Available online at www.agrifarming.org

DOI: http://dx.doi.org/10.18782/2582-7146.243

ISSN: 2582 – 7146

Curr. Rese. Agri. Far. (2024) *5*(1), 29-55

Current Research in Agriculture and Farming

Review Article

Peer-Reviewed, Refereed, Open Access Journal

A Review of the Ecological and Socioeconomic Benefits of Agroforestry Systems

Muhammad Ahmad[1*], Hira Khan[2], Abdul Manan[3], Muhammad Zaid Abdullah[4]

[1]Department of Agronomy, University of Agriculture, Faisalabad, Pakistan

[2]Department of Agronomy, University of Punjab, Lahore, Pakistan

[3]Department of Plant Pathology, University of Agriculture, Faisalabad, Pakistan

[4]Department of Forestry, University of Agriculture, Faisalabad, Pakistan

*Corresponding Author E-mail: ahmad391ch@gmail.com

Received: 19.12.2023 | Revised: 17.02.2024 | Accepted: 24.02.2024

ABSTRACT

Agroforestry is the kind of land use that integrates trees with crops and livestock for the attainment of sustainable solutions to global environment-socioeconomic challenges. This review covers the different benefits of agroforestry in improving soil health, enhancing biodiversity, and capturing carbon to mitigate the impact of climate change. Integrating trees into agricultural landscapes will maintain soils, reduce greenhouse gas emissions, enhance efficient nutrient cycling, and increase resilience and productivity in agriculture. It reduces water and air pollution and offers diversified income streams with more produce to farmers, and provides natural control against pests and diseases. Case studies indicate that agroforestry is adaptable to different climatic and soil conditions and is quite viable for both developed and developing countries. Successful implementation will require supportive policy, technical knowledge, and stakeholder commitment. Future research should be aimed at the optimization of species combinations and enhancement of economic attractiveness, and the development of frameworks that evaluate ecosystem services. This review offers a contribution to communicating information on policy, practice, and research to policy-makers, practitioners, and the community of researchers working on the promotion of agroforestry as a broader sustainable land management strategy.

Keywords: *Agroforestry, Forestry, Biodiversity, Climate Change.*

INTRODUCTION

Agroforestry is a multipurpose land use model that resembles farming but also involves animals and trees. Agroforestry systems capitalize on the interconnections between crops, trees, and livestock interactions that are usually overlooked. Numerous advantages of agroforestry have been shown, including resistance to global warming, improved water and air quality, control over natural diseases and insects, soil management, biodiversity conservation, and effective nutrient cycling (Rao et al., 1997, Mateo-Sagasta et al., 2017, Smith et al., 2013a, & Khan et al., 2021).

Cite this article: Ahmad, M., Khan, H., Manan, A., & Abdullah, M. Z. (2025). A Review of the Ecological and Socioeconomic Benefits of Agroforestry Systems, *Curr. Rese. Agri. Far.* *5*(1), 29-55. doi: http://dx.doi.org/10.18782/2582-7146.243

In the emerging world, this kind of land management is not new, it has existed since at least medieval times, and it is likely far older in other civilizations (Steppler & Nair, 1987). Agroforestry has a long history. About a thousand years ago, people began the practice of burning land and then cultivating it. The term "slash-and-burn" cultivation method has since been coined. But John Benny and his colleagues first used the word "agroforestry" in 1977 while doing a study for the Canadian International Development Research Centre (IDRC). The creation of the International Council for Research in Agroforestry, or ICRAF, was made possible by this study. Around the world financing and academic studies on agroforestry were made possible to a major extent by ICRAF. The Council's name was changed to the International Centre for Research in Agroforestry in 1991. ICRAF was awarded the title of "World Agroforestry" in 2002, reflecting its worldwide role in agroforestry studies and advancements. These days, ICRAF seeks to create new technology and introduce them to farmers (King, 1987, & Mondal et al., 2023).

The agriculture industry in industrialized countries faces several challenges concurrently and will continue to do so. Presently, land utilization and farming (LU) contribute to 15–30% of greenhouse gas (GHG) emissions (Gerber et al., 2013, Tubiello et al., 2013, Vermeulen et al., 2012, & Wirsenius et al., 2011) However, they are also among the select few sectors that efficiently store carbon. Additionally, the main cause of the decline in biodiversity in agriculture (Dudley & Alexander, 2017). The issue of feeding a growing global population and meeting the need for renewable energy coincides with the stresses that global warming is placing on agricultural productivity, for example, via unpredictable rainfall trends or increased chance of harsh climate conditions (Kurukulasuriya & Rosenthal, 2003). Agroforestry (AF) is one land use system (LUS) that has presented potential to address these intricate and interconnected challenges. It can integrate significant generation of biomass (Graves et al., 2010) with soil preservation, storage of carbon, a decrease in nutritional losses, and a reduction in water contamination (Nair, 2011, & Nair et al., 2010). Low wind velocity also results in decreased evapotranspiration and loss of soil, which is another benefit of agroforestry (AF) (Kanzler et al., 2019, & Smith et al., 2013b). Moreover, agroforestry promotes biodiversity by giving animals habitat and food, maintaining ecosystem interaction, and lowering the use of pesticides, particularly for nectar gatherers (Bentrup et al., 2019, Graham & Nassauer, 2019, Nair et al., 2010, Smith et al., 2013b, & Varah et al., 2020).

