroforestry is often complex, but it remains vital in promoting sustainable land use practices. Despite agroforestry's ability to mitigate climate change, land degradation, and food security, it faces enormous challenges with quantification and monetization of the multiplicity of its benefits. Conceptual difficulties, methodological problems, and institutional constraints interfere with correct valuation while spatial and temporal variability adds to the difficulties. For these reasons, there is an urgent call for standardization of frameworks, better tools for measurement, and integration into policy. When these constraints are dealt with, stakeholders may start recognizing the real worth of agroforestry and begin to reward its adoption so that the ecological and socio-economic resilience reflected in agroforestry systems become evident.

### **References**

- Alam, M., Olivier, A., Paquette, A., Dupras, J., Revéret, J. P., & Messier, C. (2014). A general framework for the quantification and valuation of ecosystem services of tree-based intercropping systems. *Agroforestry systems*, 88, 679-691.
- Albrecht, A., & Kandji, S. T. (2003). Carbon sequestration in tropical agroforestry systems. *Agriculture, ecosystems & environment*, 99(1-3), 15-27.
- Aryal, K., Maraseni, T., & Apan, A. (2023). Transforming agroforestry in contested landscapes: a win-win solution to trade-offs in ecosystem services in Nepal. *Science of the Total Environment*, 857, 159301.
- Barbier, E. B., Baumgärtner, S., Chopra, K., Costello, C., Duraiappah, A., Hassan, R., Kinzig, A.P., Lehman, M., Polasky, S., & Perrings, C. (2009). The valuation of ecosystem services. *Biodiversity, ecosystem functioning, and human wellbeing: An ecological and economic perspective*, 10.
- Cai, Z., & Aguilar, F. X. (2021). Economic valuation of agroforestry ecosystem services. *Agroforestry and Ecosystem Services*, 477-494.
- Daniel, T. C., Muhar, A., Arnberger, A., Aznar, O., Boyd, J. W., Chan, K. M., ... & Von Der Dunk, A. (2012). Contributions of cultural services to the ecosystem services agenda. *Proceedings of the National Academy of Sciences*, 109(23), 8812-8819.
- Felipe-Lucia, M. R., Comín, F. A., & Escalera-Reyes, J. (2015). A



- frame work for the social valuation of ecosystem services. *Ambio*, 44, 308-318.
- Jose, S. (2009). *Agroforestry for ecosystem services and environmental benefits: an overview* (pp. 1-10). Springer, Dordrecht.
- Jose, S., Garrett, H. E. G., Gold, M. A., Lassoie, J. P., Buck, L. E., & Current, D. (2021). Agroforestry as an integrated, multifunctional land use management strategy. *North American Agroforestry*, 1-25.
- Kuyah, S., Öborn, I., & Jonsson, M. (2017). Regulating ecosystem services delivered in agroforestry systems. *Agroforestry: Anecdotal to modern science*, 797-815.
- Meena, R. K., Kumari, T., Solanki, V. K., Partel, V., Singh, S. L., & Sinha, R. (2024). Soil, Water, and Biodiversity Conservation Through Agroforestry for Crop Production. In *Agroforestry to Combat Global Challenges: Current Prospects and Future Challenges* (pp. 345-366). Singapore: Springer Nature Singapore.
- Mercer, D. E., Li, X., Stainback, A., & Alavalapati, J. (2017). Valuation of agroforestry services. *Agroforestry: Enhancing resiliency in US agricultural landscapes under changing conditions. Gen. Tech. Report WO-96*. Washington, DC: US Department of Agriculture, Forest Service, 63-72.
- Montagnini, F., & Nair, P. R. (2004). Carbon sequestration: an underexploited environmental benefit of agroforestry systems. In *New Vistas in Agroforestry: A Compendium for 1st World Congress of Agroforestry, 2004* (pp. 281-295). Springer Netherlands.
- Morizet-Davis, J., MartingVidaurre, N. A., Reinmuth, E., Rezaei-Chiyaneh, E., Schlecht, V., Schmidt, S., Singh, K., Carpinter R.V., Wagner, M., & von Cossel, M. (2023). Ecosystem Services at the Farm Level—Overview, Synergies, Trade-Offs, and Stakeholder Analysis. *Global Challenges*, 7(7), 2200225.
- Notaro, M., Gary, C., Le Coq, J. F., Metay, A., & Rapidel, B. (2022). How to increase the joint provision of ecosystem services by agricultural systems. Evidence from coffee-based agroforestry systems. *Agricultural Systems*, 196, 103332.
- Nungula, E. Z., Chappa, L. R., Ranjan, S., Sow, S., Alnemari, A. M., Seleiman, M. F., Mwalulu, R., Maitra, S., & Gitari, H. I. (2024). Ecosystem Services Through Agroforestry Systems and Its Sustainability. *Agroforestry*, 223-254.
- Sistla, S. A., Roddy, A. B., Williams, N. E., Kramer, D. B., Stevens, K., & Allison, S. D. (2016). Agroforestry practices promote biodiversity and natural resource diversity in Atlantic Nicaragua. *PloS one*, 11(9), e0162529.
- Stewart, S. B., O'Grady, A. P., Mendham, D. S., Smith, G. S., & Smethurst, P. J. (2022). Digital Tools for Quantifying the Natural Capital



- 
- Benefits of Agroforestry: A Review. *Land*, 11(10), 1668.
- Sukhdev, P., Wittmer, H., & Miller, D. (2014). The economics of ecosystems and biodiversity (TEEB): challenges and responses. *Nature in the balance: the economics of biodiversity*, 135-152.
- Udawatta, R. P., & Jose, S. (Eds.). (2021). *Agroforestry and ecosystem services*. Springer International Publishing.



## Role of forests in reducing the effects of global climate change

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### Introduction

Forests are vital ecosystems that support around a billion people's livelihoods and serve as habitat for the majority of the planet's species. Because they operate as carbon sinks and absorb billions of metric tonnes of CO<sub>2</sub> annually, healthy forests are essential to reducing the effects of climate change. But because of degradation and deforestation, they are in danger. Reaching the global climate targets requires protecting and reforesting forests. There is dreadfully little finance available for forest-based climate solutions, substantially less than what is required to achieve significant advancements. The UNDP helps nations develop policies to strengthen conservation efforts and climate resilience, implement creative financing structures, and promote sustainable forest management.

### Forest and climate change

In order to maximize the climate benefits of forests, we must preserve more forest landscapes, manage them more sustainably, and restore more of the landscapes that we have lost. Preventing the loss and degradation of natural systems and encouraging their restoration could contribute to more than one-third of the total climate change mitigation that scientists say is necessary by 2030. Restoring 350 million hectares of degraded land in accordance with the Bonn Challenge could sequester up to 1.7 gigatonnes of carbon dioxide equivalent

annually. Forests help stabilize the climate by regulating ecosystems, protecting biodiversity, regulating ecosystems, supporting livelihoods, and can help drive sustainable growth.

### What is the issue?

The climate can be stabilized by forests. They sustain livelihoods, safeguard biodiversity, maintain ecosystems, contribute significantly to the carbon cycle, and provide commodities and service that can promote sustainable growth. There are two ways that forests contribute to climate change. They contribute to greenhouse gas emissions as well as acting as a remedy for them. The land sector is the second greatest producer of greenhouse gas emissions after the energy sector, accounting for around 25% of world emissions. Deforestation and forest degradation are responsible for around half of these (5–10 GtCO<sub>2</sub>e yearly). One of the most crucial ways to mitigate the consequences of climate change is through forests. Every year, forests absorb about 2.6 billion tons of carbon dioxide, or one-third of the CO<sub>2</sub> emitted by burning fossil fuels. An area the size of South America, around two billion hectares of degraded land worldwide, is thought to have restoration potential. Thus, preserving and growing trees is a crucial way to combat climate change.

### Why is it important?



- More than one-third of the overall mitigation of climate change that experts think is needed by 2030 to satisfy the goals of the Paris Agreement may be achieved by halting the loss and degradation of forest ecosystems and encouraging their restoration.
- There are numerous additional advantages that benefit both people and the environment: Nearly 25% of the world's population, or 1.6 billion people, depend on forests for their livelihoods; many of these individuals are among the poorest in the world.
- The annual value of products and services provided by forests, such as clean water and healthy soils, ranges from \$75 to \$100 billion.
- Eighty percent of the terrestrial biodiversity on Earth is found in forests.

