Agroforestry as a Sustainable Business Model: A Review

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***Abstract*—Agroforestry is a dynamic, ecologically based, natural resources management system that through the integration of trees on farms and in the agricultural landscape diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels. This innovative approach not only influence biodiversity and soil quality but also offers multiple income sources. As the demand for eco-friendly practices is increasing around the world, agroforestry provide us with beneficial business model that ensures profitability with environmental stewardship. This review paper delves into multiple benefits of agroforestry, emphasizing its contribution to climate change mitigation and economic upliftment of farmers. For farmers and rural residents, agroforestry is the key to success because it creates jobs and income, ensures food and nutritional security, meets other fundamental human requirements sustainably, and protects crops from the harsh effects of adverse climate. This practice not only focuses on farm income but also it works mainly towards the food security of the community. According to the review, growers in the country should be cognizant of the potential and expertise of agroforestry systems, and they should help make the cultivation of these systems feasible for global farmers in terms of both financial and environmental returns and can adopt agroforestry as a business. This review contains the introduction to agroforestry, its scope and future aspects, various business model related to agroforestry and its impact on environment. It has multiple income sources with high returns and low inputs which would help farmer to gain sustainability. Additionally, this review article contains solutions to roots of resistance which will act as catalyst for a greener.**

***Index Terms*—Agroforestry, Environmental Stewardship, Climate Change Mitigation, Food Security, Sustainability**

I. INTRODUCTION

The current world faces several challenges, including climate change, an exponentially increasing population, and the loss of biodiversity and environmental concerns which necessities the adoption of the sustainable nature-based solutions such as agroforestry. Agroforestry is becoming accepted as a land-use system that is capable of producing both food and wood while at the same time reduce forest resource user dependency as a means of livelihood thereby conserving and rehabilitating ecosystems. Enterprise in agroforestry is seen as a practice that serves as an alternative to the use and overuse of forest reserve resources. Before the Green revolution there was a food scarcity, frequent famine, low crop yields from conventional methods, and there was unable to feed the world's fast expanding population. Therefore, Green Revolution in India started in the 1950s which increased monoculture production, but it failed to suppress the issue of indigenous people's food security, which has prompted them to pursue sustainable development in order to guarantee food security (Goncalves et al., 2021). Monoculture has many setbacks as it led to nutrient depletion and soil degradation. This is due to harvesting a single crop led to depletion of vital minerals, infertile soil and increase use of artificial fertilizers. Moreover, monoculture led to biodiversity loss which causes ecological imbalance and making crops more vulnerable to pests, diseases and environmental changes these results in use of excessive pesticides which further degrades soil health and some other important species. High water consumption and soil erosion are also significant issues because monoculture crops particularly those cultivated in large-scale industrial farming frequently need heavy irrigation, which depletes water supplies

and makes the land more vulnerable to erosion. Additionally, monoculture farming is a financially as farmers become dependent on a single crop.

In order to become more robust, self-sufficient, and to protect biodiversity, traditional communities began implementing agroforestry techniques (Goncalves et al., 2021). In addition to serving as a viable land use system that aids in climate change adaptation and mitigation, agroforestry has drawn more attention due to its several functions in supplying wood and wood products for both residential and commercial usage. In India agroforestry play significant role for researchers, policymakers and others for its perceived ability to contribute economic growth, poverty alleviation and environmental quality. Today agroforestry is an important part of the 'Evergreen Revolution 'movement in the country (ICFRE, 2020). The most important idea that led to the development of agroforestry was initiated by International Development Research Centre (IDRC) of Canada. The IDRC Project Report suggested the establishment of an internal organization which would support, plan and coordinate research combining the land management systems of agriculture and forestry throughout the whole world. Hence, the International Council for Research in Agroforestry (ICRF) was established in 1977. In 1991, it was renamed the International Centre for Research in Agroforestry (ICRAF) and mandated to play a key role in collecting information, conducting research, disseminating research results and pioneering new approaches and systems (Nair, 1993). Together, the terms "agriculture" and "forestry" form the term "agroforestry." It embodies a judicious land-use system that maximizes agricultural output, biodiversity, and environmental preservation by integrating trees, crops, and cattle. Agroforestry is a dynamic, ecologically based, natural resources management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land user.

