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AGROFORESTRY EDUCATION FOR ENSURING SELF-SUFFICIENCY, SUSTAINABLE LIVELIHOOD, GENDER EQUALITY AND SOCIAL JUSTICE : A REVIEW

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ABSTRACT

The Indian agriculture sector is faced with multiple obstacles and constraints because of increasing demographic pressure, rising demands for food, feed, pulp, fodder, fruits, and timber, leading to a depletion of natural resources, and climate change. Agroforestry stands for land management technique which integrates trees and shrubs into agricultural landscapes to improve farm production, sustainability, and environmental quality. It can also make a substantial contribution to economic growth and the reduction of poverty. The use of tree-based farming systems in a variety of environmental factors in India dates long way back. Through the complementary interaction that exists between trees and crops, agroforestry effectively utilizes the resources that are available. Maintaining fertility and production is one potential advantage of growing trees alongside annual and perennial crops. Every agroforestry system is not suitable for every site or locality. Fruit trees and other agroforestry technologies can increase farm revenue diversity and lessen food insecurity. In addition to providing fruits for household diets, farmers perform a variety of vital ecological, social, cultural, artistic, and economic tasks that support livelihoods.

Keywords: Agroforestry, Gender equality, Food/fibre/fuelwood, Industrial agroforestry, Poverty eradication, Sustainability.

Introduction

Agroforestry is a pioneering approach to land use which integrates agriculture and forestry in such a way that provides economic as well as environmental advantages. It is a holistic system of growing crops, trees, and animals on the same piece of land designed such that it replicates the structure and function of natural ecosystems (Parewa *et al.*, 2018). This practice of combining agriculture and forestry has been found to be one of the most effective ways of promoting sustainable development, particularly in the emerging economies (Kumar *et al.*, 2019). The basic principles of agroforestry are simple: to use the land and resources to their maximum extent, to minimize waste and environmental degradation, and to increase food security and income for farmers. The integration of trees into agricultural landscapes, agroforestry helps improve soil health, conserve biodiversity, minimise the effects of climate change, and make the farming communities more robust towards the environmental and economic shocks.

History of agroforestry

The origin of agroforestry dates back to ancient civilizations, where communities integrated trees with agriculture to boost the use of land and resources Pandey *et al.* (2024). In many regions of the world, conventional agricultural systems involved planting

trees alongside crops and animals, and using the trees to provide shade, fuel, food, and medicine. According to (Nair and Garrity, 2012) fishing communities in damp tropical regions from 13000–9000 B.C. were linked to the earliest types of agriculture in Southeast Asia. Around 4000 B.C., domestic animals were brought into forests for husbandry, which is when agroforestry is said to have originated in Europe. Spain's dehesa system, which allows animals to graze beneath trees, is said to be 4,500 years old (Mosquera-Losada *et al.,* 2012). These traditional agroforestry systems have existed for thousands of years and demonstrating great effective in promoting sustainable land use and food security (Dagar *et al.,* 2020). In more recent times there has been piqued interest in the field of agroforestry, particularly in the last few decades. In the 1970s and 1980s, there was an increasing acknowledgement of the need to promote sustainable land use and conserve biodiversity, and this led to an increased focus on agroforestry as a way of addressing these challenges.

Since then, agroforestry has become increasingly popular and widely recognized as a crucial tool for promotion of sustainable development. Today, agroforestry is being practiced in various parts of the world, from the temperate regions of world, tropical regions of Africa and South America. It is supported by a growing body of research and a growing community of practitioners, who are working together towards the promotion of adopting agroforestry as an important component of sustainable land use.

History of agroforestry in India

In India, agroforestry research has been conducted for over a century (Dhyani, 2018), dating back to ancient times, when people integrated trees with crops and animals as a means of maximizing the utilization of land and resources. In various regions of India, the conventional agricultural systems involved planting trees alongside crops and used trees to offer shade, fuel, food, and medicine. Under the emperor Ashoka (274–237 BCE), mango, jackfruit, and grapes were grown on the agri-horticultural plantation. The journey journals of Ibn Battuta (1325-1354 CE) also provide the earliest examples of fruit-based agroforestry from India (Kumar *et al.,* 2012; Kumar *et al.,* 2019). These traditional agroforestry systems have been established for millennia and have established to be highly effective for promoting sustainable land use and food security. In more recent times, agroforestry has become a subject of increased interest and research in India, particularly since the 1980s. However, when ICAR started an All India Coordinated Research Project (AICRP) on Agroforestry with 20 centres in 1983,