### What can be done?

The significance of trees and forests in enhancing climate change resistance is addressed by IUCN's forest work in a number of ways:

Fighting against deforestation and forest degradation in places like primary forests and World Heritage sites that are rich in biodiversity and cultural value. Restoring forest landscapes improves climate change adaptation and mitigation. This helps preserve the advantages that people and society receive from forests, such as forest carbon stocks and livelihoods. IUCN assists national and sub-national decision makers in achieving this significant objective as the co-founder and Secretariat of the Bonn Challenge, an international initiative to restore 350 million hectares of

degraded and deforested land by 2030. Up to 1.7 gigatonnes of carbon dioxide equivalent might be sequestered annually if the 350 million hectare target is met.

Facilitating rights-based land use guarantees community participation in land-use decisions. In order to improve biodiversity, empower women and men, reduce poverty, promote community control over forests, and manage forests sustainably, IUCN works with partners and initiatives around the world.

For a sustainable and fair supply of forest products and services, it is essential to unlock the benefits of forests. In order to ensure that gains, including those from Reducing Emissions from Deforestation and Forest Degradation (REDD+), are distributed fairly to local landowners and forest communities, IUCN works to increase capacity for restoration implementation, engage the corporate sector, and more.

Consumers now are demanding forest products from sustainable sources, and more and more large firms that produce paper, lumber, palm oil, and other forest products are starting to transition to supply chains free of deforestation. Many nations, subnational governments, and individual landowners are rehabilitating degraded and deforested land in addition to establishing and preserving protected areas and initiating programs towards more sustainable management. This lessens emissions from deforestation and forest degradation and relieves pressure on healthy, intact forests. National leaders must expedite these steps as the globe discusses how to operationalize the Paris Agreement. This can be achieved by incorporating land use and forests into



nations' Nationally Determined Contributions (NDCs) under the Paris Agreement, sustaining forest climate financing, and adhering to and implementing the New York Declaration on Forests. Maintaining the climate within the widely recognized two-degree temperature increase limit may and should be aided by nature, especially trees and forests. Why are forests so vital to the earth and to people? Almost one-third of the Earth's total area is covered by forests, which is equal to the combined land areas of China, Brazil, Canada, and the United States. There is more to these 4 billion hectares of forests than just expansive green spaces. They are an essential part of practically every aspect of life on Earth. With 60,000 distinct tree species, 80% of amphibian species, 75% of bird species, and 68% of mammal species worldwide; forests are habitats where great biodiversity flourishes. They offer a wealth of ecosystem services, including preventing flooding and soil erosion, protecting water resources, and assisting in the regulation of global rainfall patterns.

For many communities worldwide, woods also serve as catalysts for sociocultural, ecological, and economic well-being. Forests lower the risk of land-based climate disasters and give access to clean water, food, and medicines for the approximately 1 billion people who rely on them for their livelihoods. Additionally, healthy forests prevent the transmission of infectious zoonotic diseases and serve as barriers between people and wildlife. In addition; 70 million Indigenous people live in forests and serve as their principal guardians and stewards. For them, maintaining the health of the woodlands

really comes down to survival. Without a doubt, people and the environment greatly benefit from the preservation, sustainable management, and restoration of forests.

### **What makes forests so important in the fight against climate change?**

Strong carbon sinks, or forests that are in good health, absorb and store carbon dioxide. Globally, forests are estimated to have absorbed twice as much carbon as they released between 2001 and 2019, or 7.6 billion metric tons of CO<sub>2</sub> annually.

In order to assist us prevent the worst effects of the climate catastrophe, forests offer a vital ability to remove greenhouse gases (GHG) from the atmosphere. The agriculture, forestry, and other land use (AFOLU) sector can contribute up to 30% of the GHG emissions reductions required to keep global warming to 2°C, according to research from the Intergovernmental Panel on Climate Change (IPCC), and at a comparatively low cost. Forests offer numerous high-impact mitigation alternatives for the AFOLU sector. Forests are excellent examples of natural recovery and adaptation, and they are among the best nature-based remedies. However, anthropogenic stressors like land-use change, deforestation, intensified agriculture, and urbanization still affect them despite their resiliency.

Deforestation and forest degradation currently account for at least a fifth of global greenhouse gas emissions. To make matters worse, as global temperatures rise, forests become more susceptible to drought, wildfires, pests, and disease. The massive potential of forests to store carbon is lost when they are destroyed, and the carbon dioxide they release exacerbates the greenhouse effect. Managing our



forests responsibly through a holistic approach is the key to effectively combating climate change. By eliminating emissions from deforestation and forest degradation and encouraging forest regeneration and landscape restoration, we can significantly reduce global net GHG emissions. Given that forests are essential to achieving the 2°C global warming threshold, we must all work together to conserve, restore, and manage them sustainably if we truly hope to avoid exceeding it.

### **What are the difficulties?**

The demand for commodities worldwide Deforestation is fueled by the world's need for goods including timber, cattle, palm oil, and soy. These commodities are vital parts of global supply networks, and their production has increased due to consumer demand for plentiful and affordable goods, frequently at the expense of forests. Stopping deforestation associated with the production of commodities is challenging if the underlying causes of this demand are not addressed. A lot of commodities producers put immediate financial gain ahead of long-term viability. They might overgraze, use excessive amounts of pesticides and fertilizers, or engage in unsustainable logging, all of which damage nearby ecosystems and forests. Furthermore, it is frequently challenging to determine the origin of products due to the intricate worldwide supply chains for commodities. Because items from legal sources may be combined with those from deforested areas, this lack of transparency may allow illegal logging and deforestation to continue unchecked.

### **Inadequate funding**

The average annual amount of domestic and foreign funding for forest-based climate mitigation options is US\$2.3 billion, which is less than 1% of the required sum. This little amount is dreadfully insufficient and seriously undercuts the transformative power of forests in accomplishing the lofty objectives outlined in the Paris Agreement. The 2030 targets of halting forest loss and degradation and restoring 350 million hectares of forest landscape are not being met by any global indicator, according to the 2022 Forest Declaration Assessment. Only a small portion of the necessary funding has been allocated to meet those indicators. Local communities (LCs) and Indigenous Peoples (IPs), who are essential to sustainable forest management, continue to get considerably less financing than they require protecting forest ecosystems and securing land tenure rights. IPs and LCs received just 1.4% of all public climate funding in 2019 and 2020, and only 3% of the yearly funding requirement for revolutionary land tenure reform is being satisfied.

### **Rights and land tenure**

In many areas, deforestation is exacerbated by ambiguous land title and rights. Forest clearing is a result of land ownership disputes, contradictory land use restrictions, and the disregard for the rights of Indigenous and local communities. While Indigenous people have traditional or customary rights, governments frequently assert ownership of large forested regions. Due to the lack of a clear authority in charge of protecting these lands, this ambiguity might provide an ideal environment for illicit logging, land invasion, and deforestation.



## Agroforestry and fight against hunger

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### Introduction

Agroforestry is the practice of growing trees and crops in interacting combinations – is recognized the world over as an integrated approach to sustainable land-use. Agroforestry systems, being multifunctional, facilitate not only the production of food and wood products but also provide a variety of ecosystem services such as climate-change mitigation, biodiversity conservation, and soil quality improvement.

The most frequent AFS are annual and perennial crops under shade, multistrata systems such as home gardens and successional AFS, silvopastoral systems, live fences, and windbreaks.

Agroforestry as a land use system can contribute to achieving at least nine out of the 17 sustainable development goals (SDG). The most significant influence of agroforestry is on reducing poverty (SDG 1), hunger (SDG 2), climate action (SDG 13), biodiversity conservation, and sustainable land management (SDG 15) is found in agroforestry. Agroforestry can also help achieve other goals, including enhancing health (SDG 3), gender equality (SDG 5), and access to clean water (SDG 6), sustainable energy solutions (SDG 7), and responsible agricultural production (SDG 12).

The member countries of the United Nations have accepted the Sustainable Development Goals (SDGs) since 2015,

among the total 17 SDGs; second aim is to end hunger, by 2030. (UN, September 25th 2015). One of the many unpleasant issues affecting human existence is the severe hunger that the world is currently experiencing. Hunger can take on many different forms, including low energy, dullness, higher vulnerability to diseases, inadequate nourishment, and early mortality. The fight between hunger and malnutrition is a factor in the development agenda.