Agroforestry systems may be defined as land-use systems in which woody perennials (trees, shrubs, palms, and bamboos) are deliberately used on the same land management unit as agricultural crops (woody or annual), animals or both, in some form of spatial arrangement or temporal sequence (Huxley and van Houten, 1997). Over than 100 years, farmers made and managed agroforestry systems by nurturing trees along with crops, grazing grounds and homesteads. Agroforestry is a system that combines old knowledge with the modern science of the country and the ideas of the small thinking's and produces higher possibilities of economic returns of the goods. Climate change has a big problem, and the solution is that increase the forest and tree cover by adopting agroforestry system with increasing resilience of the cultivation system by the sole crop adopters of the farmers (Dhyani, 2014).

The purpose of agroforestry introduction in forestry and agricultural business is to utilize the available resources in a more sustainable manner to enhance targeted outcomes to the benefit of all. Agroforestry comes in different forms, it practices include a variety of land use systems; it could be forest and crops or forest and livestock or combination of both on the same land. This is in line with various organizations' initiatives on crop physiology and agronomy (Viswanath et al., 2018). In International Development Research Center (IDRC) research, integration of plantation, crop like rubble and animal, and intercropping of legumes and coconut was sustainable. Similarly, there are many small enterprises that can be done within forest reserve through its products, resources and forest activities. These enterprises are self-sustaining or can serve as a source of additional revenue for the individual. They serve as a means of livelihood to forest dwellers and helped to reduce forest illegal usage, which many people don't know about due to lack of awareness and training. They are many and are referred to as agroforestry enterprises in practice, these include Seedling production, Mushroom production, Snailry, Fishery, Fruit tree, Spices and Medicinal Plants, Honey production, Shea butter production, Grasscutter, Briquette, African locust beans among others. Creating proper awareness of it has the capacity to reduce the unemployment rate and also serve as a source of raw material for industries (Smith, 2010).

II. METHODOLOGY

The last 20 years of research paper published in the field of agroforestry were thoroughly analyzed and reviewed. These research papers were extremely

extensive and assisted to gain the important knowledge about agroforestry. The aim of this review paper having positive impacts, benefits, suggestions, economical ideas and future scope for adopting agroforestry as business model for the improvement of the socioeconomic and environmental assets sustainability.

SCOPE AND POTENTIAL TO AGROFORESTRY

Agroforestry helps the study for biodiversity conservation, production of the goods, carbon sequestration, fertility of the soil of degraded areas, generate income and socioeconomically profitable because of the direct and indirect benefits of this system significantly affect (Pandey, 2011). Agroforestry system focused on improving or developing sustainability of socio-economic return and also a sustainable form of fulfilling the landscape by the plantation of native tree species (Kittur and Bargali, 2013). The role of agroforestry was very bigger because the tree covers an important natural source for the cleaning environment and the combination of the agricultural crops helps to make more fertile soil, benefits to the plants and microorganisms of the surrounding areas. In the world, more unpredictable changes of the climate like drier, warmer, colder are reduced by the adoption of the agroforestry plantation, which reduces environmental pollution (Mccabe, 2013; Singh et al., 2021). The scope and potential of agroforestry are enviable and permit most annual crops to grow well with tree species in the same unit of field. The adoption of agroforestry system farmers can increase the agriculture diversify by the without extra used lands and helps to the soil improvement, reduces soil erosion, carbon emission, microclimate improves, ecosystem changes and improvised the equity of the genders which practicing agroforestry (Rao, 2017).