followed by the development of National Agroforestry Research Centres, agroforestry was included in national agriculture and forestry research agendas. Research Center on Agroforestry (NRCAF) in Jhansi, Uttar Pradesh, on May 8, 1988. As of December 1, 2014, the center has been upgraded to become the Central Agroforestry Research Institute (CAFRI). Currently, 37 AICRP centres on agroforestry spread throughout 27 State Agricultural Universities (SAUs), 9 ICAR centres, and 1 ICFRE Institute centres, which together represent all the agroclimatic zones of the country (Dhyani, 2018). This was a time of increasing awareness regarding the need to promote sustainable land use and conserve biodiversity, and this led to an increased focus on agroforestry as a way of addressing these challenges. Since then, agroforestry has become increasingly popular in India, and is now widely recognized as a critical tool for promoting sustainable development. The Indian government supports the development of agroforestry through various policy measures, including the National Agroforestry Policy of 2014, which recognizes agroforestry as a key component of sustainable land use and sets out a framework for promoting the development of agroforestry in India (Pandey *et al.,* 2024). Today, agroforestry is practiced in many parts of India, from the mountainous regions of the north to the tropical regions of the south. It is supported by a growing body of research and a growing community of practitioners, who are working together to promote the adoption of agroforestry as a crucial component of sustainable land use.

Agroforestry and its approaches

One of the primary advantages of agroforestry is its role in promoting the conservation and health of soil. Trees help prevent soil erosion, retain its moisture, and reduce the degradation of soil, which can improve crop yields and overall productivity (Pandey *et al.,* 2024). Additionally, the roots of higher trees help improve the structure of soil, increase its organic matter content, and provide a habitat for beneficial soil organisms are vital for soil health. It even plays a critical role in the conservation of biodiversity. Through creating a mosaic of different land uses and habitats, agroforestry provides a home for a number of species, ranging from large mammals to small insects. This in turn can help to maintain the ecological balance of an area, and provide food source, medicine, and other resources for local communities. Another important benefit of agroforestry is that it helps to diminish the effects of climate change (Kumar *et al.,* 2019). Trees take up carbon dioxide from the atmosphere and sequester it in their leaves, stems, and

roots, which helps reduce the levels of carbon dioxide in the atmosphere. This in turn slows down the rate of global warming and diminish the impacts of climate change on agriculture and food security as well as helps make the farming communities more robust to environmental and economic crises (Pandey and Tiwari, 2022). By providing farmers with a variety of different income streams, agroforestry can help to minimise their reliance on any single crop or product, and enhance their ability to cope with price fluctuations, droughts, and other environmental challenges. This helps improve food security, reduce poverty, and promote sustainable development. Agroforestry is a crucial tool for the promotion sustainable development, particularly in developing countries.

Agroforestry for SDGs

The Green Revolution is said to have begun during the 1950s in India which rendered more productive monocultures, however, could not address the issue of food security of individuals (Sarveswaran *et al.*, 2023). Cultivating trees with crops and animal husbandry simultaneously since ancient times, and is referred as agroforestry. Furthermore, it has also been established that the agroforestry system is a more profitable option for the farmers who are low-income; which is feasible due to being lower input costs and low maintenance requirements, along with its greater recycling rate (Jazeer *et al.*, 2018). There are 17 measurable areas and 169 targets that are established by the United Nations General Assembly, which make up the Sustainable Development Goals (SDGs), being the main output of Rio20+ and are intended to be accomplished by 2030 (Leimona and Noordwijk, 2017; Sharma *et al.*, 2022). There is great potential that agroforestry and tree-based systems hold to help achieve the Sustainable Development Goals (SDGs). It is extremely necessary to integrate land use management including forests, trees, and agricultural practices, in order to achieve the Sustainable Development Goals (SDGs) which focuses on the integration of agriculture and forestry. As an alternative technology, agroforestry requires its own policy domain and the increased integration of financial and human resources within the existing frameworks, spanning from national/global to local development planning (von Noordwijk *et al.*, 2018).