Agroforestry systems can increase yield while helping us achieve SDG 2 i.e. Zero Hunger, especially for the developing country like India, it can help in SDG framework. Agroforestry also increases flexibility of crops and farm livelihoods, especially among the most vulnerable food producers. However, traditional yield improving strategies have always dominated the debate on food production, hampering the implementation of more secure methods like agroforestry. Governments and institutions have the opportunity to rebalance agricultural policy and investment toward such multi goal approaches. In doing so, we could achieve important improvements on multiple international commitments with the themes of food security, malnutrition, climate change, biodiversity conservation, and better livelihood for all.

### What does it look like?



There are generally two forms of hunger (Gopaldas, 2006). The first is overt (or raw) hunger, or the need to eat often. Simply put, hunger is the want to eat. Self-reported hunger is another name for it, when people assess their own capacity to satisfy the physiological urge to eat.

The second form of hunger appears when the body adjusts to consuming less food than is essential for healthy growth and, eventually, does not even feel the need for more food. When people consistently consume less food than they require, a condition known as biostasis occurs in which their bodies learn to function on less food (Krishnaraj, 2006).

While India produces enough food to feed its population, the country is home to 25 percent of the world's hungry population. Nearly 47 million or four out of 10 children in India do not meet their potential because of chronic undernutrition or stunting.

Zero hunger means access to nutritious food for everyone, especially women from the beginning of pregnancy and children under the age of two.

### **How it can be done?**

When times are tough and disaster strikes, it means protecting our precious food supply (UN INDIA).

By growing and consuming a variety of crops along with trees.

By encouraging farmers to grow more and better.

The cost of creating systems to fix hunger are less than 1/10 of that 270 billion dollar each year. (World food programme)

If we all work together after a phase there will be no more hunger.

### **Government of India Initiatives**

India's zero hunger programme was launched on the occasion of WorldFood day (October 16) in the year 2017 to focus on nutrition, health and Agriculture. This programme has come into the limelight as it has received the Nobel peace prize 2020.

- Under the Pradhan Mantri Matru Vandana Yojana (PMMVY), Rs.6,000 is transferred directly to the bank accounts of pregnant women for availing better facilities for their delivery.
- POSHAN Abhiyaan, launched in 2017-18, aims to reduce stunting, under-nutrition, anaemia and low birth weight babies through synergy and convergence among different programmes, better monitoring and improved community mobilization.
- The National Food Security Act (NFSA), 2013, aims to ensure food and nutrition security for the most vulnerable through its associated schemes and programmes, making access to food a legal right.
- Mid-day Meal (MDM) scheme aims to improve nutritional levels among school children which also have a direct and positive impact on enrolment, retention and attendance in schools.

### **Contribution of Agroforestry**

Agroforestry contributes to food security in multiple ways:

- Trees provide fodder, food, fuelwood, financial opportunities and soil fertility
- Many farmers, especially women, rely on forest products for food and additional income.
- Agroforestry also contributes to nutritional security as the



diversification provides farmers with a more varied diet.

- Forest products are also important to reduce malnutrition, as they are rich in nutrients, fibres and proteins.
- Agroforestry increases crop yields, which is vital to food security.
- Planting nitrogen-fixing trees can increase yields up to several hundred percent
- Farmers using agroforestry systems earn more cash from improved yields and sales of tree products
- Studies show that using fodder shrubs is a suitable agroforestry practice as it competes only marginally WITH CROPS

### **Agroforestry and target**

#### **Access to safe and nutritious food and end malnutrition**

##### **Direct contribution**

Agroforestry supports food and nutritional security through:

- The direct provision of tree foods such as fruits and vegetables and by supporting staple crop production
- by raising farmers' incomes through the sale of tree products and surplus staples;
- by providing fuels for cooking; and
- by supporting various ecosystem services such as pollination that are essential for the production of some food plants.

##### **Indirect contribution**

Support food production i.e. water regulation, soil protection, nutrient circulation, pest control, pollination, carbon cycle regulation.

- Economic benefit to purchase input needed for agriculture crops.
- Fodder for livestock'
- Wood for energy/cooking.

### **Agroforestry and target**

#### **Investing in smallholder producers**

- Agroforestry systems can provide multifunctional benefits to smallholder farmers and society at large.
- Agroforestry generates economic incentives to farmers from the joint interaction of trees and crops, and as well it generates social (intangible) benefits to the society through implementing environmentally friendly practices.
- Agroforestry systems are described as ecologically sound, economically viable, and socially just land-use practices.

#### **Producing more**

- Smallholder systems are estimated to produce between 30%(Ricciardi et al. 2018) and 70-80% (FAO 2014) of the world's food.
- Produce wide variety of products, providing resilience against economic and environmental shocks.
- Smallholder farmers (particularly women) near forests show active participation to conserve forest ecosystem through integrated land use.

### **Agroforestry and Target**

#### **Sustainable production system and resilient practices**

Integrated land use benefits include:

- High carbon value
- Biodiversity conservation



- Maintenance of ecosystem services
- Greater resilience to economic and environmental shocks sustainable livelihood
- Agroforestry can provide the next step in sustainable agriculture by :
- Promoting and implementing integrated, biodiverse processes to increase yields
- Decrease harmful effects, and advance our understanding of the complex interactions involved in increasing food production while minimizing damage.

#### **Agroforestry and Target Genetic Diversity**

- Three quarter of the varietal genetic diversity of agricultural crops has been lost over the last century alone (Khoury et al. 2016)
- Today, 12 plant crops and 14 animal species provide 98% of world's dietary needs
- Less biodiversity in food and agriculture is equivalent to vulnerable food supply
- An investment in conserving forest biodiversity is an investment in future food security that is genetically diverse, Nutritious and resilient (Sunderland 2011)
- As the raise in demand and population people are depending on agriculture crops only that are leading to loss of tree cover.
- Genetic diversity can be protected only by following practices like agroforestry for crop diversification

#### **Agroforestry as an ideal pathway to crop diversification**

- Before the 1960s, indigenous crops were grown widely. These were low-yield varieties but better suited to each area's specific topography and climate.
- The Green Revolution brought more high-yield varieties. Cultivation practices improved and farmers switched to commercial crops like wheat and rice leading to decreased native crop pattern and henceforth loss of indigenous seeds.
- People don't understand the potential of local cultivation in terms of not just sustainability but also economic viability.
- Talking about Uttarakhand, we see today Thyme sells at Rs 500 per kg and the Rhododendron flower is being used as tea worldwide.
- There are many such other species in the state that are needed to be preserved but increasing population is leading us towards clearing the forest land and practicing agriculture instead which in turn is leading to huge loss of biodiversity
- So in order to maintain crop diversity consequently genetic



diversity agroforestry is the solution.

### Challenges and opportunities

- As per the Comprehensive National Nutrition Survey 2016-18, 40 million children are chronically malnourished and half of the Indian women aged 15-49 years are anemic.
- Climate Change poses a great threat to “agrobiodiversity”, which can impact the entire value chain of food systems right from the productivity of food crops to livelihoods of farmers.
- Excessive use of chemicals and unsustainable farming practices has resulted in soil degradation, depletion of groundwater table and loss of agrobiodiversity.
- 86% of Indian farmers own less than 2 hectares of land contributing to 60% food grain production and over half fruits and vegetables of the country.
- **FINDINGS:**
- Agroforestry can help as an institutional response to contested resource access, and can allow for gender and social equity enhancement as well as be a source of empowerment. Finally, agroforestry, as an integrative mindset and culture, can help create synergies between the SDGs in multifunctional landscapes, developing innovative partnerships in pursuit of the goals as encouraged by SDG 17
- Change is needed along the entire supply chain

- Policies needed to support change in behavior and production (i.e. linking agroforestry policies with health, education, and trade policies that promote human and planetary health)
- Right and access (issues of land tenure incentives to invest and manage land ) i.e. right to food
- Challenges longstanding institutional structural and social norms.

