Agroforestry: A Sustainable Solution for Land Degradation Neutrality

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ABSTRACT

Land degradation has emerged as one of the most pressing global environmental challenges, threatening soil fertility, ecosystem services, biodiversity, and agricultural productivity. In India, a significant proportion of land is affected by water and wind erosion, salinization, and nutrient depletion, resulting in declining land productivity and increased vulnerability to climate extremes. The concept of Land Degradation Neutrality (LDN), promoted under the United Nations Convention to Combat Desertification, aims to balance land degradation with restoration and sustainable land management practices. Among the various approaches proposed to achieve LDN, agroforestry has gained considerable attention due to its ecological, economic, and social benefits. Agroforestry integrates trees with crops and/or livestock, creating multifunctional land-use systems that enhance soil health, conserve water, reduce erosion and improve biodiversity. Scientific evidence indicates that agroforestry systems significantly increase soil organic carbon, improve soil structure, and enhance water infiltration while simultaneously sequestering atmospheric carbon and mitigating climate change. Tree-based farming systems such as alley cropping, silvopastoral systems, windbreaks, shelterbelts and homegardens have shown promising results in restoring degraded agricultural lands, saline soils, shifting cultivation areas, and reclaimed mining sites. Despite its proven benefits, the adoption of agroforestry faces challenges including policy constraints, land tenure issues, limited technical knowledge and market barriers. This article highlights the role of agroforestry as a holistic and sustainable strategy for achieving Land Degradation Neutrality by restoring degraded lands, strengthening climate resilience, and supporting rural livelihoods. Strengthened policy support, extension services and stakeholder participation are essential to scale up agroforestry interventions for long-term land restoration and sustainable development.

INTRODUCTION

Land degradation is a major global environmental challenge, with far-reaching consequences for soil fertility, biodiversity, and agricultural productivity. Unsustainable farming methods, deforestation, excessive grazing, and climate change are some of the causes. The United Nations Convention to Combat Desertification (UNCCD, 2022) states that degradation affects around 3 billion people and accounts for 20–40 per cent of the world's land area. Declining land productivity, decreased carbon sequestration, loss of ecosystem services, heightened susceptibility to extreme weather events, and financial losses are all effects of land degradation. Water erosion accounts for 69 per cent and wind erosion for 20 per cent of the 121 million hectares (Mha) of degraded land in India alone (NAAS, 2009).

The idea of Land Degradation Neutrality (LDN) has surfaced as a way to preserve and enhance land resources throughout time in response to this urgent problem. A multifaceted strategy involving community involvement, regulatory changes, and sustainable land management techniques is needed to achieve LDN. Agroforestry has drawn a lot of attention among the different approaches to attaining LDN because of its capacity to improve soil health, repair degraded lands, boost biodiversity, and aid in the mitigation of climate change. By combining trees with crops and livestock, agroforestry offers a comprehensive land-use system that helps farmers financially while simultaneously enhancing ecological functions. The contribution of agroforestry to LDN is examined in this article, along with the scientific evidence for its efficacy.

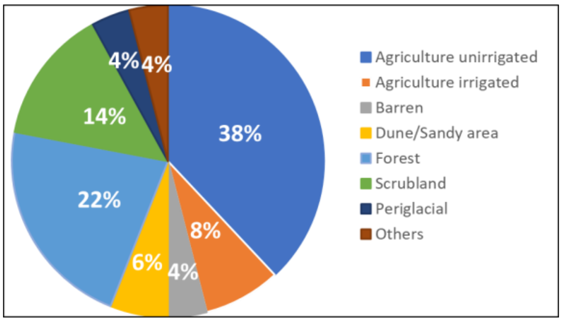

Fig. 1 Percent degraded land in India (SAC, 2021)

Understanding the Impact of Land Degradation

Land degradation is characterized by the deterioration of soil properties, loss of vegetation cover, decline in water availability, and depletion of nutrients essential for plant growth. This process results in lower agricultural yields, desertification, loss of biodiversity, and heightened food insecurity.

The Millennium Ecosystem Assessment (MEA, 2005) defines land degradation as a state of continuous decline in ecosystem services over an extended period. According to IPCC (2019), land degradation affects 3 billion people worldwide, leading to economic losses and posing a direct threat to sustainable development. In India, 20–40 per cent of land is currently experiencing degradation, impacting 50 per cent of the world's GDP (UNCCD, 2022). Furthermore, land degradation puts 1.2 billion jobs at risk globally, representing 40 per cent of the world's workforce (ILO, 2022).

