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Agroforestry in India: Overcoming Challenges to Build a Greener Tomorrow

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Abstract

Agroforestry is an age old concept which combines trees, crops and (or) animals. By cultivating diverse, resilient landscapes, it not only increases agricultural productivity and farmer's income but also helps to achieve food security and climate change mitigation. It enhances biodiversity, and strengthens ecosystem resilience. The present world agricultural scenario seems to be unsustainable and in future also, it is a big challenge to make it sustainable with current agricultural practices. Under such conditions, agroforestry is projected to drive positive changes for sustainable farming globally. It has potential for harmonizing economic growth with ecological responsibility. In the light of this background, we made an attempt to provide synthesized information about multiple benefits besides solutions to address some of the challenges in it's adoption.

1. Historical Background

Agroforestry (AF) is a sustainable land-use management system that combines agriculture and forestry practices to create more diverse, productive and resilient farming systems. In the system, woody perennials are grown with field crops either spatially or temporally on the same land unit. According to Nair (1979), AF is a land use system that integrates trees, crops and animals in a scientifically sound, ecologically desirable, practically feasible, and socially acceptable manner to the farmers. According to Steppler and Nair (1987), Agroforestry is the deliberate integration, in space or time, of woody perennials with herbaceous crops and/or animals on the same land management unit. In other words, it is the practice of growing trees with agricultural crops and/or livestock on the same piece of land (Anderson et al., 1991). Agroforestry can enhance farmers' income and improve overall ecosystem's health. It has both productive and protective functions. The simple agroforestry system is also more complex due to occurrence of both the ecological and economical interactions, than monocultures.

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Agroforestry *per se* is not a new concept. Since centuries, farmers have the convention of growing trees, crops and animals together and reaping multiple products for sustaining their livelihood. But, over the years, agriculture and forestry have been dealt separately for various reasons such as need for producing more food to meet the growing population, introduction of improved cultivars, expansion of irrigation facilities, marketing and policy issues etc., leading to monocropping. The agroforestry is a new name for old and existing set of farm practices. Thus, the art is very old, but, the science of agroforestry is new.

2. Agroforestry Systems in India

Following are the different agroforestry systems that are being practiced in various parts of India (Dhyani et al., 2009).

1. Agri-silviculture (Trees + crops)
2. Agri-horticulture (Fruit trees + crops)
3. Agri-silvi-horticulture (Trees + fruit trees + crops)
4. Agri-silvipasture (Trees + crops + pasture or animals)
5. Horti-pasture (Fruit trees + pasture or animals)
6. Silvi-pasture (Trees + pasture/animals)
7. Silvi-olericulture (Trees + vegetables)
8. Alley cropping (Hedges + crops)
9. Horti-olericulture (Fruit trees + vegetables)
10. Silvi or Horti-sericulture (Trees or fruit trees + sericulture)
11. Horti-apiculture (Fruit trees + honeybee)
12. Aqua-forestry (Trees + fishes)
13. Boundary plantation (Trees on boundary + crops)
14. Block plantation (block of trees + block of crops)
15. Energy plantation (Energy trees + crops during initial years)
16. Forage forestry (Forage trees + pasture)
17. Shelter-belts (Trees + crops)
18. Wind-breaks (Trees + crops)
19. Live fence (Shrubs and under- trees on boundary)
20. Homestead (Multiple combinations of trees, fruit trees, vegetables etc.).

3. Multifarious Benefits of Agroforestry

Agroforestry provides a variety of benefits as furnished in Figure 1 and are discussed hereunder.

