P-ISSN: 2618-0723
E-ISSN: 2618-0731

NAAS Rating: 5.04
www.extensionjournal.com

International Journal of Agriculture Extension and Social Development

Volume 8; Issue 1; January 2025; Page No. 414-419

Received: 05-10-2024
Accepted: 13-11-2024

Indexed Journal
Peer Reviewed Journal

Agroforestry is a vital necessity for India right now

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DOI: https://doi.org/10.33545/26180723.2025.v8.i1g.1560

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Abstract

Agroforestry systems hold significant potential for sustainable land use management in India, especially in the context of addressing soil erosion, improving soil health, mitigating greenhouse gas emissions, and fostering resilient agricultural systems. The world's population has been rapidly increasing, putting additional strain on land. Agricultural intensification and farm consolidation have resulted in significant standardization of farming techniques and agro-diversity during the last few decades. As a result, a diverse agroforestry system has arisen to provide resilience under limited water conditions while also increasing production and profitability. Agroforestry is thought to be a significant tool and future of global land use for improving rural people's livelihoods, safeguarding ecosystems, and assuring food security through sustainable ways. It can be understood as a one of the best dynamic, ecologically sound structure for natural resource management involving the integration of tree species on farms in agricultural landscapes. This contributes to the diversification and sustainability of production, boosting economic, environmental, and social advantages. Cultivating trees and agricultural crops in close proximity to one another is an ancient method employed by farmers all over the world. The increasing interest in agroforestry, particularly in rainfed regions, underscores its potential as an ecologically-based natural resource management approach. By integrating trees with agricultural and rangeland systems, agroforestry promotes multifunctional benefits—social, economic, and environmental—making it a cornerstone for sustainable development. This system provides solutions to the mounting pressures of land degradation, food insecurity, and climate change, offering a promising means to meet the growing demands for food, fuel, fodder, and timber. Agroforestry not only enhances productivity by creating favorable microclimates for both trees and understory crops but also supports biodiversity conservation and ecological balance. The integration of agroforestry systems such as agri-silviculture, silvopastoral, and agri-silvopastoral further enhances ecosystem services while promoting sustainable land management practices. In the face of escalating resource demands and environmental challenges, agroforestry presents an innovative solution that optimizes the use of land, agriculture, forests, and grasslands, contributing significantly to both ecological restoration and food security.

Keywords: Agroforestry, sustainable land use, soil health, climate resilience, resource management, ecosystem services

Introduction

Agroforestry, as the term implies, is a practice that integrates agriculture and forestry by growing trees or shrubs alongside crops. This combination fosters a more biodiverse, productive, and sustainable land-use system. The rapid growth of the global population has intensified the pressure on land resources. In recent decades, agricultural intensification and farm consolidation have led to the standardization of farming methods and a decline in agro-diversity. This has paved the way for the development of diverse agroforestry systems, which offer resilience under water scarcity while boosting production and profitability. Agroforestry is increasingly recognized as a vital tool for enhancing rural livelihoods, protecting ecosystems, and ensuring food security through sustainable practices. It represents a dynamic and ecologically sound approach to natural resource management, integrating tree species into agricultural landscapes. This practice promotes production diversification and sustainability, offering economic, environmental, and social benefits [Kumar *et al*., 2024] [5].

Historically, farmers across the world have practiced the co-cultivation of trees and crops, and this remains a common practice in many regions. Agroforestry is practiced globally and is critical for mitigating climate change impacts. In India, land degradation and deforestation threaten long-term food security, sustainable development, and peace. Environmental degradation in key regions has contributed to decades of social unrest and conflict. Despite its potential, many developing countries, including India, have not prioritized agroforestry due to gaps in knowledge, economics, information, and technology.