### Reference

- Colfer CJP, Achdiawan R, Roshetko JM, Mulyoutami E, Yuliani EL, Mulyana A, Moeliono M, Adnan HE (2015) The balance of power in household decision-making: encouraging news on gender in southern Sulawesi. *World development. Journal* 76:147–164
- Gopaldas, T. (2006). 'The problem of hidden hunger and possible interventions'. *Economic and Political Weekly*, 26 August
- Khoury, C.K., Achicanoy, H.A., Bjorkman, A.D., et al. (2016). Origins of food crops connect countries worldwide. *Proceedings of the Royal Society B: Biological Sciences*, 283, 20160792.
- Krishnaraj, M. (2006). 'Food security, agrarian crisis and rural livelihoods: implications for women'. *Economic and Political Weekly*, 30 December.
- Leakey RRB, Weber JC, Page T, Cornelius JP, Akinifesi FK, Roshetko JM, Tchoundjeu Z, Jamnadass R (2012) Tree domestication in agroforestry: progress in the second decade. In:



- Nair PKR, Garrity DP (eds) The future of agroforestry. Springer, New York. 145-173 pp.541 p
- Montagnini F, et.al (1992) Sistemas Agroforestales. Principios y Aplicaciones en los Trópicos 2da. ed. Organización para Estudios Tropicales (OTS) San José, Costa Rica, 622 pp.
- Nair PKR (ed) (1989) Agroforestry systems in the tropics. Kluwer Academic Publishers, Dordrecht. 672pp
- Nair PKR, Garrity DP (eds) (2012) Agroforestry: the future of global land use, Advances in Agroforestry 9. Springer, New York
- Roshetko JM, Snelder DJ, Lasco RD, van Noordwijk M (2008) Future challenge: a paradigm shift in the forestry sector. In: Snelder DJ, Lasco R (eds) Smallholder tree growing for rural development and environmental services. Springer, Dordrecht, pp 453-485
- Somarriba E, Beer J, Alegre Orihuela J, Andrade H, Cerda R, Declerck F, Detlefsen G, Escalante M, Giraldo LA, Ibrahim M, Krishnamurthy L, Menan V, Mora-Delgado J, Orozco L, Scheelje M, Campos JJ (2012) Mainstreaming agroforestry in Latin America. In: Nair PKR, Garrity DP (eds) Agroforestry: the future of global land use, Advances in agroforestry 9. Springer, New York, pp 429-453
- van Noordwijk M, Mbow C, Minang P (2015a) Trees as nexus for Sustainable Development Goals (SDG's): agroforestry for integrated options. ASB Policy Brief 50, ASB Partnership for the Tropical Forest Margins. World Agroforestry Centre (ICRAF),



## Role of dark septate endophytes in overcoming abiotic stress to combat climate change

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### Introduction

The impacts of climate change have led to prolonged and severe droughts, particularly in the Mediterranean region, where extensive farming has become nearly impossible, and intensive farming faces critical reductions in water availability (Mukherjee et al., 2018). These conditions have also disrupted plant-microorganism interactions, with drought and soil warming significantly diminishing symbiotic relationships across various ecosystems. Endophytic fungal relationships with plants are increasingly studied to better understand their interactions, the nature of their associations, and the potential benefits they provide to hosts. Dark septate endophytes (DSEs) are sterile or conidial fungal endophytes, typically isolated from healthy plants that form melanized structures, such as inter- and intracellular hyphae and microsclerotia, in plant roots. DSEs exhibit low host specificity and are distributed across a wide geographical range. Their presence is particularly important in environments experiencing extreme abiotic stresses, such as drought, high salinity, or heavy metal contamination, where they enhance plant survival (Fig. 1) (Huertas et al., 2024). The relatively high abundance of DSEs in stressed habitats suggests that they might have an important function for host

survival in these ecosystems (Likar and Regvar, 2013). Melanin, a complex polymeric compound accumulated in the cell wall of DSEs, has been widely recognized as the main responsible of the protective features of these fungi. In addition to antioxidative and thermo-protective characteristics, melanin protects hyphae from desiccation and mechanical disruption, improving cell wall rigidity, hydrophobicity, and decreasing its permeability (Li et al., 2019). Unlike many fungi, DSEs are less affected by prolonged drought, maintaining high colonization rates even under such conditions. While DSEs may not provide as many benefits as mycorrhizal fungi, their ability to colonize plants more effectively under abiotic stress makes them crucial in such environments. However, simultaneous exposure to high temperatures and drought reduces DSE colonization rates, though it does not result in a loss of fungal diversity (Gehring et al., 2020). These unique traits highlight the critical role of DSEs in supporting plant resilience under climate change-induced stresses, making them a promising focus for further research in sustainable agriculture and ecosystem management. A recent patent highlights the potential of *Rutstroemiacalopus* as a dark septate endophyte (DSE) capable of enhancing crop growth and development under conditions of water and salinity stress.



This biostimulant has demonstrated remarkable effects, including maintaining growth with an 80% reduction in fertilizer application for cucumber plants. Studies have shown that applying *Rutstroemiacalopus* CG11560 with reduced fertilization led to a 33.8% increase in leaf area and a 30.43% increase in total dry weight compared to standard fertilization practices (Santos and Diáñez, 2017). The benefits of DSEs like *R. calopus* are primarily linked to their biostimulatory effects, which enhance plant morphology, improve drought resistance, boost secondary metabolic activity, and increase the uptake of water, nutrients, and carbon. Additionally, DSEs elevate antioxidant enzyme activity and aid in the development of adaptation mechanisms to cope with heavy metal stress. Their colonization triggers changes in cellular metabolism, biosynthesis, and signaling pathways, further modulating plant growth and resilience (Wu et al., 2021). These attributes make DSEs particularly valuable under abiotic stress conditions, where their presence can significantly reduce the need for irrigation and fertilizers. While their use may not always result in increased production, it offers an opportunity to minimize agricultural inputs while maintaining or enhancing yield, contributing to sustainable farming practices.

#### ***DSEs and their Connection to Drought and Salinity Mitigation***

Dark septate endophytes (DSEs) play a significant role in helping plants tolerate abiotic stresses such as drought and salinity, which are increasingly prevalent due to climate change. These melanized fungi colonize plant roots and establish

mutualistic relationships, where both the fungi and the host plant benefit. One of their key mechanisms in drought mitigation lies in enhancing water absorption and retention. DSEs improve root morphology by promoting the growth of fine roots, which increases the surface area available for water uptake (Bi et al., 2024). They also produce extracellular enzymes that break down organic matter in the soil, releasing bound water and nutrients, making them more accessible to the plant. Moreover, DSEs influence the plant's internal water balance by regulating osmolyte production, such as proline, which helps maintain cell turgor under water deficit conditions. In saline environments; DSEs mitigate salt stress through multiple pathways. High salt concentrations in soil often disrupt ionic balance and lead to ion toxicity, but DSEs help reduce this impact by modulating ion transport within plant roots. They enable selective uptake of essential ions like potassium while limiting the absorption of harmful ions such as sodium and chloride. Additionally, DSEs produce antioxidant enzymes, such as superoxide dismutase and catalase, which combat the reactive oxygen species (ROS) generated during salt stress (Zandi and Schnug, 2022). This reduces oxidative damage to plant cells and maintains cellular integrity. DSEs also contribute to osmotic adjustment by enhancing the synthesis of compatible solutes, such as sugars and amino acids, which stabilize cellular functions in saline conditions.

The production of melanin in DSE hyphae further aids in stress tolerance. Melanin protects the fungal cells from desiccation and extreme environmental conditions,



allowing them to remain functional in drought-prone and saline soils (DoSanto et al., 2017). This durability ensures a continuous symbiotic relationship with host plants, even under severe stress. Through these mechanisms, DSEs not only improve plant growth and survival in challenging environments but also contribute to the restoration of degraded lands and the sustainability of agricultural systems. Their potential for enhancing resilience to drought and salinity makes them a promising tool in climate-smart agriculture and ecosystem management.