Dhyani et al., (2007) have illustrated the potential of agroforestry contribution to the sectors like fuel, wood, timber, fodder, food, fruits, livestock and bioenergy. Forest Survey of India (FSI, 2021) reports India's forest carbon stock as 7 billion ton and annual increment is only 21 million ton, which is only 1% of the NDC requirement. Today the trees cover 24% of India's land with forests (21%) and trees out of forest (TOF) 3%. The growing, young trees such as agroforestry plantations are net carbon sequester e.g. *Poplar* can sequester carbon, upto 50 t/ha at7 years rotation (Rizvi et al., 2011). *Poplar* has faster growth rate and greater carbon sequestration (8 t/ ha/ year) than even *Eucalyptus* (6 t/ ha/ year) or teak forests (2 t/ ha/ year) or Sal forests (1 t/ ha/year) (Kaul et al., 2010). This is consistent with earlier studies in north east India (Melkania, 2009) that also suggest that the *Eucalyptus* (27 MtC/ year, 40%) and Teak (21 MtC, 33%) contribute 73% of about 68 Mt C sequestration/ year in Indian forests. India's forests can only sequester 7% of India's GHG (green house gas) emissions in 2030 compared to 12% presently, assuming 9 billion ton C storage in forests with this growth trend (Singh et al., 2013).Thus the Net zero pledge needs strong agroforestry mission, to cover 26 million ha to reach the target of covering30% of India's land cover (100Mha) under trees from 70 million ha as of today (as aimed long ago), by 2030 i.e. 3 million ha/year. Thus, vigorous agroforestry mission is needed for rapid increase in tree cover as experienced during 1990s till 2000 due to the “social forestry” schemes that increased the tree cover in India from 64 to 69 million ha in just 15 years i.e. a growth of 5 million ha (Mathur et al., 2021). Slow pace growth followed after 3 million ha in 10 years. Bamboo cover grew from 9Mha to 13Mha but 65% of it is in the forest area, randonly1/3 being in TOF category, though Bamboo sequesters Carbon faster than trees (FSI, 2017)

WHY CHOOSE AGROFORESTRY AS A BUSINESS?

Multiple Income Sources

By agroforestry, farmers can earn timber, firewood and non timber products like bamboo, resin and various medicinal plants. Agroforestry provides multiple income sources by combining trees with crops as well as livestock on the same land. Additionally, Honey production can also be done through beekeeping. By diversifying income sources, Farmers ensure financial stability by agroforestry. By growing a mix of fruits, nuts, vegetables, and timber on the same land, farmers can diversify their revenue streams. This ensures continuous income even if one crop fails due to unfavorable conditions

Low input, High outputs

Higher returns can be gained by incorporating trees and shrubs with crops prove can be profitable. As additional income is reaped from diversified livelihood sources -in addition to crop income; there is also income from timber, fuelwood, and fodder. Among crops, especially vegetables yield higher

returns on an average than the standard field crops.

Assistance to environment

Agroforestry provides multiple environmental services such as controlling runoff and soil erosion, increases soil fertility by incorporation of trees and crops that biologically fixes nitrogen, rehabilitation of degraded land and mitigating land depletion, improving microclimate by protecting the crops and livestock from direct sunlight reducing wind speed and associated erosion, reducing temperature and increases humidity furthermore. It improves water infiltration and flow regulation it also conserves biodiversity by reducing rates of conversion for natural habitat, providing corridors between habitats and supporting other ecosystem services. Agroforestry systems sequester more carbon as compare to traditional cropping system moreover it also stores carbon below ground.

Market Demand

The demand for sustainable alternatives like agroforestry is being driven by growing awareness of the negative environmental effects of traditional agriculture. Agroforestry systems appeal to farmers because it improves soil fertility, protect crops from wind, restore degraded land, and conserve water. The industry is expanding as a result of government programs supporting agroforestry to fight climate change and preserve natural resources. As the world's population grows and the need for food security increases, agroforestry systems are being introduced to meet the growing need for lumber and food.

Government Support

National Agroforestry Policy was made by the Government in 2014 by recognizing the land use by its very nature to be integrative. The following measures were taken under this policy. Over 30 research centers of ICAR involved in agroforestry research which is coordinated by National Research Centre for Agroforestry (NRCAF). Opportunities are provided to farmers through governmental institutions such as Krishi Vigyan Kendra's, Trainers' Training Centers to learn agroforestry and make optimums of soil and land resources. Various short term extension courses and lectures are organized by the government to educate the farmers. National Bureau for Plant Genetics Resources (NBPGR) is emphasising on conserving and providing guidelines for germplasm exchange of agroforestry species. Agroforestry commodities are enlisted under Warehouse Development and Regulation Act 2007 (WDRA) for ensuring adoption of quality standards of the "Warehousing Manual for Operationalizing of Warehousing (Development and Regulation) Act, 2007 so as to become eligible for availing finance for harvested produce.

