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Agroforestry as a Tool for Reclaiming Degraded Lands

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Abstract

Land degradation poses a critical threat to global food security, biodiversity and ecosystem stability. Agroforestry, the intentional integration of trees with crops and/or livestock, has emerged as a sustainable land management practice capable of reversing land degradation trends. This literature review explores how agroforestry contributes to the reclamation of degraded lands, focusing on soil fertility restoration, biodiversity enhancement, water conservation and socio-economic benefits. Drawing on global case studies, it evaluates the efficacy, limitations and future potential of agroforestry systems in land restoration. The review concludes that agroforestry presents a viable, adaptable and multifunctional approach for rehabilitating degraded landscapes, especially in regions facing severe environmental and socio-economic challenges.

1. Introduction

Land degradation is the reduction or loss of biological or economic productivity of croplands, forests, pastures and woodlands. It results from natural processes (droughts, floods) and human activities (deforestation, overgrazing, improper land use, excessive irrigation, urbanization). It includes soil erosion, nutrient depletion, salinization, waterlogging, pollution, desertification and vegetation loss, ultimately reducing ecosystem services. Degradation may be physical (compaction, erosion), chemical (soil acidity, nutrient loss) or biological (weed invasion, reduced organic matter, loss of soil biota)

Globally, over 2 billion hectares are degraded, especially in Sub-Saharan Africa, South Asia and Latin America (UNCCD, 2017), leading to reduced productivity, higher greenhouse gas emissions and biodiversity loss. Around 40% of global land is degraded, affecting more than 3.2 billion people and may reach 90% by 2050, with about 12 million hectares lost annually, according to the United Nations Convention to Combat Desertification (UNCCD).

In India, nearly 97.85 Mha (29.77% of TGA) is degraded, increasing

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from 94.5 Mha (2003–05) and projected to exceed 100 Mha by 2050. Rajasthan is most affected (62%), followed by Maharashtra and Gujarat (52%), while Jammu & Kashmir (50%), Karnataka (46%), Jharkhand (45%), Odisha (44%) and Madhya Pradesh (41%) also face severe degradation due to erosion, deforestation and mining.

It is identified by soil and vegetation changes, such as erosion, salinity patches, compaction and reduced organic matter, leading to lower yields and in some cases, land abandonment. Land degradation threatens food security and ecosystems. Conventional methods are often costly and less adaptable, whereas agroforestry improves soil health, water infiltration, carbon sequestration and farm productivity while providing ecological and livelihood benefits.

Agroforestry typologies

Major agroforestry typologies are (Figure 1)

I. **Agri-silviculture:** Integration of crops and trees.

• Ex: *Eucalyptus tereticornis* + rice-wheat

• **Effectiveness:**

o Improves soil fertility through litter addition and nitrogen fixation

o Suitable for nutrient-depleted and erosion-prone soils

• **Advantages:** Enhances crop yield stability and soil organic carbon

• **Limitations:** Tree–crop competition for light, water and nutrients

• **Best suited for**: Moderately degraded agricultural lands

II. **Silvo-pasture**: Integration of trees with pasture and livestock.

Ex: *Morus alba* + *Setaria anceps* grass+ goat

• **Effectiveness:**

o Restores overgrazed and degraded grazing lands

o Improves soil structure and biomass production

• **Advantages:** Enhances livestock productivity and carbon sequestration

• **Limitations:** Requires proper grazing management

• **Best suited for:** Rangelands and severely degraded pastures

III. **Agri-silvo-pastoral systems**: Combination of crops, trees and livestock.

Ex: Sorghum + Acacia + sheep, Maize + Gliricidia + cattle

• **Effectiveness:**

o Provides holistic restoration (soil, water, biodiversity)