The sustainable development pathways must ensure the provision of certain basic securities, such as access to clean drinking water, sufficient amounts of nutritious food, healthy environment, reliable energy supply, protection from 'natural' disasters; SDGs 6, 2, 3, 7, 9. They must create sufficient job opportunities so as to help escape poverty by means of education (SDGs 8,1,4), at the same time allowing the expression of human identities through the reduction in inequalities, promoting a fairer balance between responsible production and consumption, safeguarding rights, and enhancing transparency and accountability in governance (SDGs 5, 10, 12, 16), while re-investing in the worlds' ecological infrastructure (SDGs 13, 14, 15), within an international framework of shared responsibility and means of implementation (SDG 17) (Noordwijk, 2020). According to the recent reports by the Agroforestry Network, certain land management systems like agroforestry can potentially achieve nine out of the 17 SDGs. There has been a comparatively higher emphasis on goals like 1 (No Poverty), 2 (Zero Hunger), 13 (Climate Action), and 15 (Life on Land) than others (Agroforestry Network 2018) (Sharma *et al.*, 2022; Goparaju *et al.*, 2020). Agroforestry is one of the most important multipurpose farming systems which plays a significant role in enhancing rural livelihoods also it is the most successful tool for eradicating rural poverty from the local to the national level when applied in the appropriate system with proper planning at all levels (Ahmad and Goparaju, 2017). In the study conducted by Wolka *et al.*, (2021) it was found the that Ethiopian HG contributes 25–85% of the household's food needs, which is greater than croplands. Similarly, to fullfil the third SDG Caballero-Serrano *et al.*, (2016) found that the in Ecuador about 91 % of farmer use home garden as a place to grow medicinal and aromatic plant in their backyard and also a played a major role in maintaining the physical, mental, and emotional well-being of older individuals during COVID-19 pandemics (Corley *et al.*, 2021). The agroforestry system such as windbreaks, shelterbelts, silvopastoral, home garden, Agri horticulture, taungya system etc. are the system which plays a crucial role in achieving the sustainable development gaols. So, agroforestry as an integrative culture and attitude, may support the development of creative collaborations to achieve the goals as promoted by SDG 17 and help establish synergies between the SDGs in multifunctional landscapes.

Agroforestry for sustainable food security

Growing awareness around the globe in recent years has demonstrated that agroforestry is more significant than previously thought in tackling the crises of food security and environmental resilience (Nair and Garrity, 2012). One of the key ways in which agroforestry contributes to food security is by increasing food availability. Agroforestry systems include a mix of food and tree crops, which can provide a more diverse and reliable source of food. For

example, agroforestry systems that integrate food crops with fruit and nut trees can provide a year-round source of food, including fresh fruits and nuts in the growing season, and dried or stored food in the non-growing season. Another important way in which agroforestry contributes to food security is by improving soil health. Trees can help conserve soil moisture, reduce erosion, and improve soil fertility, all of which are critical for growing food crops. In addition, agroforestry systems can help to conserve biodiversity, that plays crucial role in maintaining ecosystem services that support food production. Agroforestry also helps in mitigating the ill-effects of climate change, which have been affecting food security. For example, agroforestry systems aid in conserving soil moisture, reducing erosion, and improving fertility of soil, which in turn help increase the resilience of agriculture towards the impacts of climate change, such as droughts, floods, and temperature extremes.
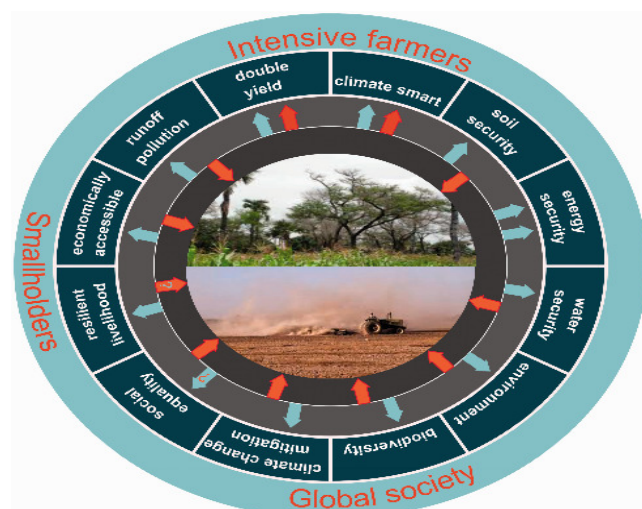

Fig. 1 : Potential of agroforestry to achieve multiple goals
(Waldron *et al.,* 2017)

Agroforestry systems such as agri-horticulture, horti-medicinal, and home-garden etc, is a powerful tool for promoting sustainable food security.

Agroforestry for fuelwood production

Trees can yield considerable amounts of fuel wood whether planted in fallows, contour strips, rotational woodlots, or strewn across cropland (Akinnifesi *et al.,* 2008). Agroforestry helps in production of fuelwood, which is a critical source of energy for many people, particularly in rural communities in developing countries. Fuelwood is utilised for cooking, heating, and lighting, and is mostly the sole energy source available in rural areas where access to electricity and other forms of energy is limited. Agroforestry systems can be designed to maximize fuelwood production while also contributing

to achieve the goal of 33 percent required tree cover (Pandey, 2023) as well as other land use objectives, such as food production, conservation of biodiversity, and carbon sequestration.