Agroforestry is practiced all over the world, and it is critical for mitigating the effects of climate change. Land degradation and deforestation jeopardize India's long-term food security, sustainable development, and peace chances. The substantial deterioration of environmental services in various major sections of the country is one of the root causes of decades of social struggle and violence. However, due to a lack of knowledge, economics, information and technology, many developing nations like India, do not give it appropriate and effective attention and neglect to practice. Adopting a long-term strategy for addressing food poverty necessitates more sustainable farming techniques. Crop failure is becoming more common in monoculture farming

systems due to increasing weather anomalies. Specialized crop production methods, in which a small number of seasonal crops occupy huge arable areas, result in increased biotic and abiotic pressures in the agro-ecosystem. Addressing food insecurity requires a shift toward sustainable farming techniques. Monoculture farming systems, which dominate large areas of arable land, are increasingly vulnerable to crop failure due to climate anomalies. Such systems exert significant biotic and abiotic pressures on the agro-ecosystem. Climate change exacerbates the impacts of droughts, floods, and pest outbreaks, and farmers' ability to adapt to these challenges will determine their ability to sustain their livelihoods. Agroforestry offers various adaptation strategies, improving agricultural landscapes through carbon sequestration, wood energy, enhanced soil fertility, and better local climatic conditions.

The advantages of agroforestry are well-documented: it helps alleviate poverty among farmers by increasing the production of wood and other tree products for both home use and sale. Additionally, agroforestry enhances food security by restoring soil fertility, thereby improving the productivity of food crops. This holistic approach not only supports agricultural yields but also promotes environmental sustainability. It also plays a crucial role in reducing deforestation and stabilizing soil against erosion. An appropriate mix of tree and crop species can enhance the resilience of agricultural land, enabling it to withstand extreme weather events such as floods and droughts, as well as the broader impacts of climate change. Thus, agroforestry can be confidently regarded as a vital tool for building resilience among farmers and rural communities in the face of climate change and natural disasters. This integrated approach not only protects ecosystems but also supports the livelihoods of those who depend on the land.

For India, agroforestry represents a crucial alternative for achieving the ambitious goal of increasing forest and tree cover to 33% from the current level of less than 25%, as outlined in the National Forest Policy of 1988. Successful examples of agroforestry practices can be found among farmers, such as those in Bareilly district, Uttar Pradesh, where cultivating Eucalyptus and Poplar alongside traditional crops led to net profits increasing by 2.5 to 3 times over seven years. However, such instances remain sporadic. Despite its potential to address climate change, enhance food security, and improve rural livelihoods, many farmers remain hesitant to adopt agroforestry for various reasons, including lack of knowledge, access to resources, and perceived risks. Addressing these barriers is essential for promoting wider adoption of this sustainable land-use system.

Finally, the long-awaited development of a National Agroforestry Policy is underway. The Indian Council of Agricultural Research (ICAR) is actively discussing its scope and has begun compiling data from various regions across the country to support this policy initiative. This effort aims to provide a structured framework that encourages the adoption of agroforestry practices, ensuring they are tailored to the diverse ecological and socio-economic contexts of India. By establishing this policy, the government hopes to enhance the benefits of agroforestry for farmers, the environment, and the economy as a whole.

India is situated in a region recognized as the cradle of agroforestry, having been a pioneer in the scientific advancements related to this practice. The time has come to develop this sector for income and employment generation, as agroforestry is uniquely positioned to drive sustained growth of 4% in Indian agriculture. It offers a viable solution for optimizing farm productivity, particularly as landholding sizes continue to shrink. By embracing and promoting agroforestry, India can enhance both agricultural resilience and economic opportunities for rural communities.

Why We Need Agroforestry

The increasing population will significantly raise the demand for household wood products, paper, packaging materials, and firewood. Relying solely on forests to meet this growing demand is not feasible; thus, private agroforestry has become essential. Currently, India's per capita consumption of paper and paperboard is less than 10 kg, compared to 72 kg in China. Additionally, timber productivity in India stands at only 0.7 cubic meters per hectare per year, while the global average is 2.1 cubic meters per hectare per year. With forests covering only 69 million hectares—19.5% of the country's area—the availability of forest land per person in India is among the lowest globally, at just 0.08 hectares. This is significantly less than the average of 0.5 hectares for developing countries and 0.64 hectares worldwide. The demand for timber was 85 million cubic meters in 2008, and it is expected to exceed 153 million cubic meters by 2020. However, the projected supply of wood from forests is only around 60 million cubic meters by that same year. This disparity indicates that India will need to rely on imports or, alternatively, develop agroforestry on private and community lands to meet its growing wood requirements. Embracing agroforestry can provide a sustainable solution to fulfill these demands while enhancing rural livelihoods and conserving the environment.