o Maximizes resource-use efficiency

• **Advantages:** Diversified income and improved system resilience

• **Limitations:** Complex management and higher knowledge requirement

Best suited for: Highly degraded and resource-poor farming systems

IV. **Alley cropping**: Growing crops between the alleys formed by tree rows.

Ex: Maize + Leucaena, Pigeon pea + Sesbania

• **Effectiveness:**

o Controls soil erosion and enhance nutrient cycling

o Improves soil moisture retention

• **Advantages:** Regular biomass addition and improved soil fertility

• **Limitations:** Requires frequent pruning and labor input

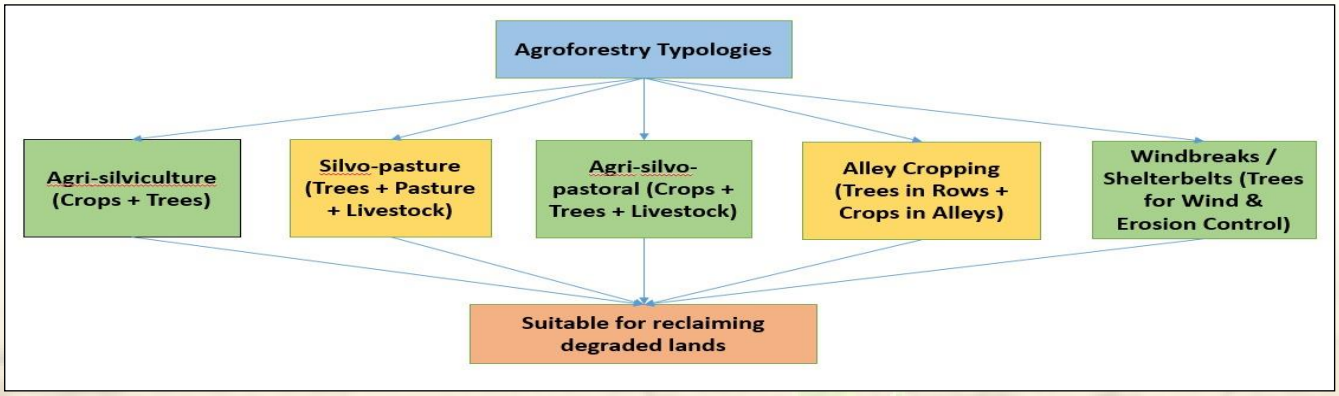

Figure 1: Agroforestry typologies

• **Best suited for:** Sloping lands and erosion-prone areas

V. **Windbreaks/shelterbelts**: Trees planted to protect crops from wind and erosion. These systems offer ecological and economic benefits, making them suitable for reclaiming degraded lands.

Ex: Casuarina (coastal), Eucalyptus/Acacia (drylands)

• **Effectiveness:**

o Reduces wind erosion and protects crops

o Improves microclimate regulation

• **Advantages:** Low maintenance and high protective function

• **Limitations:** Limited direct impact on soil fertility

• **Best suited for:** Arid and semi-arid regions

2. Agroforestry in Reclaiming Degraded Lands

Agroforestry offers a nature-based, holistic approach to rehabilitating degraded lands by combining ecological restoration with productive land use. Different agroforestry tree species are used to manage land degradation (Table 1) and this section elaborates on how agroforestry functions as a reclamation tool across key ecological and socio-economic dimensions.

2.1. Soil restoration

Agroforestry systems improve soil structure and fertility by continuously adding organic matter from leaf litter, roots and tree–crop interactions. In Rajasthan, systems with *Prosopis cineraria* and *Acacia nilotica* have enhanced soil fertility and productivity (Dhyani et al., 2013). These systems also reduce erosion through root binding and windbreak effects. Studies in the Madhupur Sal forest, Bangladesh, reported higher soil organic carbon (2.05% vs. 1.05%), pH and nutrient availability under agroforestry compared to degraded lands (Islam et al., 2024). Additionally, agroforestry improves soil structure, moisture retention and biological activity due to greater microbial diversity and root interactions.

2.2. Water regulation

Tree roots in agroforestry systems create soil porosity, improving infiltration and reducing surface runoff. Water regulation benefits drylands and degraded watersheds, where water availability is a limiting factor. The presence of vegetation helps buffer seasonal rainfall variability by regulating water storage and microclimatic conditions.