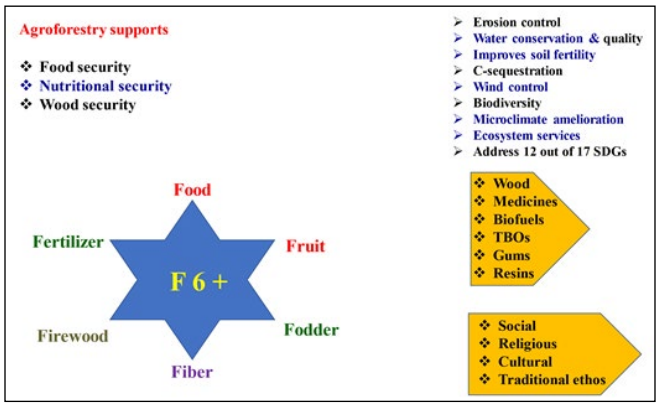

Figure 1: Benefits of Agroforestry – An Overview

3.1. Diversified products and services

Agroforestry has the potential to produce multiple products needed for the farmers, society and other stakeholders. It supplies 6Fs i.e., food, fruit, fodder, fertilizer, fuelwood, fibre besides wood, timber, medicines, gums, resins, biofuels, tree borne oilseeds (TBOs) etc., Further, AF can help in providing shade, erosion control, improving soil water conservation, soil health, carbon sequestration, biodiversity, microclimate amelioration and mitigating climate change effects thus enhances sustainable livelihoods. It also satisfies social, religious, cultural and traditional ethos. Overall, it can address 12 out of 17 sustainable development goals (SDGs) of United National Organization (UNO) to be achieved by 2030 (Figure 2). These 12 SDGs include SDG 1: No poverty; 2: Zero hunger 3: Good health and wellbeing 6: Clean water and sanitation 7: Affordable and clean energy 8: Decent work and economic growth 12: Responsible consumption and production 13: Climate action 14: Life Below water 15: Life on land 16: Peace, justice, and strong institutions 17: Partnerships for the goals.

Figure 2: Sustainable Development Goals (SDGs)

3.2. Enhanced income and insurance against crop failure

Due to presence of multiple components like tree, crop, livestock/poultry/fishery/apiculture/vermicompost etc., AF enhances or stabilizes farm net income under favourable conditions or acts as insurance against loss due to partial or complete failure of crop or any other enterprise under unfavourable climate conditions and market fluctuations. About 80% of participants in Philippines experienced medium to high income changes due to adoption of agroforestry (Bugayong, 2003). Similarly, enhancement in socio-economic, food and livelihood opportunities among agroforestry practitioners in Kerala's Attappady block within the Nilgiri Biosphere Reserve were reported (Kumar, 2006).

3.3. Enhances soil health

Agroforestry systems (AFSs) have high potential for nutrient recycling. The trees significantly add leaf litter over the time, which upon *in-situ* incorporation in soil and decomposition through microbial action in the presence of moisture enhances soil fertility. Further, above ground biomass due to regular pruning of branches/twigs/leaves and below ground biomass (roots) due to pruning following mechanical intercultivation leads to substantial amount of organic matter. The trees and shrubs bind the soil particles strongly through their deep and extensive root system thus reduce the soil erosion from wind and water. Trees act as natural wind breaks thus reduce the erosive effect of strong winds on soil loss. Further, tree canopy intercept the rainfall and reduces its direct impact on splashing of soil particles minimizing the soil erosion. Trees grown on slopy lands also protect or stabilize the soils from erosion due to strong bonding between roots and soil.

Tree roots also help improve soil structure and water infiltration, reducing runoff and enhancing groundwater recharge. Thus, AFSs protect the soil health throughout the year including lean periods due to it's closed nature as compared to that of open nature of agricultural landscapes. Hence, AFSs are self-sustaining and minimise the need for addition of synthetic fertilizers. Increase in soil organic carbon from 0.36% in monocrop systems to 0.66% in poplar-based agroforestry systems with wheat and green gram in Central Punjab, India with an increase of 2.9-4.8 Mg ha^{-1} with the tree age (Gupta et al., 2009) was reported.

3.4. Microclimate regulation

Trees provide shade, reduce the wind speed and help moderate soil and air temperature extremes, creating a more favourable environment for crops. The diversity in agroforestry systems make them more resilient to climate change impacts, such as droughts, floods, hailstorms etc.