### **Implications of DSEs in Fertilisation Reduction**

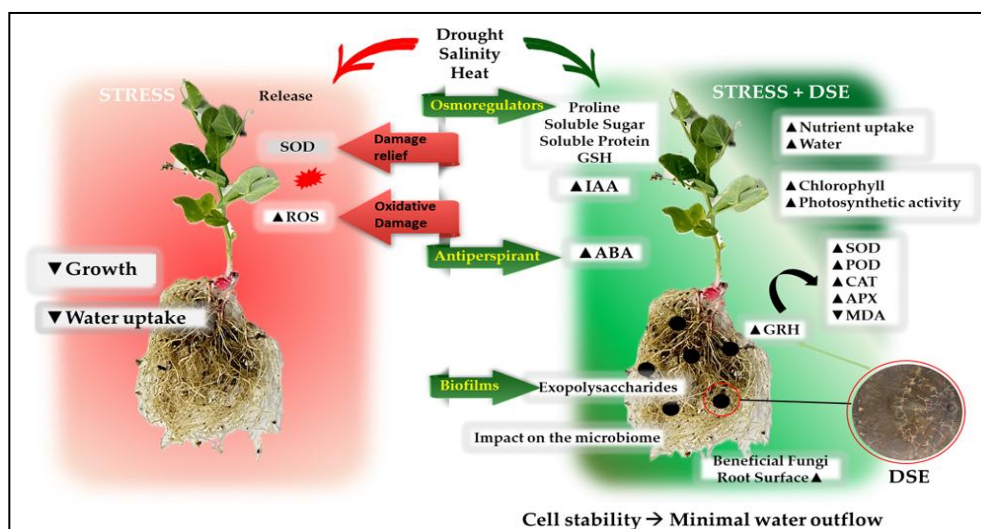
DSEs hold significant potential in reducing dependence on chemical fertilizers by enhancing nutrient acquisition and utilization efficiency in plants. These fungi colonize plant roots and extend their hyphal networks into the surrounding soil, effectively increasing the root surface area for nutrient uptake. One of their primary contributions lies in mobilizing essential nutrients like nitrogen (N), phosphorus (P), and micronutrients, which are often limited in availability. DSEs produce extracellular enzymes, such as phosphatases and proteases, which break down organic matter and convert complex, unavailable forms of nutrients into simpler, plant-accessible forms (Huertas et al., 2024). For instance, they can solubilize inorganic phosphate or degrade organic nitrogen sources, reducing the need for synthetic fertilizers. In addition to mobilizing nutrients; DSEs improve nutrient-use efficiency within plants. By modulating nutrient transport pathways, they enable plants to optimize nutrient uptake and reduce wastage. This is

particularly beneficial in systems where overuse of fertilizers often leads to environmental degradation, such as eutrophication and soil acidification. Furthermore, DSEs promote the synthesis of plant growth-promoting compounds, such as phytohormones and secondary metabolites, which enhance overall plant health and productivity without the excessive input of fertilizers. Another significant benefit of DSEs is their ability to function in nutrient-poor soils, where conventional fertilizers may be ineffective or economically unsustainable. By improving the availability and cycling of nutrients within the soil ecosystem, DSEs contribute to the long-term maintenance of soil fertility. Additionally, their symbiotic relationship helps reduce the loss of nutrients through leaching or volatilization, particularly in sandy or heavily irrigated soils. The ability of DSEs to reduce the need for chemical fertilizers has far-reaching implications for sustainable agriculture. Lower fertilizer inputs can decrease production costs for farmers, reduce greenhouse gas emissions associated with fertilizer manufacturing and application, and mitigate the environmental impacts of nutrient runoff. Integrating DSEs into farming systems can thus support the transition to eco-friendly agricultural practices, ensuring food security while preserving natural resources. As a result, DSEs represent a valuable biological tool for addressing the twin challenges of sustainable crop production and environmental conservation.

### **Compatibility of DSEs with Other Microorganisms**



DSEs exhibit strong compatibility with stresses. By producing extracellular



**Figure 1.** Schematic representation regarding the different effects and mechanisms of action reported with DSE inoculation in plants (retrieved from Huertas et al., 2024).

other microorganisms, forming microbial networks that benefit plant and soil health. They often coexist with beneficial microbes like mycorrhizal fungi, nitrogen-fixing bacteria, and plant growth-promoting rhizobacteria (PGPR), engaging in synergistic interactions rather than competition. For instance, DSEs complement arbuscular mycorrhizal fungi (AMF) by thriving in harsher conditions where AMF may be less effective, collectively improving nutrient and water uptake and enhancing stress tolerance (Santos et al., 2021). DSEs also work alongside nitrogen-fixing bacteria like *Rhizobium* and *Azospirillum* to optimize nitrogen availability, with DSEs mobilizing nutrients and bacteria supplying fixed nitrogen, reducing the need for synthetic fertilizers. Additionally, DSEs interact with PGPR, such as *Pseudomonas* and *Bacillus*, which promote plant growth and suppress pathogens. These collaborations create a multi-functional microbial consortium that boosts plant productivity and resistance to

enzymes and secondary metabolites, DSEs support microbial diversity and soil health. Melanin production enhances soil organic matter, benefiting other soil microbes, while biofilm formation with other microorganisms improves microbial survival and nutrient cycling (Huertas et al., 2024). This compatibility highlights DSEs' potential in integrated microbial inoculants for sustainable agriculture, fostering resilient ecosystems and supporting modern agricultural practices through multi-functional biofertilizers and biostimulants.

### Compatibility of DSEs with Active Chemical Substances

DSEs demonstrate resilience and adaptability in chemically stressed environments, making them compatible with agricultural practices involving fertilizers, pesticides, and herbicides. Their robust traits, including melanized hyphae, antioxidant enzymes, and the ability to metabolize complex compounds, enable them to thrive despite chemical inputs. DSEs contribute to soil detoxification by



producing enzymes like peroxidases and laccases, breaking down toxic compounds such as pesticides and heavy metals, thereby maintaining a healthier rhizosphere (Santos et al., 2021). DSEs also enhance nutrient uptake efficiency, reducing the need for excessive fertilizer use and mitigating issues like leaching and eutrophication (Huertas et al., 2024). Their tolerance to reactive oxygen species generated by chemical inputs ensures continued functionality and plant association. Additionally, DSEs coexist with certain biocides, using their melanized structures for protection against antimicrobial agents.

However, their compatibility depends on the type and concentration of chemicals, as excessive exposure may suppress activity. Integrating DSEs into agriculture requires judicious chemical use, offering potential for sustainable practices by combining biological inoculants with minimal agrochemical inputs. This approach can improve plant productivity, reduce environmental impact, and support long-term soil health.

### Conclusion and future directions

DSEs play a pivotal role in mitigating abiotic stresses such as drought, salinity, and nutrient deficiencies, enhancing plant resilience and productivity in challenging environments. Their ability to improve nutrient uptake, water absorption, and oxidative stress management makes them valuable allies in addressing the adverse impacts of climate change. Integrating DSEs into climate-smart agricultural practices offers a sustainable solution for improving crop yields, reducing reliance on chemical fertilizers, and restoring degraded soils. Future research should

focus on unravelling the ecological interactions of DSEs with diverse plant species, understanding their genetic mechanisms of stress tolerance, and optimizing their practical applications in large-scale farming. Expanding knowledge in these areas will enable the development of tailored DSE-based bioinoculants, fostering sustainable agriculture and contributing to global climate change adaptation strategies.

### References

- Huertas, V., Jiménez, A., Diáñez, F., & Santos, M. (2024). Importance of Dark Septate Endophytes in Agriculture in the Face of Climate Change. *Journal of Fungi*, 10(5), 329.
- Santos, M.; Diáñez, F. (2017). Strain of *Rutstroemia calopus*, Compositions and Uses. Patent ES2907599.,
- Do Santos, S.G.; Silva, P.R.A.; Garcia, A.C.; Zilli, J.É.; Berbara, R.L.L. (2017). Dark septate endophyte decreases stress on rice plants. *Braz. J. Microbiol.*, 48, 333–341.
- Mukherjee, S.; Mishra, A.; Trenberth, K.E. (2018). Climate change and drought: A perspective on drought indices. *Curr. Clim. Chang. Rep.* 4, 2.
- Gehring, C.; Sevanto, S.; Patterson, A.; Ulrich, D.E.M.; Kuske, C.R. (2020). Ectomycorrhizal and dark septate fungal associations of pinyon pine are differentially affected by experimental drought and warming. *Front. Plant Sci.* 11, 582574.
- Wu, F.L.; Li, Y.; Tian, W. (2021). A novel dark septate fungal endophyte



- positively affected blueberry growth and changed the expression of plant genes involved in phytohormone and flavonoid biosynthesis. *Tree Physiol.* 40, 1080–1094.
- Santos, M.; Cesanelli, I.; Diáñez, F.; Moreno-Gavira, A. (2021). Advances in the role of dark septate endophytes in the plant resistance to abiotic and biotic stresses. *J. Fungi*, 7, 939.
- Bi, Y.; Wang, S.; Song, Y.; Christie, P. (2024). Effects of a dark septate endophyte and extracellular metabolites on alfalfa root exudates: A non-targeted metabolomics análisis. *Physiol. Plant.*, 176, e14165.
- Zandi, P.; Schnug, E. (2022). Reactive oxygen species, antioxidant responses and implications from a microbial modulation perspective. *Biology*, 11, 155.
- Li, X., He, C., He, X., Su, F., Hou, L., Ren, Y., & Hou, Y. (2019). Dark septate endophytes improve the growth of host and non-host plants under drought stress through altered root development. *Plant and Soil*, 439, 259-272.