Even though agroforestry has several environmental advantages, many farmers place a high value on financial sustainability when making decisions (Beer and Theuvsen, 2020, & Tsonkova et al., 2018). Furthermore, financial incentives are a simpler way to handle this issue than they are in intricate social settings. Agroforestry systems (AFS) studies are not well-synthesised. Unfortunately, a small number of evaluations are accessible, and those that are typically out of date (Bandolin & Fisher, 1991, Garrett et al., 1991, & Herzog, 1997), fail to address economic outcomes (Smith et al., 2013b) or are simply not available in English, making them unavailable to a significant portion of the research population (Langenberg & Theuvsen, 2018).

2. Ecological Benefits of Agroforestry Systems

2.1 Enhancing Biodiversity and Habitat Creation:

Agroforestry is essential to both the preservation of threatened species and for lowering the rate of decline of species in agricultural environments (Mosquera-Losada et al., 2009, Torralba et al., 2016, & Udawatta et al., 2019). As an element of the EU Biodiversity Strategy for 2030, safeguarding biodiversity is one of the targets for Europe 2030 in creating a 'resource-efficient' Europe. It supports a number of services that enhance the welfare of people, including the production of fiber and food along with regulating and cultural services. However, the Mediterranean, particularly to agroecosystems, is seen to be an area of greatest biodiversity where there has been a particularly sharp decline in species (Palacin & Alonso, 2018), (Rosas-Ramos et al., 2019). Thus, considering its relevance for supporting the best agri-environment initiatives and for ongoing environment planning, it is crucial to understand how agroforestry affects trends in biodiversity (Ansell et al., 2016, & Pavlis et al., 2016). Agroforestry may improve habitat and landscape variability, enhance the complexity of structures, and aid in the preservation of species in agricultural and forest settings (Torralba et al., 2016, Boinot et al., 2019, & Haggar et al., 2019). However, our capacity to forecast the possible effects of agroforestry growth on services provided by ecosystems and biodiversity is restricted due to our inadequate knowledge of the interconnected impacts of agroforestry micro-habitats on biodiversity dynamics (Boinot et al., 2019, Santos et al., 2019, & Richard et al., 2020).

The Habitat Amount Hypothesis (HAH), which was created recently, provides insight into trends in biodiversity and preservation methods for agricultural landscape biodiversity (Fahrig, 2021, Melo et al., 2017, & Watling et al., 2020). According to the HAH, a habitat site's variety of species, appearance, and richness (henceforth referred to as "diversity") are solely dependent on how much of that habitat is present in the "local landscape," which is defined as the region that surrounds the location (impact of scale) (Watling et al., 2020). Despite criticism from some writers who believed that theories like "Spatial Configuration" or "Island Effect" were more useful in characterizing and controlling diversification in agricultural landscapes (Hanski, 2015, Evju & Sverdrup-Thygeson, 2016, & Haddad et al., 2017), recent studies indicate that HAH is actually supplementary to these theories and may even help to combine them (Bueno & Peres, 2019, Watling et al., 2020, Fahrig, 2021, &Saura, 2021). In fact, (Saura, 2021) proposed that the majority of the debate may have arisen from a misreading of the HAH, i.e., that the arrangement of the habitat and landscape is crucial for the distribution of HAH biodiversity. Furthermore, as the original research pointed out, HAH is not the only variable that determines variation, other elements like the kind of organisms against the kind of habitat, the proper dimension to investigate, and the caliber of the habitat array should be taken into account (Fahrig, 2013).

2.2 Improved Soil Health and Fertility:

According to the crop type, temperature, and location, agroforestry may have varying impacts on soil quality via variations in ecological services and functions triggered by both the immediate and subsequent impacts of plants. Due to their long roots, which act as a "safety net" from depletion of nutrients from the cycle of nutrients, trees are essential to the cycling of nutrients because they pump and retrieve nutrients that have been leached **(Figure 1).** In tree-based systems, trees also aid in moisture absorption and absorb atmospheric nutrients (Schroth & Burkhard, 2002). With the increasing intensity of agriculture and the excessive application of fertilizers and intensive tillage, there is an opportunity to keep and collect carbon in the soil through agroforestry (Chatterjee et al., 2018). The practical and structural variety of the elements obtained in a multiple-cropping canopy makes agroforestry a more efficient use of resources than single-crop farming (Hailu Gebru, 2015).