Around the world, 2.7 billion people depend on traditional fuels for cooking, like firewood, charcoal, and dung, while 1.2 billion people lack access to electricity (Sharma *et al.,* 2016). The ability of agroforestry towards its contribution to a steady and sustainable fuelwood supply is one of its main benefits for fuelwood production. Agroforestry provides nearly 72 % of the fuel wood, 2/3rd of the small timber, 70-80 % wood for plywood, 60-80 % raw material for paper and pulp, 9-11 % of the requirement of green fodder (Pandey, 2023). Rapid growth, great coppicing capacity, and high calorific value are important factors to consider when selecting suitable trees for fuel wood production in agroforestry practices. There are various important tree species which gives good fuelwood as well as improve soil quality such as *Leucaena leucocephala* (300-548 kg N ha^{-1} yr^{-1}), *Acacia nilotica* (40-100 kg N ha^{-1} yr^{-1}), *Prosopis juliflora* (30-80 kg N ha^{-1} yr^{-1}), *Albizia lebbeck* (94 kg N ha^{-1} yr^{-1}), and *Casuarina equisetifolia* (50-80 kg N ha^{-1} yr^{-1}) are notable species that fix nitrogen, with an average of roughly 60-600 kg N ha^{-1} yr^{-1} (Singh *et al.,* 2021). In agroforestry systems there are different agroforestry system which helps to maximise production of farm and provide fuelwood such as agri-silviculture, silvi-pasture, horti-silviculture, agri-horticulture, boundary plantation (Pandey, 2023). Agroforestry can help to reduce the time and effort that people must spend collecting fuelwood from natural forests, and can help to improve the energy efficiency of households, which can free up time and resources for other activities.

Agroforestry for fibre production

One of the biggest industrial sectors in the world in terms of volume is the textile industry, with demand for its products rising quickly due to rising global average income and population (Oliveira *et al.,* 2019). Agroforestry is an important tool to produce fibre, which are used for a variety of purposes, including textiles, paper, and construction materials. When compared to synthetic fibres, natural fibre yielding plants like cotton, fax, hemp, jute, sisal, banana, coir, and bamboo have several advantages. One of the key advantages of agroforestry for fibre production is that it can help to ensure a sustained and reliable supply of fibres. Research conducted in China by Wang *et al.,* (2016) reported that in a cotton (*Gossypium hirsutum*) and jujube trees (*Zizyphus jujube*) based agroforestry system may boost yield and revenue, particularly during the initial years of tree plantations. The barks of

some tree species, such as *Pilostigma* species, *Anona Seneglensis*, and *Adansonia digitata*, are used to produce fibres, whereas the edible leaves and fibre of rural farmers come from trees like *Adansonia digitata* and *Moringa oleifera* (Gideon *et al.,* 2013).

In addition, agroforestry systems have helped great deal to reduce pressure on natural forests, which are major source of fibres, but are also threatened by over-harvesting and deforestation. Another advantage of agroforestry for fibre production is that it can help to improve the livelihoods of rural communities. By providing a source of fibres, agroforestry can help to support local economies and provide employment opportunities, particularly in rural areas where other sources of income may be limited. Agroforestry systems can be designed to include fast-growing tree species that can be harvested for fibre; along with other benefits, such as shade for crops and habitat for biodiversity. Overall, agroforestry is an important tool for fibre production, and has the potential to play a critical role in promoting sustainable land use and supporting local economies.

Agroforestry for sustainable fodder production

An approach to deal with the delicate and unstable state of food security in the smallholder sector is to increase livestock productivity (Akinnifesi *et al.,* 2008). Agroforestry is a crucial tool for the production of animal feed or fodder, which is essential for the health and productivity of livestock, and is a critical component of food security in many rural communities. The integration of trees with crops and/or livestock in agroforestry systems help support the production of fodder while also promoting sustainable land use and conservation of natural resources. During the lean season, trees and shrubs in hilly and semi-arid locations frequently provide significant amounts of leaf fodder by tree lopping and trimming, a practice known as "top feed (Handa *et al.,* 2016). Tree fodder banks can serve as protein banks so as to reduce the need of purchased concentrate feed, for year-round fodder production, or to bridge fodder scarcity during the annual dry season (Raj *et al.,* 2023).

One of the key advantages of agroforestry for fodder production is that it can help to ensure a sustainable and reliable supply of feed for livestock. Agroforestry systems can help to conserve and enhance the resources that support feed production, such as soil, water, and the biological diversity. In addition, they also help reduce pressure on natural pastures, which are often a major source of feed for livestock, but are also threatened by over-grazing and degradation. *Prosopis cineraria, Albizzia lebbeck, Acacia spp.,*

Leucaena leucocephala, Dalbergia sissoo, Ailanthus excelsa, Azadiracta indica, and Acacia leucophoela are the most significant top feed species for desert and semi-arid environments, whereas *Gehwia optiva, Morus alba*, and *Celtis australis* are the most significant top feed species for hilly areas (Handa *et al.,* 2016).