Table 1: Agroforestry tree species used for land degradation management

Species	Scientific Name	Agroforestry role	Type of degraded land targeted
Australian Wattle	*Acacia auriculiformis*	Field borders	Poor soils, wastelands, erosion-prone lands
Khair	*Acacia catechu*	Soil conservation, afforestation	Tropical drylands, arid zones and canal-irrigated areas
Babul	*Acacia nilotica*	Farm boundaries, wasteland rehabilitation	Arid regions, sand dunes, saline and alkaline soils
Bael	*Aegle marmelos*	Horti pastoral systems, field borders	Wind-prone areas, border planting on farmlands
Siris	*Albizia lebbecks*	Windbreaks, plantation shade	Wind-exposed croplands
Uttish	*Alnus nepalensis*	Taungya systems, agroforestry plantations	Abandoned cultivated areas, nitrogen-poor soils
Cashew	*Anacardium occidentale*	Horti-silvi-pastoral systems	Hill slopes, poor and eroded soils
Neem	*Azadirachta indica*	Intercropping, wasteland planting and avenue plantations	Arid and semi-arid regions, calcareous soils
Tanki	*Bauhinia variegata*	Field boundaries, shelterbelts	Coastal areas, field margins
Sissoo	*Dalbergia sissoo*	Silvo-pastoral, windbreaks and ravine reclamation	Ravines, degraded farmland, nutrient-poor soils
Giliricidia	*Gliricidia maculata*	Borders, wasteland improvement	Wastelands, garden edges, degraded roadside strips

(source: Acharya and Kafle, 2009)

A silvo-pasture system based on Anjan (*Cenchrus ciliaris*) and bamboo (*D. strictus*) grass has been created to increase the productivity of ravines. More than 80% of rainwater can be absorbed by this system, which also reduces soil and nutrient losses by 90% and 70%, respectively, showing strong potential for restoring degraded ravine ecosystems. (Jinger et al., 2023).

2.3. Biodiversity and ecosystem recovery

Agroforestry supports the restoration of degraded ecosystems by providing habitat and corridors for wildlife, increasing plant and microbial diversity and re-establishing ecological functions. In participatory agroforestry programs, species richness increases by introducing indigenous and multipurpose trees, shrubs and understory crops. For example, in the Madhupur Sal forest, 31 native plant species were successfully restored (Islam et al., 2024). Farmer-Managed Natural Regeneration (FMNR) in Niger has restored 5 million hectares of degraded land, increasing crop yields and tree cover (Reij et al., 2009). Agroforestry mimics natural forest structure and functions, thus playing a significant role in restoring biodiversity in fragmented and degraded landscapes.

2.4. Carbon sequestration and climate resilience

Trees in agroforestry systems act as carbon sinks, storing carbon in biomass and soil. They enhance carbon sequestration from 1.80 to 3.50 Mg C ha^{-1} $year^{-1}$ and reduce soil loss and runoff by 94% and 78% in Northeast India (Jinger et al., 2023). Agroforestry also improves climate resilience by reducing vulnerability to extreme weather, regulating temperature and diversifying income and food sources. These systems mitigate land degradation by stabilizing land surfaces and increasing vegetation cover. In the Indira Gandhi Nahar Pariyojna (IGNP) area of Jaisalmer, double-row shelterbelts of *Dalbergia sissoo* (15–20 years old, 8–10 m tall) effectively moderate the microclimate and protect crops from wind hazards (Jinger et al., 2023).

2.5. Socio-economic benefits

Agroforestry generates multiple products like timber, fruits, fodder, fuelwood, medicinal plants and non-timber forest products thus offering economic diversification. Integrated land use lowers dependence on a single crop or livelihood source, improving household resilience. In Nepal, agroforestry improved farm productivity and food security while restoring degraded land (Acharya and Kafle, 2009). Silvopastoral systems in Colombia and Brazil have rehabilitated overgrazed pastures, improving soil quality and livestock productivity (FAO, 2013).