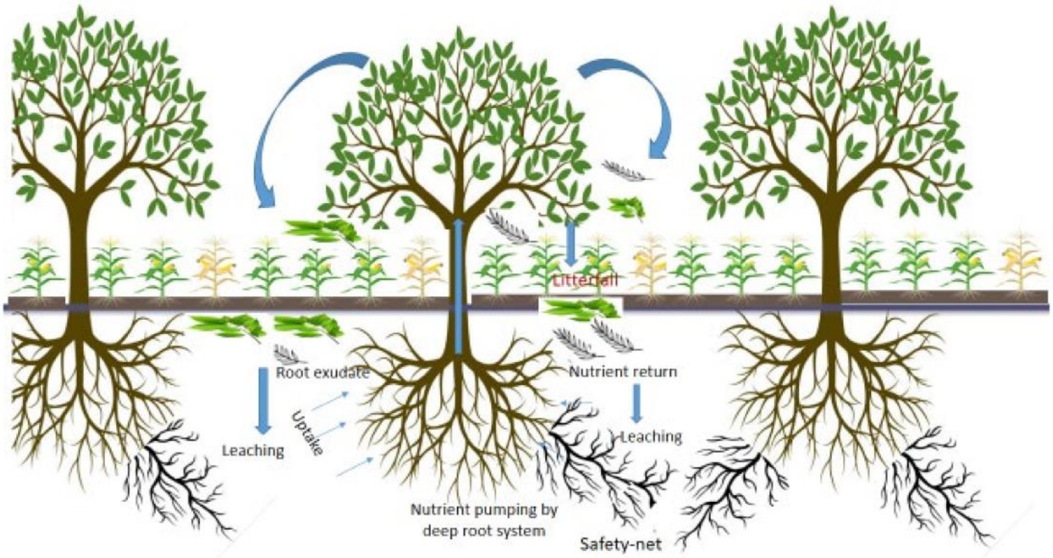

Figure 1 Nutrient circulation and redistribution in an agroforestry system through the creation of a 'safety net'. From the paper of (Fahad et al., 2022)

Incorporating trees into agricultural fields boosts field capacity (FC) and organic matter (OM) (Chatterjee et al., 2018), enhances available potassium, phosphorus, and soil carbon stocks (Abbasi Surki et al., 2020), and decreases bulk density (BD) (Hailu Gebru, 2015). These improvements increase water retention by raising the water holding capacity (WHC), which gradually releases water to plants similarly to a sponge (Schroth & Burkhard, 2002). An essential part of soil consolidation and large quantities of density of soil decline is the addition of organic matter (OM).

This reduced soil BD enhances air movement, water distribution within the roots, groundwater replenishment, and soil quality of nutrition in dry and semi-arid areas (Abbasi Surki et al., 2020). The primary nutritional supply and organic carbon (OC) in agroforestry systems is the buildup of litter from the dropping of buds and leaves. Both environmentally and economically, the soil organic carbon (SOC) affects how efficiently nutrients are used in farming. Since soil having a substantial amount of organic matter and a vigorous deep root structure will absorb and make more nutrients available, the efficiency of using those nutrients will be improved (Sönmez et al., 2016). Furthermore, the incorporation of OM is likely to have enhanced diversity of microbes (Lacombe et al., 2009), which in turn produces mycorrhizae that release P and make it available to crops (Lorenz & Lal, 2014).

The integration of trees alongside crop farming influences the microbial populations present in the soil, as well as the physical and chemical properties of the soil. The community of microbes in the soil ultimately stimulates plant development by improving nutrients and efficiency. The soil microbial community, which is important for increasing production and nutrition, indirectly affects plant growth (Li et al., 2020). The survival and growth of plants, as well as the cycling of nutrients, are greatly influenced by soil microorganisms, especially microbes. When agroforestry systems are contrasted with monocropping, the soil has a greater number of varied and functioning soil bacteria. In these situations, it is anticipated that this will lead to improved organic soil fertility. Agroforestry systems have greater rates of microbial growth and diversity because of the depositing of organic matter, the effect of trees, excrement from roots, quantity levels, and a variety of litter quality. Earthworms, fungi, acari, diplopoda, nematodes, and other insects affect the cycling of nutrients and the conversion of carbon to oxygen. Ants, termites, and earthworms are examples of soil engineers who are crucial for gravel development and soil structure maintenance. Important for biological control include centipedes, ground or rove beetles, predatory mites, collembola, and carnivorous nematodes (Marsden et al., 2020).