3.5. Biodiversity conservation and pest and disease management

Agroforestry systems support diversified species, flora, fauna, microbiome etc., thus promote ecological balance and biodiversity. Diverse plantings can harbour pest eating birds, disrupt pest cycles and reduce the incidence of diseases through micro-climate amelioration. Thus, they minimize the need for chemical pesticides. According to Bhagwat et al. (2008) and Nath and Vetaas (2015), agroforestry supports biodiversity conservation by extending natural habitats, creating corridors, buffering reserves and enhancing landscape heterogeneity.

3.6. Carbon sequestration and carbon credits

Agroforestry systems act as natural sinks for CO_2 and regulate the global carbon cycle. Trees absorb CO_2 through photosynthesis, convert it into organic carbon and stores it in above (stems, branches, leaves etc.,) and below ground biomass (roots) for centuries (Terrestrial carbon sequestration) thus reduce atmospheric CO_2 in the long run contributing towards climate change mitigation. Further, this mechanism also helps farmers to gain additional income through sale of carbon credits. Agroforestry in India has an estimated carbon storage potential of 2,400 million tonnes, averaging 25 tonnes C ha^{-1} across 96 Mha. Globally, agroforestry covers 8.2% of the reported geographical area (305.6 Mha) and accounts for 19.3% of total carbon stock across land uses (2,755.5 MT C). As concluded by Kaur et al. (2017), agroforestry systems were effective in enhancing above-ground biomass (AGB) and soil carbon stocks thus mitigate climate through reduction in greenhouse gas emissions.

3.7. Market and employment opportunities

Agroforestry provide gainful employment in the form of setting up of nurseries for production and supply of quality planting material (QPM). Additionally, it also opens up new markets for non-timber forest products (NTFPs) such as honey, mushrooms, medicinal herbs etc., The study of Anonymous (2007) shown that the improved agroforestry systems could generate 943 million person-days of employment annually across 25.4 Mha.

3.8. Reduced cost of production

AFSs reduce the need for chemical fertilizers and

pesticides over the time thus lowers the input and operational costs, while enhancing the crop yields due to increased soil health. As reported by Singh and Pandey (2011), agroforestry systems involving *Acacia* and *Oryza* species accrued higher benefit:cost ratio of 21.47.

3.9. Organic farming/Natural farming

Agroforestry plays a key role in promoting organic and natural farming as it includes green leaf manures (*Glyricidia sepium*, *Leucaena leucocephala*, *Azadirachta indica*, *Pongamia pinnata* etc.,), N fixing trees (*Leuceaena leucocephala, Acacia mangium, Faidherbia albida,*

Casuarina equisetifolia, Glyricidia sepium etc.,), perennial fodder trees (*Acacia nilotica, Dalbergia sissoo, Faidherbia albida, Leucaena leucocephala, Prosopis cineraria etc.,*), livestock and it's products like dung and urine besides promoting healthy food production.

3.10. Eco-tourism

Meticulously planned and well managed agroforestry systems like multifunctional agroforestry (MFAF) can attract visitors as a part of eco-tourism and provide additional income to the growers. Studies of Singh et al. (2016) proved that leveraging existing agroforestry systems for agro-ecotourism can promote agro-biodiversity, preserve rural heritage and enhance farm income, serving as a driver for socio-economic development through active tourist engagement.

3.11. Ecosystem services

AF provides all four types of ecosystem services (ESs) needed for sustenance of life *viz.,* a. *Provisioning services* (direct benefits like food, fruits, vegetables, timber, oil etc.,); b. *Regulatory services* (basic services like carbon sequestration, air and water purification, decomposition, pollination, biological control of pests and diseases, soil erosion and flood control); c. *Cultural services* (non-material benefits like recreation, tourism, education, aesthetic and spiritual, mental and physical health); d. *Supporting services* include photosynthesis, nutrient cycling, primary production, formation of soils and the water cycle.