## Restoration forestry techniques: Healing our forests

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Forest ecosystems are crucial for maintaining biodiversity, regulating the climate, and supporting livelihoods. However, human activities such as deforestation, agriculture, and urbanization have caused significant damage to these essential habitats (Ajuet *al.*, 2015). Traditional restoration forestry methods aim to rehabilitate degraded forests, enhancing their ecological functions and resilience (Löfet *al.*, 2019). These techniques include replanting native species, protecting natural regeneration, and integrating trees into agricultural landscapes. By employing various restoration strategies, environmental damage can be reversed, carbon can be sequestered, and biodiversity preserved, ensuring the future health of forests (Cicareseet *al.*, 2012). Reforestation, for instance, involves planting trees in deforested or degraded areas to restore native ecosystems. This technique is effective in regaining lost forest cover and capturing carbon, although it requires substantial investment and time (Di Sacco *et al.*, 2021). It plays a key role in fighting climate change by sequestering carbon and restoring wildlife habitats. An example of this is the Great Green Wall project in Africa, which aims to restore millions of hectares across the Sahel region (Gadzama, 2017). Assisted Natural Regeneration (ANR) focuses on nurturing

the natural vegetation present in degraded areas. By removing invasive species and promoting native plants, ecosystems can regenerate naturally (Rinaudo *et al.*, 2019). For instance, the Mount Apo project in the Philippines uses ANR to restore forests. ANR is a cost-effective method that promotes biodiversity and often results in faster recovery by leveraging existing vegetation (Boquiren, 2004). Agroforestry involves integrating trees into agricultural land, improving soil fertility, enhancing water retention, and providing farmers with a sustainable income (Fahad *et al.*, 2022). This method is increasingly used in regions where both farming and deforestation are prevalent. For example, in Karnataka, India, agroforestry is used to restore degraded land. Agroforestry enhances soil fertility, improves water retention, and supports livelihoods, making it effective in regions where both agricultural and forest restoration are needed (Dagaret *al.*, 2020). Assisted Migration addresses climate change by moving tree species to areas where they are better suited for survival. This technique is vital in helping forests adapt to climate change and ensure the survival of species (Camacho, 2010). Forest Enrichment increases biodiversity and resilience, helping ecosystems recover more rapidly (Cerullo and Edwards, 2019).



As climate change, deforestation, and ecosystem degradation continue to impact the planet, innovative techniques are emerging to restore forests more effectively. These advanced methods combine cutting-edge science with traditional practices to address the complexities of forest ecosystems (Raj *et al.*, 2023). Below are some of the latest advanced techniques in forest restoration:

#### **Drone-Assisted Reforestation**

Drones are transforming forest restoration by enabling the rapid planting of trees in remote areas. Drones can map landscapes, monitor plant growth, and distribute seed pods containing native species over large areas. This approach is cost-effective, efficient, and especially useful for large-scale reforestation projects where human labor would be too slow or costly (Robinson *et al.*, 2022).

Example: BioCarbon Engineering uses drones to plant seeds in degraded areas, carrying out large-scale restoration projects in countries such as Australia and the UK (Mohan *et al.*, 2021).

#### **Genetic Restoration and Assisted Evolution**

Genetic restoration involves selecting tree species with genetic diversity and resilience to adapt to changing environmental conditions. In response to climate change, assisted evolution breeds tree species that are more suited to future conditions, such as drought tolerance or disease resistance. These genetically optimized species are planted to strengthen ecosystem resilience and ensure the success of restoration projects (Thomas *et al.*, 2014).

Example: Research projects in the Pacific Northwest focus on breeding climate-

resilient conifers to endure frequent wildfires and droughts (Gaines *et al.*, 2022).

#### **Mycorrhizal Inoculation and Soil Microbial Enhancement**

Soil health is essential for successful forest restoration. Inoculating soil with beneficial mycorrhizal fungi accelerates the recovery of degraded land by improving nutrient absorption and soil structure. These fungi form symbiotic relationships with tree roots, helping plants thrive in poor soil conditions. Recent studies show that introducing a variety of beneficial soil microbes can improve forest regeneration by enhancing soil fertility, water retention, and pest resistance (Asmelashet *et al.*, 2016). Example: The Trillion Trees Initiative incorporates microbial inoculation in restoration projects to improve soil quality and accelerate tree growth (McKinley, 2019).

#### **Remote Sensing and AI for Monitoring and Planning**

Advanced technologies such as remote sensing (using satellites, drones, and LiDAR) and Artificial Intelligence (AI) are employed to monitor forest restoration efforts. Remote sensing maps deforestation, tracks forest health, and evaluates restoration success, while AI analyzes large datasets to predict the outcomes of various restoration strategies. AI also automates tasks like tree counting, biodiversity assessments, and growth predictions, making monitoring more efficient and accurate (Pandey and Arellano, 2022).

Example: The World Resources Institute's Global Forest Watch uses satellite imagery to monitor deforestation and assist in



global restoration efforts (World Resources Institute, 2000).

### **Ecological Engineering: Creating Self-Sustaining Ecosystems**

Ecological engineering focuses on designing solutions that foster natural processes in ecosystem restoration. Techniques include creating artificial wetlands or planting pioneer species to transform degraded landscapes into fertile habitats for future plantings. By integrating water management and soil conservation, ecological engineering creates self-sustaining ecosystems that require minimal human intervention after restoration. This method ensures long-term stability in forest ecosystems (Nellemann and Corcoran, 2010).

Example: The Loess Plateau restoration project in China used ecological engineering to transform degraded land into a productive, self-sustaining landscape with improved vegetation cover (Stokes *et al.*, 2010).

### **Ecosystem-Based Adaptation (EbA) and Climate-Smart Restoration**

Ecosystem-Based Adaptation (EbA) uses ecosystems to help both people and nature adapt to climate change impacts. In forest restoration, EbA combines ecological restoration with adaptation strategies to mitigate challenges like flooding, drought, and soil erosion. Climate-Smart Restoration incorporates local climate predictions and resilience-building strategies, ensuring that restored forests can withstand future climate changes (Saroar, 2018).

Example: In the Himalayas, climate-smart restoration techniques are used to restore mountain forests while enhancing

resilience to floods and landslides (Meeteiet *al.*, 2023).

### **Forest Carbon Offsetting and Payment for Ecosystem Services (PES)**

Forest restoration through carbon offsetting has become a prominent method for addressing climate change. Forest Carbon Offsetting involves restoring or protecting forests to absorb carbon dioxide from the atmosphere. Individuals and companies can invest in these projects to offset their carbon emissions. Additionally, Payment for Ecosystem Services (PES) provides financial incentives for landowners to engage in restoration by rewarding them for ecosystem services like water filtration, biodiversity conservation, and carbon sequestration (Nunes *et al.*, 2020).

Example: REDD+ (Reducing Emissions from Deforestation and Forest Degradation) is a global initiative that offers financial incentives to countries and communities for protecting and restoring forests, emphasizing carbon credits (Venter and Koh, 2012).

### **Green Infrastructure for Urban Forestry**

Urban forestry is becoming an essential part of forest restoration, especially in cities. Green infrastructure, such as tree planting, green roofs, or parks, restores ecological functions in urban areas, such as air purification, heat reduction, and biodiversity support. This technique not only restores local ecosystems but also enhances urban residents' quality of life by reducing pollution and promoting mental well-being (Tyrväineniet *al.*, 2005).

Example: Cities like New York and Singapore incorporate green infrastructure into their urban planning to restore forests



and reduce the urban heat island effect (Block *et al.*, 2005).

As environmental challenges grow more complex, innovative restoration techniques are providing effective solutions to heal degraded forests. From drone-assisted reforestation to genetic restoration and ecosystem-based adaptation, these cutting-edge methods are increasing the scale, efficiency, and success of forest restoration projects. By adopting these techniques, we can repair ecosystems, boost biodiversity, and combat climate change, ensuring that forests continue to provide vital services for future generations.