Agroforestry can help improve the livelihoods of rural communities by increasing the productivity and health of livestock, through production of food and fodder for livestock which are important sources of food, income, and cultural value in many rural communities. By providing a source of feed, agroforestry can help to support the growth and productivity of livestock, which can lead to enhanced food security and economic opportunities. Agroforestry systems can be designed to maximize fodder production while also supporting other land use objectives, such as food production, conservation of biodiversity, and carbon sequestration. Agroforestry systems can be designed to include fast-growing tree species that can be harvested for feed along with the provision of other benefits, like shade for crops and habitat for wildlife.

Agroforestry for carbon sequestration

Agroforestry occupies a leading place for mitigation of climate change through the sequestration of carbon from the atmosphere and its storage in the soil and vegetation (Montagnini and Nair, 2004; Albrecht and Kandji, 2003). Agroforestry has the capacity to store carbon through diversity in plant species, making it a valuable source of carbon sequestration. With proper design and management, it can be made into a more effective carbon sink (Pandey, 2023). Carbon sequestration is one such method of reducing the amount of greenhouse gases that are released into the atmosphere through the burning of fossil fuels and other human-caused activities (Kumar *et al.,* 2019). Trees play a critical role in carbon sequestration by taking in carbon dioxide by the process of photosynthesis and storing it in the wood, leaves, and roots. In semiarid, sub-humid, humid, and temperate environments, the average amount of carbon sequestered by these techniques has been calculated to be 9, 21, 50, and 63 Mg C ha^{-1}. It has been discovered that in tropical regions, small-scale agroforestry systems can store up to 1.5 to 3.5 Mg C ha^{-1}yr^{-1}, making them a feasible option for storing carbon (Roshetko *et al.,* 2007; Montagnini and Nair, 2004). When trees are introduced into agroforestry systems, they help remove carbon from the atmosphere and store it in the soil, thereby reducing the amount of carbon in the atmosphere and reducing the ill-effects of

climate change (Pandey and Tiwari, 2022). The sequestered carbon is stored in standing biomass and below ground biomass as soil carbon is enhanced by root biomass in different agroforestry systems like Agri silviculture, Silvi-pastural, and Boundary plantations (Murthy *et al.,* 2013). In addition to the benefits of carbon sequestration, agroforestry systems also help reduce emissions from other sources, such as livestock and fertilizer use. By promoting growth of trees and other vegetation, agroforestry systems can help to reduce the need for other forms of land use, such as conversion of forests to agriculture, which can result in significant emissions of greenhouse gases. It may be concluded that agroforestry, can potentially play significant role in mitigating climate change through sequestering carbon and reducing emissions from other sources.

Agroforestry for reclamation of wasteland

Wastelands are areas of land that have been degraded by factors such as over-grazing, deforestation, soil erosion, and improper land use practices. These areas are often characterized by low soil fertility, low vegetation cover, and high levels of degradation. Reclaiming wastelands through agroforestry can help to restore these areas to productive and sustainable land use systems. In India, nearly 68.35 million hectares of land are currently designated as wastelands. Approximately 6.75 million hectares of India's land are classified as salinized or sodic. Nevertheless, water logging has caused 6.41 Mha of land to degrade (Dhan *et al.,* 2022). To improve soil health, degraded soils must be transformed into a restorative land use by afforestation and the implementation of site-specific RMPs. Agroforestry plays an essential role in reclaiming wastelands, through converting degraded and unproductive lands into productive and sustainable agroforestry systems. This can help to restore ecosystems, improve soil fertility, conservation of biodiversity, even support the local livelihoods. The agroforestry systems like extensive use of agri-silviculture, agri-horticulture, silvi-pasture, multipurpose woodlots, strip plantations, and boundary plants, which are based on cultural traditions could be useful for the reclamation of saline, waterlogged conditions (Saravade *et al.,* 2017). This can include planting fast-growing trees and crops (grasses) that can

improving soil fertility and water retention timber and provide fuelwood, or other products, while also. Reclaiming wastelands through agroforestry can also help to conserve biodiversity and promote ecosystem services, such as pollination, pest control, and water regulation. By integrating trees and other vegetation into agroforestry systems, these areas can provide habitat for wildlife, and help to conserve important ecosystems and biodiversity hotspots. Agroforestry is an effective tool for the reclamation of wastelands, and has the potential to conserve natural resources while also improving local livelihoods. It maximizes the use of land, and help restore degraded land and promote sustainable development.