AGROFORESTRY BASED BUSINESS MODELS

1. Agrisilviculture: This is the most prominent system in India which is practiced in 7 agroclimatic regions. These production techniques combine the growing of crops with simultaneously raised tree crops.
2. Agri-horticulture: Practiced in six agro- climatic regions and it combines fruit trees with crops.
3. Agri-silvi-horticulture: Practiced in two agro-climatic regions it combines trees and fruit trees with crops.
4. Agri-silvi-pasture: Practiced in two agro-climatic regions. This involves the deliberate association of a woody component (trees or shrubs) with cattle on the same land area.
5. Boundary plantation: Where trees are planted on boundary of agricultural fields.
6. Block plantation: Practiced in the Eastern plateau and hills or Central plateau and hills, tree is plants in closed spacing or in compact blocks of more than 0.1 hectare on lands outside recorded forest areas.
7. Alley cropping: An agroforestry intercropping system in which crops are grown in rows between trees and shrubs. It improves soil fertility and decrease erosion.
8. Silvi-olericulture: Trees are grown with Vegetable crops.
9. Horti-pasture: This system combines horticulture (fruit tress) with pasture (fodder for livestock).
10. Horti-olericulture: This agroforestry system combines horticulture trees with vegetables crops
11. Silvi-pasture: An agroforestry system that combines livestock, forage production, and trees on the same land unit.
12. Forage forestry: Agroforestry practices that integrate forage trees with pasture.
13. Shelter-belts: Practiced in the East Coast plateau and hills and Western dry regions which integrate trees with crops.
14. Wind-breaks: Planting of trees around crops.
15. Live fence: Where shrubs and under trees form the boundary around the crops on the same land.

16. Horti-sericulture: System of Agroforestry that combines Horticulture (fruit trees) and sericulture (silkworm rearing).
17. Horti-apiculture: Combining Fruit trees with honeybees.
18. Aqua-forestry: System in which Trees are combined with fisheries.
19. Homestead: Multiple combinations of trees, fruit trees, vegetables, etc. 'There are also specialized systems such as Jhum (shifting cultivation) in Eastern Himalaya and home gardens in East coast plateau and hills, West coast plains and ghats, and Islands (fig. 1).