In the face of increased cultivation costs, labor shortages, and rising farm wages, many farmers are shifting towards less investment and labor-intensive practices, such as short-term commercial crops and forestry plantations. Agroforestry systems tend to be predominantly practiced by larger farmers who have alternative sources of income beyond agriculture. For small farmers, relying solely on agroforestry can be challenging, as they require annual returns to sustain their livelihoods. However, some small farmers have begun to adopt agroforestry by intercropping food crops between tree rows for the first one to two years, until the trees mature. This approach not only provides immediate food security but also contributes to wood security in the long term. Such practices highlight the potential for agroforestry to enhance both agricultural productivity and sustainability, benefiting smallholders and fostering resilience in rural communities.

Leucaena and Eucalyptus trees are widely cultivated in Andhra Pradesh, providing farmers with a reliable source of income. The yield from each acre typically ranges from 25 to 30 tonnes every four years, as these trees are harvested at that interval. The wood is primarily used in the paper industry, as well as for plywood, particle boards, and wood veneer. Additionally, waste wood is utilized in biomass

power generation plants as a substitute for coal and other fossil fuels, helping to reduce greenhouse gas emissions. Many progressive farmers are increasingly inclined to adopt the agroforestry model as a means to enhance farm productivity and profitability, supporting sustainable agricultural practices while securing their livelihoods.

Carbon pool in different agroforestry system

Agroforestry systems, as a land-use practice, have the potential to reduce atmospheric carbon dioxide concentrations. Recent projections indicate that the global area under agroforestry will expand significantly in the near future, which will likely have a profound impact on the flux and long-term storage of carbon in the terrestrial biosphere (Dixon, 1995) [3]. Agroecosystems are integral to the global carbon cycle, storing approximately 12% of the world's terrestrial carbon (Smith *et al*., 1993; Dixon, 1995) [14, 3]. Carbon is accumulating in the atmosphere at a rate of 3.5 petagrams (Pg) per year (1 Pg = 10^15 grams or billion tons), with the largest share resulting from the burning of fossil fuels and the conversion of tropical forests into agricultural land (Paustian *et al*., 2000) [10]. While increased atmospheric carbon flux can lead to some positive effects, such as improved plant productivity, negative climate changes—such as rising temperatures, more frequent droughts, and floods—are often more consequential.

Agriculture, forestry, and other land uses (AFOLU) are bidirectional in their ability to absorb and release carbon dioxide. Land used under different practices, land use changes, and forestry practices (LULUCF) were responsible for 12.5% of all human-caused carbon based emissions (Tripathi *et al*., 2023) [16]. Land-use management practices, like agroforestry systems, which combine tree cultivation with agricultural crops, play a crucial role in mitigating climate change. These systems absorb excess carbon dioxide, which is then used in photosynthesis by trees. Carbon is stored in both tree biomass and soil, which not only contributes to carbon sequestration but also helps protect natural carbon sinks. Agroforestry systems improve land productivity while providing forest products on agricultural lands, further supporting sustainable land use and climate change mitigation.

India has achieved self-sufficiency in food production, and now the focus should shift toward ecological sustainability, conserving fossil fuels, and addressing the growing demand for wood driven by population growth and economic development. Agroforestry systems have the potential to sequester significant amounts of carbon, thereby helping to mitigate the risks associated with greenhouse gas emissions. Implementing agroforestry can be particularly effective on large barren lands and along farm boundaries, enhancing soil fertility and promoting water conservation. There is substantial potential for agroforestry to address various ecological issues, support biomass production, provide cattle fodder, and supply diverse outputs for industries, while also generating employment opportunities.