Agroforestry in flourishing MSME's

Agroforestry plays a key role in supporting micro, small and medium-sized enterprises (MSMEs) by providing raw materials for their operations like timber, fuelwood, fibre, and non-timber forest products (NTFPs). It ensures a reliable and sustainable source of raw materials for MSMEs, helping to reduce dependence on traditional, extractive, and often unsustainable land use practices. For example, agroforestry systems can provide MSMEs with access to wood and other forest products that are traditionally sourced from natural forests, reducing the need for deforestation and promoting sustainable land use. In addition, agroforestry systems can support the production of NTFPs, such as medicinal plants, fruits, and spices, that can be used as raw materials by MSMEs. These products can be harvested from agroforestry systems, providing MSMEs with a reliable and sustainable source of raw materials that are in high demand. Agroforestry can also support MSMEs by improving the quality and quantity of raw materials available for their operations. For example, by improving soil fertility and water retention, agroforestry systems can enhance the productivity and quality of crops, while also lowering the likelihood of crop failure due to drought and other environmental stressors. In general, it may be concluded that, agroforestry holds the potential to play significant role in supporting MSMEs by providing a reliable and sustainable source of raw materials, improving the quality and quantity of raw materials available, and promoting sustainable land use practices.
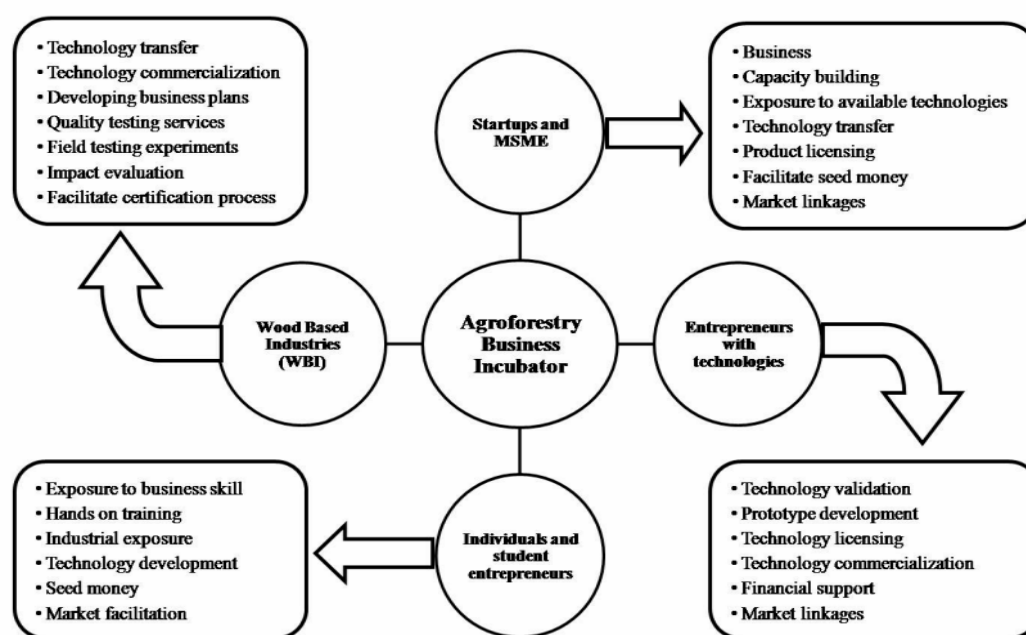
Fig. 2 : Agroforestry as business incubator (Parthiban *et al.,* 2021)

Agroforestry providing Raw Materials for Industries

Agroforestry provides important raw materials for various industries, including the wood and paper, food and beverage, and cosmetic industries, among others. Agroforestry systems provide a wide range of products and services, including timber, fuelwood, fibre, and non-timber forest products (NTFPs), that can be used as raw materials by industries. It is a reliable and sustainable source of raw materials for industries, helping to reduce dependence on traditional, extractive, and often unsustainable land use practices. For example, agroforestry systems can provide the wood and paper industry with access to wood and other forest products that are traditionally sourced from natural forests, reducing the need for deforestation and promoting sustainable land use. In addition, agroforestry systems support the production of NTFPs, such as medicinal plants, fruits, and spices, that could be used as raw materials by different industries. These products can be harvested from agroforestry systems, providing industries with a reliable and sustainable source of raw materials that are in high demand. Products made from rattan and bamboo are produced by several SSFEs. The majority of bamboo is used to make handcrafted goods including trays, lampshades, table mats, and other home items. Traditional crafts like mat and basket making that are based on reed bamboo are vital to the rural economy. Similarly, willow, cane, mulberry, maple, ash, and rosewood are the principal raw materials utilized. It can be said that, agroforestry possesses the potential to play an important role in supporting various industries through providing a reliable and sustainable source of raw materials, improving the quality and quantity of raw materials available, and promoting sustainable land use practices. The integration of trees with crops and livestock, agroforestry systems help support the local livelihoods and promote economic development, while also conserving natural resources and improving the environment.