4. Challenges and Solutions

The challenges faced by agroforestry practitioners and solutions to overcome the same are furnished in Table 1.

Table 1: Challenges and solutions in agroforestry

Sl. No.	Particulars	Challenge	Solution/Remarks
1.	Initial investment	Establishing agroforestry systems requires upfront costs and time before benefits are realized.	Take help from forest nurseries, government subsidies, intercropping, integration of animals, carbon credits etc.,
2.	Knowledge and training	Agroforestry needs innovative thinking and planning, hence, farmers need knowledge, skills and education in managing diverse systems and selecting appropriate species for a particular zone.	Strengthen and promote agroforestry extension services to practitioners.
3.	Market access	Agroforestry products need strong marketing and they need to be traceable and trustworthy. Developing markets for new products is challenging but essential for profitability.	Formation of FPOs, planting in tune with nearby industrial needs, formation of state/location specific Consortium of Agroforestry.
4.	Quality planting material (QPM)	Lack of quality planting material (QPM) is the major constraint for it's promotion.	Establishing certified nurseries, training, seedling-care workshops, best nursery and silvicultural practices, sound seed sourcing.
5.	Competition	Trees offer competition for space, light, moisture and nutrients with intercrops thus may reduce food or fodder crop yields.	Adopt agroforestry systems developed scientifically by the scientists in a given agro-climatic zone.
6.	Host	Trees act as hosts to insect pests, birds, animals etc., which in-turn feed on food crops. This may further augment the menace of biotic stresses in organic farming which excludes use of synthetic chemicals.	Careful selection of tree species, strategic planting of pest-repellent plants or flowers (e.g., marigolds, lavender, or basil), pheromone traps, nets or mesh, pruning, spraying deterrents, regular monitoring etc.

Sl. No.	Particulars	Challenge	Solution/Remarks
7.	Laborious	Laborious to prune/lop the branches and incorporate the same in the field.	Mechanization of pruning/lopping/brashing with suitable tools/instruments.
8.	Decomposition of residue	Decomposition of tree parts i.e., leaves, small twigs, loppings is slow and may interfere with crop management.	Use of waste decomposer/Pusa decomposer/ microbial consortia can reduce the waiting period.
9.	Difficulties in harvesting	Harvesting of tree products interfere with the crop maintenance.	Mechanization of harvesting with user friendly and cost effective tools and instruments.
10.	Mechanization	Limited mechanization and severe labour scarcity.	Develop complete mechanization for ease of silvi-cultural operations, harvesting etc.
11.	Research output	Location specific scientific research output is limited.	Location specific, cost effective, profitable, climate resilient and sustainable AFSs are to be developed and promoted.
12.	Carbon credits	Though many people speak on carbon monetization, but, realization is less.	It is the fast developing area in India. Many NGOs and corporates are working on this. Awareness programmes are to be conducted for linking all AF farmers with the industry.
13.	Policy support	Lack of support for agroforestry.	Governments should support agroforestry through favourable policies, subsidies, and helping farmers transition to these systems.
14.	Community engagement	Lack of community engagement by the farmers groups.	Involving local communities in decision-making ensures that agroforestry practices meet their needs and are culturally appropriate.
15.	Problems in harvesting, transport and marketing	Inadequate policy and uncertainties in tree felling, transport and marketing regulations and rules in various zones.	Government should exempt state wise predominant agroforestry trees from felling, transit and marketing norms for ease of marketing.
16.	Cultural and social resistance	Some of the farmers resist agroforestry systems due to animal-man-crop conflicts, slow and low returns.	Awareness about multiple benefits for the farmers, environment and society is created.

5. Conclusion

Agroforestry strikes a perfect balance among sustainable development, economic benefits and environmental conservation. It contributes for food security, nutritional security and wood security while achieving climate resilience and economic prosperity through diverse ecosystems. Now, it has been recognized as a powerful and perfect tool for carbon monetization. Thus, agroforestry can transform agricultural landscapes and improve the livelihoods of multiple stakeholders to build a green India.

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