In the Garhwal Himalaya, integrating water harvesting with agroforestry improved the system's input-output ratio by 1.97, compared to 0.86 in the non-irrigated system. It recovered investment within three years (Maikhuri et al., 1997). These models highlight the viability of agroforestry for both ecological and economic sustainability, especially in marginalized rural communities.

4. Government Efforts to Arrest Land Degradation through Agroforestry in India

4.1. National agroforestry policy (2014)

The National Agroforestry Policy, 2014 was formulated to ensure convergence among agroforestry-related programmes and schemes of the Government of India. It promotes the adoption of tree-based systems to meet the growing demand for timber and non-timber forest products, enhance tree cover, conserve the environment and mitigate climate change (Jinger et al., 2023). The policy has laid a strong foundation for integrating agroforestry into national initiatives to rehabilitate degraded lands.

In north-western India, particularly Punjab, Haryana and western Uttar Pradesh, poplar- and eucalyptus-based agroforestry systems expanded rapidly under this supportive policy framework. These systems enhanced tree cover outside forests, diversified farm income through timber and pulpwood production, reduced pressure on natural forests and improved land-use efficiency while protecting soil from wind erosion.

4.2. National mission on agroforestry (NMAF)/ sub-mission on agroforestry (SMAF)

To operationalize the National Agroforestry Policy, the Government launched SMAF in 2016 as part of the National Mission for Sustainable Agriculture. It provides financial support for tree planting on farmlands, including degraded and marginal lands, with an emphasis on high-quality planting material and nursery development. The mission promotes cluster-based agroforestry models suited to local agro-climatic conditions. It also ensures convergence with schemes like watershed development and MGNREGA, making it a key instrument for combating land degradation.

The NMAF aims to support about 1.8 lakh farmers and

cover 7.5 lakh hectares by promoting agroforestry with help from local authorities, farmer group and NGOs. By 2024 it has also trained 25,268 people (35% women) and supports state agroforestry policies under the Trees outside forest in India (TOFI) initiative. (Naik et al., 2025)

4.3. National mission for sustainable agriculture (NMSA)

The National Mission for Sustainable Agriculture (NMSA), under the National Action Plan on Climate Change, promotes agroforestry for conserving soil and moisture in degraded drylands. Tree litter improves organic matter and nutrient cycling, while its integration into climate-resilient agriculture enhances soil moisture, builds soil carbon and strengthens the resilience of rainfed systems.

4.4. Green India mission (GIM)

Launched in 2010, the Green India Mission initially aimed to expand forest and tree cover and restore degraded ecosystems. In its revised framework, it adopts a broader landscape approach covering both forest and non-forest lands, with agroforestry and social forestry as key strategies for restoration, carbon sequestration and livelihood improvement.

The Mission has been implemented in states such as Madhya Pradesh, Odisha, Uttarakhand, Andhra Pradesh, Chhattisgarh, Himachal Pradesh, Kerala, Maharashtra, Manipur, Mizoram, Nagaland, Punjab, Sikkim and Jammu & Kashmir. Its activities include plantations, natural regeneration and livelihood-based restoration across landscapes. By 2023–24, it supported plantations over 1,55,130 hectares, contributing to vegetation recovery and ecological restoration in degraded areas.

4.5. Compensatory afforestation fund management and planning authority (CAMPA)

Funds under CAMPA are used for large-scale afforestation and agroforestry to compensate for forest land diverted for development. A major share supports plantations on degraded and marginal lands outside forests. Agroforestry models under CAMPA help restore tree cover, control erosion, enhance carbon sequestration and support livelihoods, with species like Casuarina and Acacia showing potential to convert marginal lands into productive systems.

In coastal Tamil Nadu and other dryland peninsular regions, CAMPA-supported plantations of Casuarina and Acacia on degraded lands have stabilized sandy soils, reduced erosion and increased biomass cover in underutilized landscapes.