Agroforestry for reduction in cost of cultivation

Agroforestry plays very important role in limiting the use of fertilizers through improvement of soil fertility and promotion of sustainable land use practices, by the integration of trees with crops and livestock. Several Nitrogen fixing trees of genus Leguminoceae are used for this purpose. Similarly, trees incorporated helps in nutrients recycling and optimise cost of production. Rahman *et al.,* (2007) conducted a study and found that agroforestry systems have much higher net present value (NPV) than shifting agriculture, according to the financial analysis. A similar study was conducted by Amin *et al.,* (2023) which reported that okra-forest tree-based agroforestry models offer advantages when it comes to yield, profitability, and environmental benefits as compared to okra monoculture system. The study shows that by raising the BCR of okra production, these agroforestry techniques are associated with better financial returns. According to Hanif and Bari (2013), the *M. azedarach-*based agroforestry techniques had the highest benefit-cost ratio (3.75) and financial return. Rahman *et al.,*

(2016) reported that compared to the single production technique, intercropping vegetables with multipurpose trees produced a high income.

Agroforestry for Microclimate amelioration

Agroforestry involves the incorporation of trees and crops in such a way that maximizes their benefits, such as improved food production, soil health, and increased biodiversity. One of the key ways in which it contributes to the conservation of microclimate is through providing shade, wind breaks, and moisture control. This can help to maintain more favourable growing conditions for crops, particularly during periods of extreme heat or drought. Trees can also help to regulate soil moisture levels, prevent erosion, and reduce water run-off, which can protect against soil degradation and degradation of water resources. Tree systems have the capacity to enhance the microclimatic conditions through decreasing temperature, evaporation, transpiration, and moisture absorption, in addition to functioning as a filter to provide shade from direct sunshine (Kumar, 2015). The basic idea behind agroforestry is to keep windbreaks and shelterbelts in place in dry and semiarid regions of the nation to reduce the effects of wind speed. By altering the field's weather, these are giving farmers crop insurance against extreme weather events. Shelterbelts and windbreaks provide shade from the sun while simultaneously reducing wind velocity, which raises moisture content and lowers temperature (Chavan *et al.,* 2014). Mukherjee *et al.,* (2008) found that the temperature of the air and soil decreased by 2-3°C when compared to an open, non-shaded condition, while relative humidity values rose by 3-9% in the shade. Carvalho *et al.,* (2021) reported that in unshaded area, the shaded agroforestry coffee systems encouraged enhancement of microclimate conditions. In addition, agroforestry contributes to carbon sequestration, which helps in mitigating the effects of climate change. Trees capture carbon dioxide from the atmosphere and sequester it in their biomass and soil, reducing the share of greenhouse gases in the atmosphere. Overall, agroforestry provides multiple benefits for conservation of microclimate, including improved soil health, increased biodiversity, and greater endurability to climate change. By integrating trees and crops in a complementary manner, agroforestry systems help conserve and enhance microclimate, while also providing multiple other benefits to farmers and the environment.

Agroforestry for gender equality

Agroforestry plays significant role while promoting gender equality by offering multiple benefits to both women and men. Among the sustainable developments Goals (SDGs), SDG 5 emphasises on gender equality and women empowerment, especially in food systems. Women encounter a numerous obstacles and constraints, like limited access to opportunities, technologies, financing, and other productive resources, along with weak tenure and resource rights, but they also play important roles in the food systems as producers, wage workers, processors, traders, and consumers (Njuki *et al.,* 2021). In a study Abate, (2017) reported that women managed most of the postharvest processing, cooking, grinding, fetching, barn cleaning, milk processing, fuelwood gathering and caring for newborn cattle as well as they also worked together with men to weeding, harvesting, threshing, and safeguarding of crops from wildlife. Women are recognized as the primary knowledge bearers and overseers of customary household gardens. Additionally, they account for roughly 60% of those who engage in cutting-edge agro-forestry techniques including cultivating native fruit trees and manufacturing dairy feed (Catacutan and Naz, 2015). Agroforestry increases farm productivity and income, providing benefits to both men and women who are involved in agriculture. Women can benefit from agroforestry through increased access to income-generating activities, such as the sale of tree products and other non-timber forest products. Place *et al.,* (2004) found that in western Kenya, women used biomass transfer methods and improved fallows more than man did, who used fertilizer more frequently. Because low input costs are paired with substantial returns, women farmers find low-cost agroforestry technology appealing for restoring soil fertility. Women are frequently active in the marketing of agroforestry products, especially those like native fruits, spices, and vegetables that are viewed as belonging to women and children (Kiptot and Franjel, 2012). Kanmegne *et al.* (2007) found that 93% of retailers in Cameroon's *G. africanum* trade were female whereas only few men were involved in dominated in wholesale trading. In many societies, women have limited access to land ownership. Agroforestry practices can help to promote gender equality by giving women more control over land and resources, and providing them with a secure source of livelihood. Lambrecht and Mahrt, (2019) found an advantageous relationship between women's ownership of assets and their involvement in northern Ghanaian agricultural groups. De Pinto *et al.,* (2020) found that when women have more involvement in constructive household decision-making, households in Bangladesh have higher diversity of crops. By participating in agroforestry practices and decision-making, women