### References

- Aju, P. C., Iwuchukwu, J. J., & Ibe, C. C. (2015). Our forests, our environment, our sustainable livelihoods. *Eur. J. Acad. Essays*, 2(4), 6-19.
- Löf, M., Madsen, P., Metslaid, M., Witzell, J., & Jacobs, D. F. (2019). Restoring forests: regeneration and ecosystem function for the future. *New Forests*, 50(2), 139-151.
- Ciccarese, L., Mattsson, A., & Pettenella, D. (2012). Ecosystem services from forest restoration: thinking ahead. *New forests*, 43, 543-560.
- Di Sacco, A., Hardwick, K. A., Blakesley, D., Brancalion, P. H., Breman, E., CecilioRebola, L., ... & Antonelli, A. (2021). Ten golden rules for reforestation to optimize carbon sequestration, biodiversity recovery and livelihood benefits. *Global Change Biology*, 27(7), 1328-1348.
- Gadzama, N. M. (2017). Attenuation of the effects of desertification through sustainable development of Great Green Wall in the Sahel of Africa. *World Journal of Science, Technology and Sustainable Development*, 14(4), 279-289.
- Rinaudo, T., Muller, A., & Morris, M. (2019). Farmer managed natural regeneration (FMNR) manual. *World Vision Australia: Melbourne, Australia*.
- Boquiren, R. R. (2004). *Rewards for environmental services in the Philippines uplands: Constraints and opportunities for institutional reform*. Bogor, Indonesia: World Agroforestry Centre (ICRAF).
- Fahad, S., Chavan, S. B., Chichaghare, A. R., Uthappa, A. R., Kumar, M., Kakade, V., ... & Poczai, P. (2022). Agroforestry systems for soil health improvement and maintenance. *Sustainability*, 14(22), 14877.
- Dagar, J. C., Gupta, S. R., & Teketay, D. (Eds.). (2020). *Agroforestry for Degraded Landscapes*. Springer.
- Camacho, A. E. (2010). Assisted migration: redefining nature and natural resource law under climate change. *Yale J. on Reg.*, 27, 171.
- Cerullo, G. R., & Edwards, D. P. (2019). Actively restoring resilience in selectively logged tropical forests. *Journal of Applied Ecology*, 56(1), 107-118.
- Raj, A., Jhariya, M. K., Banerjee, A., Nema, S., & Bargali, K. (Eds.). (2023). *Land and environmental management through forestry*. John Wiley & Sons.
- Robinson, J. M., Harrison, P. A., Mavoa, S., & Breed, M. F. (2022). Existing



- p>and emerging uses of drones in restoration ecology.
- Methods in Ecology and Evolution*
- , 13(9), 1899-1911.
- Mohan, M., Richardson, G., Gopan, G., Aghai, M. M., Bajaj, S., Galgamuwa, G. P., ... & Cardil, A. (2021). UAV-supported forest regeneration: Current trends, challenges and implications. *Remote Sensing*, 13(13), 2596.
- Thomas, E., Jalonon, R., Loo, J., Boshier, D., Gallo, L., Cavers, S., ... & Bozzano, M. (2014). Genetic considerations in ecosystem restoration using native tree species. *Forest Ecology and Management*, 333, 66-75.
- Gaines, W. L., Hessburg, P. F., Aplet, G. H., Henson, P., Prichard, S. J., Churchill, D. J., ... & Vynne, C. (2022). Climate change and forest management on federal lands in the Pacific Northwest, USA: Managing for dynamic landscapes. *Forest Ecology and Management*, 504, 119794.
- Asmelash, F., Bekele, T., & Birhane, E. (2016). The potential role of arbuscular mycorrhizal fungi in the restoration of degraded lands. *Frontiers in microbiology*, 7, 1095.
- McKinley, V. L. (2019). Effects of land use and restoration on soil microbial communities. *Understanding terrestrial microbial communities*, 173-242.
- Pandey, P. C., & Arellano, P. (Eds.). (2022). *Advances in remote sensing for forest monitoring*. John Wiley & Sons.
- World Resources Institute. (2000). *The World Resources Institute's 'Global Forest Watch'*. The Institute.
- Nellemann, C., & Corcoran, E. (Eds.). (2010). *Dead planet, living planet: Biodiversity and ecosystem restoration for sustainable development: A rapid response assessment*. UNEP/Earthprint.
- Stokes, A., Sotir, R., Chen, W., & Ghestem, M. (2010). Soil bio- and eco-engineering in China: past experience and future priorities. *Ecological engineering*, 36(3), 247-257.
- Saroar, M. M. (2018). Ecosystem-based adaptation (EbA) for coastal resilience against water related disasters in Bangladesh. *Climate Change Impacts and Adaptation Strategies for Coastal Communities*, 187-205.
- Meetei, K. B., Tsopoe, M., Giri, K., Mishra, G., Verma, P. K., & Rohatgi, D. (2023). Climate-resilient pathways and nature-based solutions to reduce vulnerabilities to climate change in the Indian Himalayan Region. In *Climate change in the Himalayas* (pp. 89-119). Academic Press.
- Nunes, L. J., Meireles, C. I., Pinto Gomes, C. J., & Almeida Ribeiro, N. M. (2020). Forest contribution to climate change mitigation: Management oriented to carbon capture and storage. *Climate*, 8(2), 21.
- Venter, O., & Koh, L. P. (2012). Reducing emissions from deforestation and



- forest degradation (REDD+): game changer or just another quick fix?. *Annals of the New York Academy of Sciences*, 1249(1), 137-150.
- Tyrväinen, L., Pauleit, S., Seeland, K., & De Vries, S. (2005). Benefits and uses of urban forests and trees. *Urban forests and trees: A reference book*, 81-114.
- Block, A. H., Livesley, S., & Williams, N. S. (2012). Responding to the urban heat island: a review of the potential of green infrastructure.



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## Computational approaches for assessing genetic diversity

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### Introduction

Genetic diversity refers to the variation in genetic material within and among populations of species (Hughes et al., 2008; Ennos et al., 2000). It encompasses the differences in DNA sequences, alleles, and genotypes that contribute to individuals' unique traits and characteristics. High genetic diversity within a population is essential for the survival and adaptability of species, as it increases their ability to cope with environmental changes, diseases, and other challenges. Conversely, low genetic diversity can lead to inbreeding and an increased risk of extinction, as populations become more susceptible to genetic disorders and less adaptable to changing conditions. Genetic diversity is a fundamental concept in evolutionary biology, conservation genetics, and biodiversity studies (Frankham et al., 2002). Understanding genetic diversity helps in monitoring the health of populations, designing conservation strategies for endangered species, and studying evolutionary processes. Moreover, it provides insights into the genetic basis of traits that are important for agriculture, medicine, and biotechnology. Molecular markers are essential tools for assessing genetic diversity in plants. Commonly used markers include Microsatellites (SSRs), which are highly

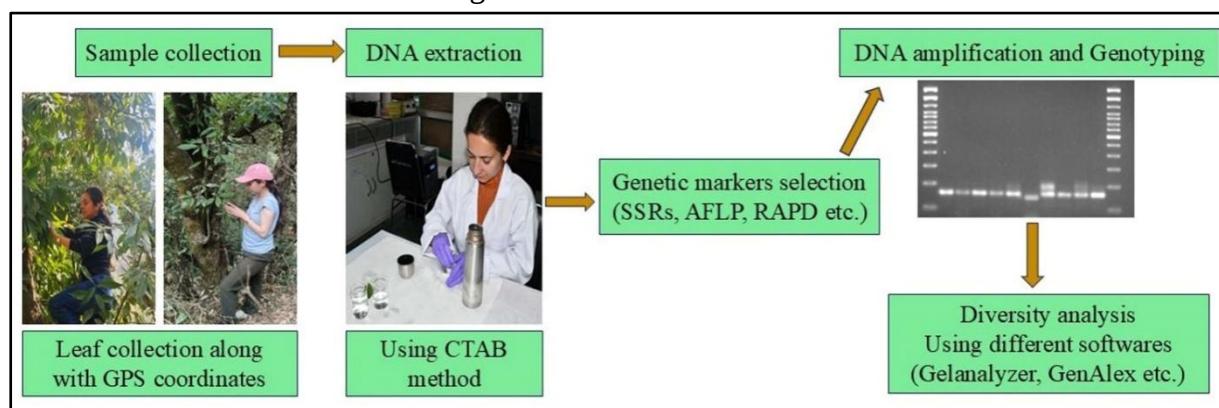
polymorphic and co-dominant; RAPD markers, which are quick and inexpensive but dominant; AFLP, which generates numerous polymorphisms across the genome; SNPs, which are abundant and useful for fine-scale variation studies; ISSRs, which are more reliable than RAPDs and can assess genetic diversity effectively; and EST-SSRs, which focus on functional genomic regions. Additionally, DNA barcoding is used to distinguish species and study biodiversity. The choice of marker depends on the specific objectives, species, and resources. Software tools for estimating genetic diversity play a crucial role in modern genetic research, allowing scientists to analyse and interpret complex genetic data with accuracy and efficiency. These tools utilize a range of statistical and computational methods to assess the genetic variation within and between populations, helping to quantify parameters such as allele frequencies, genetic distances, and heterozygosity. By integrating data from molecular markers like SSRs, SNPs, or AFLPs, these programs provide insights into the genetic structure of populations, evolutionary processes, and the effects of environmental or human-induced factors on biodiversity. Software such as GenAlex, STRUCTURE, and PAST is widely used in fields such as conservation biology, evolutionary