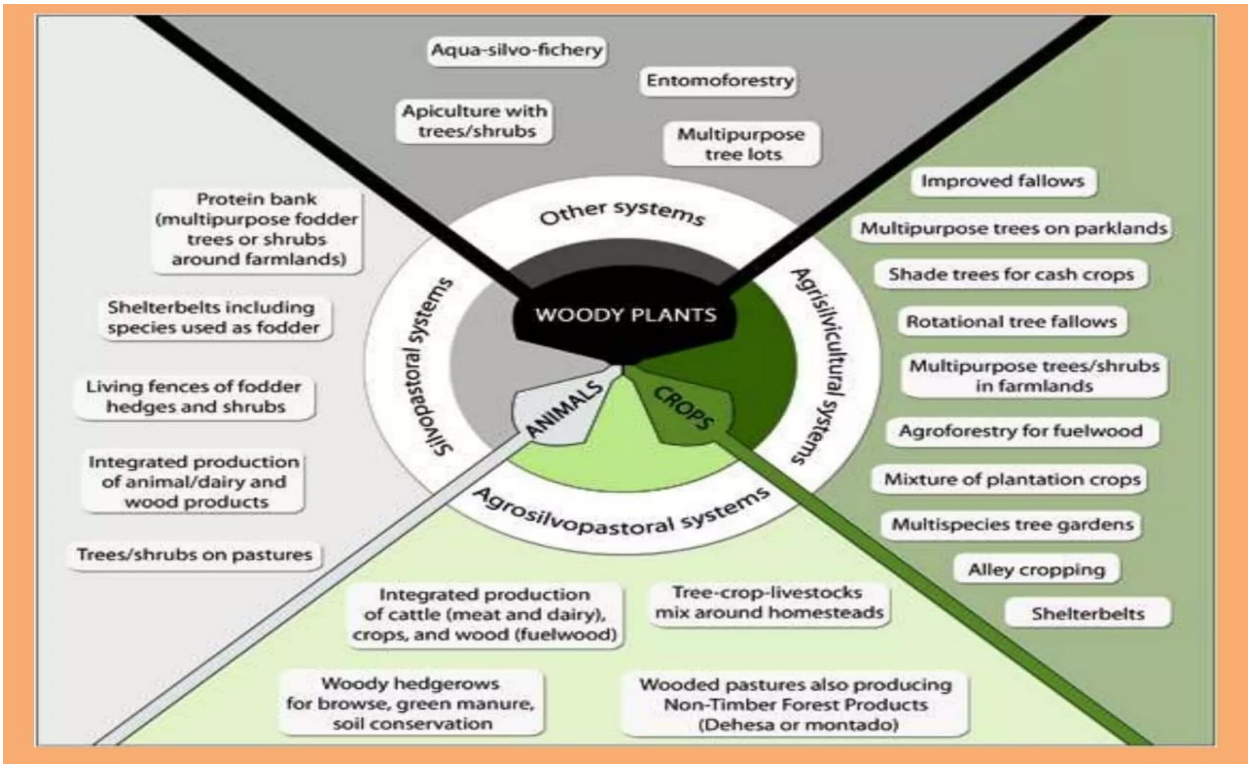

Figure1. (Introduction classification of agroforestry, Bhalawe, 2021)

FUTURE OF AGROFORESTRY

Agroforestry is bound to play a major role in future, not only for its importance in food and livelihood security, but also for its role in combating the environmental challenges because country's land area cannot be stretched (CAFRI, 2015). According to CAFRI 2015, in 2050, requirement of fodder increases by 1.5 times; food grain and fuel wood by two times; and timber by three times. Therefore, to fulfill the needs of increasing population we need to make integrated use of land. This can be achieved by adopting agroforestry and view of entrepreneurship it is the emerging field of the farmers to increase their income and as well as to meet the need of their families. Agroforestry is a reliable system and help farmers to earn their bread. A major role for agroforestry in the near future will be to give environmental service such as climate change mitigation (carbon sequestration), phytoremediation, watershed protection and biodiversity conservation. However, this will need the development of mechanism to reward the rural poor for the environmental services that they provide to society (CAFRI, 2015).

WHAT CAN BE THE ROOTS OF RESISTANCE WHILE ADOPTING AGROFORESTRY?

Despite of multiple uses, due to lack of research and education of farmers, knowledge regarding agroforestry become major constraint for adopting agroforestry. Root competition between crops and trees has been a major issue so proper tree-crop selection is needed. Unavailability of information regarding agroforestry in rural and remote areas. However, many schemes have been started by government which the farmers are unaware (Allelopathy effect-chemical interactions between

plants). Some trees releases toxic allelochemicals (e.g. *Eucalyptus* releases volatile oils) that inhibit the germination and growth of nearby crops. Continuous release of allelochemicals can led to soil toxicity, making it unsuitable for certain crops. (e.g. Pine trees release mono terpenes that can reduce plant diversity under their canopy. Likely, some allelopathic trees can harm crop growth, so careful species selection and management practices are essential for a successful agroforestry system. Technical support limitations: Inadequate technical support services to guide farmers on proper agroforestry practices can hinder successful implementation.

III. CONCLUSION

Agroforestry is profitable in most of the aspects of the farming. After reviewing many research works it can be concluded that it has far more merits than demerits. For farmers and rural residents, agroforestry is the key to success because it creates jobs and income, ensures food and nutritional security, meets other fundamental human requirements sustainably, and protects crops from the harsh effects of climate change. Agroforestry is considered as one of the emerging field for entrepreneurship as it is an eco-friendly business option. This practice not only focuses on farm income but also it works mainly towards the food security of the community. Furthermore, agroforestry systems have greater positive benefits on climate change, carbon sequestration, and water conservation than they do on profitability. According to the aforementioned assessments, agroforestry requires attention in the beginning and thereafter has positive, sustainable impacts. Agroforestry is practiced by small land holders which help them to generate more revenue. Although, agroforestry have some setbacks but they are temporary and will be overcome in couple of time by the undergoing work by researchers.

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