4.6. Watershed development programmes and MGNREGA

Watershed development projects and the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) programme have been effectively linked with agroforestry interventions to restore degraded lands. Trees are planted on farm bunds, community pastures and degraded commons as part of soil and water conservation measures. These efforts not only reduce erosion and enhance groundwater recharge but also provide rural employment through plantation activities. These programmes have supported groundwater recharge while generating rural employment through plantation activities.

4.7. National bamboo mission (NBM)

The National Bamboo Mission promotes bamboo-based agroforestry on degraded and marginal lands. Bamboo plays a critical role in soil stabilization, erosion control and moisture conservation, while also supplying raw material for industries such as paper, furniture and handicrafts. By integrating bamboo cultivation into farming systems, the mission enhances both ecological and economic resilience of degraded areas. It has become an important initiative in rehabilitating wastelands while simultaneously contributing to rural income and employment. The mission has helped restore degraded lands through soil stabilization, erosion control and moisture conservation.

4.8. Tree outside forests in India (TOFI) programme (2022)

Recently, the Ministry of Environment, Forest and Climate Change, in collaboration with USAID, launched the Trees Outside Forests in India (TOFI) programme to expand tree planting on farmlands, community areas and degraded non-forest lands. It targets increasing tree cover on 2.8 million hectares, with agroforestry as a key component for land restoration and climate mitigation.

Implemented in states like Odisha, Tamil Nadu and Rajasthan, it supports planning, species selection, nursery development and farmer participation, leading to improved tree cover, climate resilience, carbon sequestration and productivity of degraded lands.

4.9. Greening and restoration of wasteland with agroforestry (GROW)

GROW, launched by NITI Aayog in 2024, is a report and geospatial portal that supports agroforestry-based restoration of wastelands in India. Using remote sensing, GIS and a district-level Agroforestry Suitability Index via the Bhuvan portal, it helps identify suitable areas for

agroforestry, improving planning and effectiveness of degraded land reclamation while contributing to India's restoration and carbon sink targets.

5. Challenges and Knowledge Gaps

• **Land tenure insecurity**

o Unclear or insecure land ownership discourages long-term investments in tree planting

o Common in community lands and tribal regions

• **Long Gestation Period**

o Trees require several years to generate economic returns

o Farmers prefer short-term income crops, limiting adoption

• **Farmer Acceptance and Awareness**

o Lack of awareness about benefits and management practices

o Resistance due to traditional monocropping practices

• **Weak policies and institutional gaps**: Poor land-use policies and limited institutional support hinder integration into national restoration agendas.

o Complex regulations on tree harvesting and transport

o Poor coordination among government agencies

• **Technical knowledge gaps**: Lack of extension support, quality planting materials and species selection and management training.

• **Insufficient research**: Limited region-specific studies on tree–crop compatibility and system performance reduce confidence in adoption.

• **Economic constraints**: High initial costs, delayed returns and weak markets for agroforestry products deter resource-poor farmers.

• **Monitoring and evaluation gaps**: Lack of reliable frameworks prevents evidence-based scaling of successful models.

• **Social resistance**: Traditional practices and low community engagement slow the adoption of new systems.

• Most of the agroforestry practices developed in India were primarily focused on obtaining the environmental and reclamation benefits and secondly, getting the economic benefits, which was one of the main reasons for farmers' low adoption of agroforestry (Jinger et al., 2023).

6. Conclusion

Agroforestry is a sustainable approach to reclaim degraded lands by integrating trees with crops and livestock, offering ecological and economic benefits. Successful applications across ecosystems, from Bangladesh's Sal forests to the Indian Himalayas, demonstrate its adaptability in restoring productivity and improving livelihoods. However, challenges such as land tenure insecurity, limited technical support sand weak market access hinder its potential. With supportive policies, community participation and investment in research, agroforestry can significantly advance land restoration and rural development.

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