genetics, and plant breeding, enabling researchers to assess the health and adaptability of species, design effective conservation strategies, and study the genetic basis of traits. These tools have become indispensable for understanding the genetic complexity of organisms and managing genetic resources. Therefore, this article provides an overview of various software tools used to estimate genetic

diversity, highlighting their features, applications, and significance in genetic research. These tools are essential for analysing genetic variation within and between populations, enabling researchers to gain valuable insights into genetic structure, evolutionary processes, and biodiversity conservation.

### PROCESS FOR ESTIMATING GENETIC DIVERSITY



### Software tools for diversity analysis and population structure analysis

**Gel analyzer software (23.1.1)** is used to estimate the molecular weight of bands in gel electrophoresis by comparing them to a known molecular weight ladder. The software helps identify the size of the molecular bands by analyzing their migration through the gel matrix. Typically, smaller molecules travel faster and thus appear lower in the gel, while larger molecules travel slower and remain higher. The software not only estimates molecular weight but also provides precise measurements, visual analysis, and automated band detection, making it an essential tool for quantifying and comparing protein or DNA samples in research and diagnostics.

**GenAlex software (6.503)** is a robust and advanced tool designed to estimate genetic

diversity by analyzing molecular data across various populations, genotypes, and loci. To use this software, you first need to gather and input data on the molecular weights of the bands obtained from Gel analyzer software. This data should include information from different populations and genotypes across various loci. Once the data is organized into an Excel sheet, the software can analyze it to calculate key genetic diversity parameters, such as allele frequencies, heterozygosity, and genetic differentiation. GenAlex allows for the assessment of genetic variability within and between populations, helping researchers to better understand evolutionary processes, gene flow, and the genetic structure of populations. The software also provides various statistical outputs and graphical representations, AMOVA and Principal component analysis (PCoA) making it a



valuable tool in population genetics studies.

**HP-rare software (1.1)** is used to estimate allelic richness, which is a measure of the number of different alleles present in a population, normalized for sample size. This software is particularly useful in population genetics studies, as it helps quantify genetic diversity by providing insights into how many distinct alleles are present across different loci. HP-rare can analyse data from multiple populations and account for variations in sample sizes, ensuring that comparisons of allelic richness are not biased by unequal sample sizes.

**Structure software (2.3.4)** is used to analyse population structure by identifying and estimating the genetic composition of populations, including the number of distinct genetic clusters (or subpopulations) within a dataset. It uses genetic data, typically from multiple loci, to assign individuals to different populations based on their genetic similarities. Structure can reveal the underlying patterns of genetic differentiation among populations and provide insights into gene flow, migration, and the historical processes that shape population structure. By running simulations for various numbers of populations (K), the software helps researchers determine the most likely number of genetic clusters in the data. It is widely used in conservation genetics, evolutionary biology, and studies of human and plant genetic variation, offering graphical outputs and statistical estimates to support inferences about population connectivity and genetic diversity. Further, the best K value (the

optimal number of genetic clusters) is determined using  $\Delta K$ , which can be calculated through an online tool called **Structure Selector**. This tool is specifically designed to assist in selecting the most appropriate K value by analysing the results of multiple Structure runs. It uses the  $\Delta K$  method, which evaluates the rate of change in the likelihood of the data between different K values, helping to identify the point where the model best fits the genetic data. Structure Selector provides an easy-to-use interface for visualizing and interpreting the results, making it a valuable resource for researchers working with Structure software. By accurately selecting the optimal K, researchers can more confidently interpret population structure and genetic differentiation in their studies.

**PAST (Paleontological Statistics) software (4.0.3)** is a versatile statistical tool widely used for analyzing and clustering genetic diversity data. It provides a range of statistical methods, including clustering algorithms, that help researchers group populations or individuals based on their genetic similarities. Using genetic data such as allele frequencies or molecular markers, PAST can perform various types of clustering, such as hierarchical clustering or principal component analysis (PCoA), to identify patterns of genetic variation. This makes it particularly useful for studying population structure, evolutionary relationships, and genetic diversity across different groups or species. In addition to clustering, PAST offers a variety of other statistical tests, data visualization options, and graphing tools, making it comprehensive software for conducting



genetic diversity assessments in both ecological and evolutionary research.

**Darwin software (6.0.021)** is a tool used for analyzing molecular data and estimating genetic diversity in populations. It is particularly useful for handling large datasets derived from genetic markers such as microsatellites, SNPs, and other molecular techniques. Darwin software allows researchers to calculate various genetic parameters, including allele frequencies, genetic differentiation ( $F_{st}$ ), and heterozygosity, making it an essential tool for population genetics studies. The software also supports various statistical analyses, such as clustering, principal component analysis (PCoA), and multivariate analysis, to assess genetic structure and relationships among populations. Its user-friendly interface and robust analytical capabilities make it popular in both basic and applied genetic

research, including conservation genetics, evolutionary biology, and breeding programs.

1. **PowerMarker (3.2.5)** is a widely used, though older, software tool designed for analyzing genetic data, particularly for assessing Polymorphism Information Content (PIC). PIC is a measure of the informativeness of a genetic marker, reflecting its ability to differentiate between different genotypes within a population. PowerMarker calculates PIC values for various molecular markers, including SSRs (simple sequence repeats), SNPs, and AFLPs, helping researchers assess the diversity and variability of genetic traits. In addition to PIC, PowerMarker can also compute other genetic parameters like allele frequencies, gene diversity, and heterozygosity.

**Table 1: Links for downloading software tools online**

| Software Tools      | Link for downloading                                                                                                                                                                                                                |
|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Gelalyzer (23.1.1)  | <a href="http://www.gelalyzer.com/?i=1">http://www.gelalyzer.com/?i=1</a>                                                                                                                                                           |
| GenAlex (6.503)     | <a href="https://biology-assets.anu.edu.au/GenAlEx/Download.html">https://biology-assets.anu.edu.au/GenAlEx/Download.html</a>                                                                                                       |
| HP-rare (1.1)       | <a href="https://www.montana.edu/kalinowski/software/hp-rare.html">https://www.montana.edu/kalinowski/software/hp-rare.html</a>                                                                                                     |
| Structure (2.3.4)   | <a href="https://web.stanford.edu/group/pritchardlab/structure_software/release_versions/v2.3.4/html/structure.html">https://web.stanford.edu/group/pritchardlab/structure_software/release_versions/v2.3.4/html/structure.html</a> |
| PAST (4.0.3)        | <a href="https://past.en.lo4d.com/download">https://past.en.lo4d.com/download</a>                                                                                                                                                   |
| Darwin (6.0.021)    | <a href="https://mybiosoftware.com/darwin-diversity-phylogenetic-analysis.html">https://mybiosoftware.com/darwin-diversity-phylogenetic-analysis.html</a>                                                                           |
| PowerMarker (3.2.5) | <a href="https://brcwebportal.cos.ncsu.edu/powermarker/downloads.htm">https://brcwebportal.cos.ncsu.edu/powermarker/downloads.htm</a>                                                                                               |

## References

- Ennos, R.A., Worrell, R., Arkle, P., & Malcolm DC. (2000). Genetic diversity and conservation. In: Genetic variation and conservation of British native trees and shrubs current knowledge and policy implications. *Forestry commission technical paper 31. Forestry Commission, Edinburgh.*
- Frankham, R., Ballou, J.D. & Briscoe, D.A. 2002. Introduction to Conservation Genetics. *Cambridge: Cambridge University Press*, 617.
- Hughes RA, Brian D, Inouye BD, Marc TJJ, Underwood N, Vellend M (2008) Ecological consequences of genetic diversity. *Ecol Lett*, 11, 609-623.





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