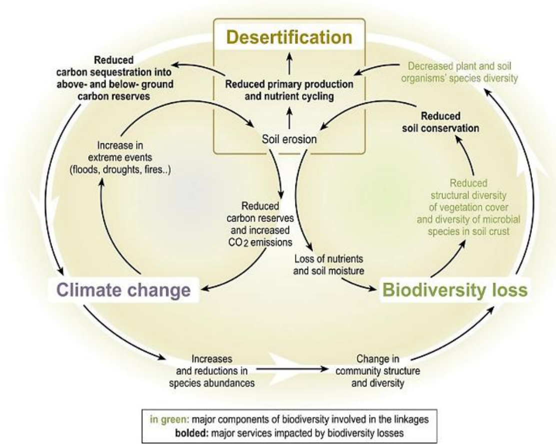

Fig 2. Systemic interactions driving environmental degradation

How Agroforestry Helps Achieve Land Degradation Neutrality (LDN)

Agroforestry is a key strategy for preventing, reducing, and reversing land degradation by integrating tree cover with agricultural landscapes. Research has demonstrated that agroforestry enhances soil structure, prevents erosion, improves water retention, and supports biodiversity. It plays a significant role in carbon sequestration, thereby mitigating climate change. Studies have shown that six-year-old Eucalyptus-based agroforestry systems sequester significant amounts of carbon (Singh *et al.*, 2022), helping reduce greenhouse gas emissions.

One of the primary benefits of agroforestry is soil conservation and erosion control. Wind and water erosion are major causes of land degradation, particularly in semi-arid regions. Jinger *et al.* (2022) found that hedgerows and windbreaks in agroforestry systems significantly reduce soil erosion, thereby improving land productivity. Adhikary *et al.* (2017) reported that agroforestry interventions in shifting cultivated lands of eastern India enhanced soil organic matter and improved soil stability, ultimately reducing runoff and increasing water infiltration. Moreover, agroforestry practices contribute to reclamation of saline and acid soils. Study by Li *et al.* (2017) demonstrated that tree-based farming in saline wastelands improved soil properties through drip irrigation and salt-tolerant species, making the land suitable for crop cultivation.

Another critical function of agroforestry is carbon sequestration and climate mitigation. Trees in agroforestry systems act as carbon sinks, capturing and storing atmospheric carbon dioxide. ICRAF (2023) reports that agroforestry landscapes store significantly more carbon than monoculture cropping systems. The sequestration potential varies across tree species, with Eucalyptus storing 43 Mg ha^{-1} of carbon, Casuarina sequestering 38.5 Mg ha^{-1}, and other mixed species storing 31.5 Mg ha^{-1}. These findings indicate that agroforestry systems not only restore degraded land but also help in climate adaptation and resilience.

Agroforestry Models for Land Restoration

Different agroforestry models have been successfully implemented to restore degraded lands. Silvopastoral systems, which integrate trees with pasturelands, enhance fodder availability while reducing soil erosion. Alley cropping, a system where crops are grown between rows of trees, has been proven to improve soil fertility and increase crop yields.

Windbreaks and shelterbelts, such as those studied by Prajapati *et al*. (2024), provide protection against wind erosion and enhance microclimatic conditions for crops. Homegardens, a traditional agroforestry system, contribute to food security and biodiversity conservation.

Additionally, agroforestry on reclaimed mining sites has been effective in restoring degraded lands. Kumar *et al*. (2015) examined vegetation succession on coal mine reclaimed lands in India and found that tree plantations significantly improved soil quality and biological productivity. Similarly, research by Mukhopadhyay *et al*. (2016) in the Jharia coalfield demonstrated that agroforestry interventions increased soil organic carbon and facilitated the natural recovery of plant species in degraded mining areas.

Challenges in Implementing Agroforestry for LDN

Despite its proven benefits, agroforestry faces several challenges. Policy and land tenure issues can hinder farmers from adopting tree-based farming due to unclear property rights. Initial investment costs and long gestation periods for tree crops also discourage smallholder farmers. Additionally, lack of technical knowledge and extension services limits the adoption of agroforestry practices. Market constraints, such as inadequate value chains for agroforestry products, further pose barriers to large-scale implementation.

CONCLUSION

Agroforestry offers a holistic and sustainable solution for achieving Land Degradation Neutrality (LDN). By integrating trees with agriculture, agroforestry enhances soil fertility, prevents erosion, improves water retention, sequesters carbon, and restores degraded lands. Scientific research and field studies have consistently demonstrated its effectiveness in tackling land degradation across diverse landscapes. With strong policy support, scientific innovations, and community engagement, agroforestry can play a crucial role in reversing land degradation and promoting climate resilience.

Governments and stakeholders must prioritize investment in agroforestry, strengthen extension services, and create favorable market conditions for agroforestry-based products. By doing so, we can ensure that degraded lands are restored, livelihoods are improved, and ecosystems are preserved for future generations. Agroforestry is not just a land-use strategy; it is a pathway towards a sustainable and resilient future.

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