can gain confidence, knowledge, and skills that can empower them in other areas of their lives. This can help to break down gender-based barriers and promote gender equality. According to Diiro *et al.,* (2018), higher agricultural productivity in Kenya is linked to the enhancement of empowerment of women, particularly their involvement in community leadership. Agroforestry practices also help improve the health and well-being through providing a cleaner and safer environment, which can reduce the burden of disease for both women and men. For example, agroforestry can help in the prevention of soil erosion and its degradation, which would in turn, improve the quality of water and reduce the risk of waterborne diseases.

Table 1: Use of tree products by gender in Western Kenya.

Percentage of farmers using products						
Gender	Timber	Poles/posts	Fuel wood	Fodder	Charcoal	Stakes
MA	26.7	35.5	15.8	14.9	20.1	8.2
FA	1.7	5.0	57.4	11.7	15.0	7.4
MC	5.8	12.5	9.1	7.4	8.4	4.1
FC	0.0	2.5	24.1	4.9	5.8	4.1
% of HH	27.5	37.5	59.2	18.3	23.3	10.8

Source: **Kiptot and Franzel, (2011)**
MA=Male Adult, MC=Male Child, FA=Female Adult. F=Female Child

Agroforestry for eradication of poverty

Agroforestry has the capacity to play significant role in eradicating poverty through offering multiple benefits to rural communities. In agroforestry system trees with crops and livestock, can increase farm productivity and income, providing benefits to both small-scale farmers and rural communities. Through selling tree products and other non-timber forest products, a source of additional income can be provided, particularly to the poor and marginalized groups who may have limited access to other income-generating activities. Agroforestry also improves food security through providing source of food and nutrition, both for consumption in households and for sale. This can be particularly important for poor and marginalized communities who may face food shortages and malnutrition. In a study Raj and Chandravanshi, (2016) found that in agri-horticulture model that integrates horticultural trees (Aonla) and field crops (gram and groundnut) with several input/output parameters for economic analysis, showing a 1.09 B:C ratio. According to Abtew (2014) in the arid areas of Ethiopia and Sudan, the income from gum and resin accounts for 14% to 23% of the household income of small-scale farmers. In agroforestry system, crop and tree combination plays a significant role in the productivity of system along with revenue generation and gives many directs and indirect benefits to the farmer to combat with poverty and livelihood crises.

Conclusion

Agroforestry is a land management system that incorporates trees with crops and livestock in a manner which ensures food security and encourage sustainable land management of land use, thereby playing a leading role in converting degraded and unproductive land into productive and sustainable agroforestry systems. It has proven to be a novel technique of climate change mitigation through the sequestration of carbon from the atmosphere and its storage in the soil and vegetation. The use of various agroforestry systems even helps enhance the microclimatic conditions as the tree systems help decrease temperature, evaporation, transpiration, and moisture absorption, in addition to functioning as a filter to provide shade from direct sunshine. AFS can assist in the restoration of ecosystems, improvement in soil fertility, conservation of biodiversity, and supporting the local livelihoods. One can count on it as an important factor for reduction in fertilizer use by incorporating trees with crops and livestock, thereby improving the fertility of soil and promoting sustainable land use practices. Agroforestry plays a key role in assisting the micro, small and medium-sized enterprises (MSMEs) through providing raw materials for their operations. The incorporation of trees with crops and livestock provides a large number of goods and services, which includes timber, fuelwood, fibre, and non-timber forest products (NTFPs), that can be used as raw materials by industries. Agroforestry has proven to be a crucial tool for promoting sustainable development, particularly in developing countries, and help conserve biodiversity, which has a crucial role to play in maintaining ecosystem services which support food production. It has been a saviour for many rural families by providing a means of livelihood to several families, thereby helping eradicate poverty.

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