Key Benefits of Agroforestry

- **Food Supply:** Meet the needs of the increasing population.
- **Increased Forest Cover:** Enhance forest areas outside of traditional forest boundaries.
- **Soil Improvement:** Boost soil productivity, reduce erosion, and establish sustainable land management practices.
- **Economic Upliftment:** Improve the social and economic status of rural farmers.
- **Consistent Raw Material Supply:** Ensure a steady supply of raw materials for forest-based industries.

Agroforestry and Climate Change Mitigation and Adaptation

In India, emerging evidence suggests that agroforestry systems offer a promising land-use approach for enhancing and conserving aboveground and soil carbon (C) stocks, thereby contributing to climate change mitigation (Kumar *et al*., 2020) [6]. The average potential of agroforestry for carbon storage has been estimated at 25 tons of carbon per hectare across 96 million hectares (Sathaye and Ravindranath, 1998) [13]. This would translate to a total potential of about 2400 million tons of carbon stored through agroforestry in India. Other estimates indicate that agroforestry occupies 8.2% of the total reported geographical area (305.6 million hectares) and contributes 19.3% of the total carbon stock across various land uses (2755.5 million tons of carbon). The higher productivity potential of agroforestry systems may be attributed to the efficient capture of growth resources such as light and water, as well as enhanced soil fertility. Numerous studies conducted in different parts of India have shown that agroforestry can be more profitable for farmers compared to traditional agriculture or forestry on the same piece of land (Tokey, 1997) [15]. Recent projections indicate that the area under agroforestry in India is expected to increase significantly in the near future (NRCAF, 2006) [9]. The carbon sequestration potential of various agroforestry systems depends on the specific practices implemented. Carbon storage estimates for different agroforestry systems vary widely, ranging from 12 to 228 megagrams (Mg) of carbon per hectare in different regions of the world (Ram Newaj and S.K. Dhyani, 2008) [12].

Agroforestry plays a vital role in both mitigating and adapting to climate change through several key mechanisms:

- **Impact Reduction:** Integrating trees into agricultural systems can help diminish the effects of climate change on agriculture while also reducing agriculture's contribution to greenhouse gas emissions.
- **Forest Conservation:** Sourcing wood products from on-farm production lessens the reliance on forest trees, thereby decreasing deforestation rates, a major contributor to climate change.
- **Nutrient Management:** Improved soil nutrient management in agroforestry reduces the dependency on chemical fertilizers, which are significant sources of greenhouse gas emissions.
- **Carbon Sequestration:** Trees planted within agroforestry systems contribute to climate change mitigation by sequestering carbon dioxide from the atmosphere.
- **Carbon-Neutral Energy:** Utilizing woodfuel from agroforestry systems allows people to meet their energy needs in a carbon-neutral manner, further contributing to climate change mitigation.

- **Microclimate Regulation:** By providing shade and creating cooler environments for sensitive crops and livestock, agroforestry can help maintain or even increase agricultural yields in the face of climate change, enhancing the resilience of farming systems.

Agroforestry Promotion

India has implemented several important agroforestry promotion and plantation schemes to encourage sustainable land management, improve farm productivity, and restore degraded landscapes. Key initiatives include the National Agroforestry Policy (2014), which promotes the integration of trees into agricultural systems for ecological and economic benefits, and the Green India Mission, part of the National Action Plan on Climate Change, which focuses on increasing green cover and enhancing carbon sequestration through agroforestry. Additionally, schemes like the National Afforestation Programme (NAP) and the National Mission for a Green India (GIM) support large-scale plantation activities, including the promotion of agroforestry practices on marginal lands and the restoration of degraded ecosystems. The National Horticulture Mission and the National Bamboo Mission also encourage tree planting alongside crops for diversified income generation. These schemes offer financial incentives, technical support, and capacity-building programs to farmers, aiming to create sustainable farming systems that provide long-term environmental, social, and economic benefits.

The National Agriculture Policy (2000) highlights the importance of promoting agroforestry as a strategic solution to the challenges faced by farmers, stating, "Agriculture has become a relatively unrewarding profession due to unfavourable price regimes and low value addition, leading to farm abandonment and increasing migration from rural areas." The policy advocates for encouraging farmers to adopt agroforestry as a means of enhancing income generation, facilitated by technology, extension services, credit support, and the removal of existing constraints. Rural communities have historically practiced tree planting to fulfil household needs for fuel, timber, and medicinal plants. With the introduction of social forestry, agricultural diversification has been promoted to enhance income generation and mitigate the risks associated with conventional cropping systems. Globally, millions of households depend on the ecosystem services and resources provided by forests, underscoring the need to evaluate forest sector activities in the context of climate change mitigation, sustainable development, and community well-being. Forestry mitigation activities can be designed to complement climate change adaptation strategies, biodiversity conservation, and the advancement of sustainable development.

Scientific evidence strongly supports the capacity of agroforestry systems to improve water use efficiency by reducing unproductive components of the water balance, thereby enhancing resource sustainability. Additionally, as climate and environmental challenges intensify, there is a pressing need for innovative land-use strategies that bolster livelihood security and reduce vulnerability. Traditional resource management practices, particularly agroforestry systems, provide promising solutions to improve rural livelihoods by concurrently producing food, fodder, and firewood, while mitigating the adverse impacts of climate change. By offering multiple environmental, social, and economic benefits, agroforestry can play a crucial role in fostering both ecological sustainability and community resilience amid changing environmental conditions.

The Planning Commission of India (2001) proposed the following recommendations for promoting agroforestry:

- **Tailored Strategies:** Instead of a one-size-fits-all approach, adopt commercial agroforestry in irrigated districts, and develop a separate strategy for rainfed areas focusing on environmental security, sustainable agriculture, and food accessibility.
- **Species Selection:** Suitable species for commercial agroforestry include *Acacia nilotica*, various bamboo species, *Casuarina equisetifolia*, *Eucalyptus* species, *Populus deltoides*, and *Prosopis cineraria*, tailored to different climatic and soil conditions.
- **Tree Improvement:** Identify specific institutes for the improvement and development of clones of selected species, and encourage corporate involvement in research and development.
- **NGO Involvement:** Identify around 100 NGOs to facilitate clonal propagation of seedlings for distribution to farmers at reasonable prices, along with training in planting techniques and silvicultural practices.
- **Market Support:** Adjust export-import policies to support the marketing of agroforestry products, and establish market regulation systems to protect the interests of both producers and consumers. Implement a market information system to keep farmers informed about buyers and pricing trends.
- **Legal Framework:** Amend existing laws related to tree felling, transport, processing, and sale to facilitate agroforestry.
- **Land Coverage Goals:** Plan for commercial agroforestry in irrigated districts covering 10 million hectares, aiming to bring one million hectares under multipurpose tree species annually. Expand NABARD's schemes for farm/agroforestry with an annual investment of Rs. 100 crores.
- **Rainfed Area Focus:** Target 18 million hectares of rainfed areas for soil and water conservation through agroforestry, proposing annual afforestation of 1.8 million hectares with hardy species like Eucalyptus, Bamboo, and Babul. An estimated annual investment of Rs. 2,700 crores will be required.
- **Cooperative Development:** Establish Agroforestry Cooperative Federations in major states to enhance farmers' bargaining power in the marketing of agroforestry products.
- **Quality Assurance:** Ensure that wood-based industries supply quality planting material to farmers and establish buy-back arrangements to create a sustainable market for agroforestry products.

Issues and Challenges in Agroforestry

Although, agroforestry presents a promising approach for sustainable land use, it faces significant challenges related to knowledge, economics, land tenure, policy support, and environmental conditions. Overcoming these challenges

requires concerted efforts from governments, institutions, and communities to promote education, provide economic incentives, clarify land rights, and develop supportive policies that encourage the widespread adoption of agroforestry systems.

- **Short-Term Focus:** Agroforestry is inherently a long-term investment, but many farmers prioritize short-term, hassle-free gains, leading them to prefer horticulture over agroforestry.
- **Lack of Region-Specific Models:** There has been insufficient development of tailored agroforestry models for small, marginal, and large farmers, limiting its applicability and effectiveness across different contexts.
- **Underemphasis on Innovative Systems:** Unique and high-tech systems, such as aquaforestry, have not received the attention and promotion they deserve, which could enhance the diversity of agroforestry practices.
- **Government Ambiguity:** The governmental framework surrounding agroforestry remains unclear, with bureaucratic inefficiencies and corruption hindering effective implementation and support.
- **Limited Awareness and Education:** There is inadequate awareness and knowledge dissemination about agroforestry among farmers. Poor policy initiatives have failed to effectively promote agroforestry, and the roles of the business and development sectors in supporting these efforts have been unsatisfactory.

Challenges in Agroforestry

Lack of Knowledge and Awareness

- Farmers, especially in rural areas, often lack adequate knowledge about the benefits of agroforestry systems.
- Many farmers are unfamiliar with how to effectively integrate trees into their cropping systems, limiting the potential of agroforestry.
- Traditional farming practices are deeply rooted, and adopting agroforestry requires a shift in mindset, which necessitates education and awareness.
- Insufficient extension services and support contribute to the knowledge gap, further hindering the adoption of agroforestry.

Economic Constraints

- Agroforestry systems require significant initial investment for tree planting, management, and maintenance, which can be costly for farmers, particularly in developing countries.
- Many farmers, especially those in low-income regions, lack access to affordable credit, making it difficult to cover the upfront costs of agroforestry.
- Agroforestry yields delayed returns as trees take time to mature, adding to the economic burden, particularly compared to traditional agriculture that provides quicker financial returns.
- Limited market access for agroforestry products (e.g., timber, fruits, medicinal plants) further complicates the economic viability of agroforestry.

Land Tenure Issues

- In many rural and forested regions, land tenure systems are unclear, insecure, or complex, discouraging farmers from investing in agroforestry.
- Without guaranteed ownership or long-term rights to land, farmers may be hesitant to commit to long-term agroforestry projects that take decades to yield benefits.
- Unclear land tenure can also lead to conflicts over land use and ownership, complicating the integration of agroforestry into rural livelihoods.

Policy and Institutional Support

- Land-use, agriculture, and forestry policies are often fragmented and lack coordination, making it difficult to implement effective agroforestry systems.
- National policies may advocate for agroforestry, but their local implementation is often inconsistent or inadequate.
- There is a need for integrated policies that recognize agroforestry's role in carbon sequestration, biodiversity conservation, and rural development.
- The lack of institutional frameworks, subsidies, or technical assistance prevents agroforestry from gaining widespread adoption in many regions.

Environmental Challenges from Climate Change:

- Agroforestry systems face risks from changing weather patterns, including prolonged droughts, floods, and extreme temperatures, exacerbated by climate change.
- These unpredictable environmental conditions can affect tree growth and survival, complicating long-term planning and management in agroforestry.
- Pests and diseases can threaten agroforestry systems, as the diversification of species does not guarantee immunity to evolving environmental threats.

Conclusion

The world's population has been rapidly increasing, putting additional strain on land. Agricultural intensification and farm consolidation have resulted in significant standardization of farming techniques and agro-diversity during the last few decades. As a result, a diverse agroforestry system has arisen to provide resilience under limited water conditions while also increasing production and profitability. Agroforestry is thought to be a significant tool and future of global land use for improving rural people's livelihoods, safeguarding ecosystems, and assuring food security through sustainable ways. Agroforestry systems in India play a vital role in meeting the basic needs of rural communities. They contribute significantly to increasing overall productivity while addressing the domestic demands of farmers and the growing needs of our population for food grains, fuelwood, timber, and more. As these demands continue to rise, current availability and supply remain insufficient. With over 200 million people heavily reliant on forests for their subsistence and livelihoods, it is clear that traditional farming practices alone cannot meet these needs. Agroforestry emerges as a realistic and effective approach to not only conserve natural resources but also help achieve the goal of increasing forest

cover to 33% from the current level of 23.81%. By promoting agroforestry, we can enhance sustainability, bolster rural economies, and support the resilience of communities dependent on agriculture and forestry.

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