One of the main ecological problems is soil erosion, which also has an adverse effect on plant nutrition and development, nutrient weathering and fertility, soil form and texture changes, and the sustainbility of biological and agricultural ecosystems. Precipitation is the primary climatic element controlling sediment movement and soil deterioration (Béliveau et al., 2017, & Cao et al., 2020). Different agroforestry practices handled in different parts of the earth may help restore the natural world and generate revenue by reducing discharge and avoiding soil destruction to some extent. By leveling slopes, the use of such tree-based techniques in dryland settings may maximize agricultural production (Montagnini & Metzel, 2017). The implementation of agroforestry is a crucial strategy to lessen soil deterioration since these systems may help hold onto soils and their nutrients while mitigating the impacts of variable rainfall (Béliveau et al., 2017).

2.3 Mitigation and Adaptation to Climate Change:

In 2019, the worldwide mean level of carbon dioxide was 409.8 ppm (with a possible error margin of ±0.1 ppm) (Lindsey, 2020). The primary cause of this increase is the combustion of fossil fuels. (Lee & Cheong, 2018) Research has demonstrated a positive correlation between CO2 levels and temperature. Based on (Plass, 1956) CO2 theory, a doubling of atmospheric CO2 concentration results in a 3.6 °C increase in ground temperature, while halving the CO2 quantity leads to a 3.8 °C decrease in surface temperature. Callendar's analysis also revealed that rising carbon dioxide levels led to rising temperatures at a pace of 0.003 °C (Callendar, 1938) Callendar's analysis also revealed that rising carbon dioxide levels led to rising temperatures at a pace of 0.003 °C. The greater amount of CO2 will retain more heat and raise the temperature as a result. Controlling the CO2 content is necessary to maintain the thermal budget equilibrium. The agroforestry system, which stores carbon in the soil and biomass via the process of photosynthesis is among the most effective approaches for controlling greenhouse gas emissions.

As part of the adaptation strategy for climate change, less heat-trapping greenhouse gas (GHG) is released into the environment of the Earth. This may be achieved by either increasing carbon storage facilities or decreasing GHG producers. It makes sound financial sense to act during or after an international financial crisis, given the dangers and expenses of doing nothing. A progressive approach would be less costly and more cost-effective than delaying reducing objectives, which would just delay the unavoidable and likely need higher cutbacks later. It is necessary that such steps be performed at the lowest feasible cost, given the scale of emission reduction necessary to prevent global warming by balancing greenhouse gas (GHG) quantities at a specific level (OECD, 2009). A more economical approach for minimizing the impacts of climate change is agroforestry. Because AFS can gather and use growth resources (light, water, and nutrients) more efficiently than single cropping systems, it has a better potential for sequestering carbon (Nair, 2010). According to (Sahoo et al., 2021) carbon was eliminated from all sources when agroforestry was converted to agriculture. One such environmentally friendly strategy for raising agricultural output and performance is agroforestry. In addition to providing services for supply (food, fuelwood, and fiber), it offers ecological services as well (carbon preservation, nutrient exchange, erosion management, and social and recreation benefits) (Fagerholm et al., 2016). Agroforestry is essential to long-term growth and reducing the effects of global warming. Limiting the release of greenhouse gases while preserving ecosystems, protecting the current forests, and creating new plantations may also provide cash from logging and provide jobs both on and off the farm (Sharma et al., 2016b). Temperatures are lowered and climatic conditions are controlled by the biomass generated in the AFS (Monteith et al., 1991).

2.4 Pest and Disease Control:

An estimated 20–40% of crops worldwide are destroyed due to disease (Savary et al., 2012), while 37% of agricultural yields in the USA are wasted due to pests (Pimentel et al., 1992). In addition, it is anticipated that disease and pest outbreaks will rise in the future (Frison et al., 2011). Using synthetic pesticides on plants is the foundation of many modern pest management strategies, especially in wealthy nations. In 2008, 480 million pounds of insecticides cost USD 11 billion in the USA alone (Fernandez-Cornejo et al., 2009). Comparably, exotic plant diseases in the USA are thought to be responsible for USD 21 billion in agricultural losses annually as a result of harmed crops (Rossman, 2009). However, chemical control of pests and diseases is not a long-term solution from an environmental or economic perspective. Agricultural practices that support natural predators of pests present a more environmentally friendly and cost-effective alternative, as they can minimize crop loss without the harmful ecological impacts of pesticides (Chaplin-Kramer et al., 2011, & Bianchi et al., 2006). In reality, the United States spent USD 13 billion a year on biological enemies for pest management (Losey & Vaughan, 2006). Annual crops had no effect by agroforestry interventions, whereas perennial crops showed reduced insect population and injury to plants in a meta-analysis by (Pumariño et al., 2015), The impacts of tree shading were mainly blamed for this, while other research also linked it to the more complex AFS terrain (Bianchi et al., 2006, & Stamps & Linit, 1997). Apart from trees, physical obstacles such as hedges, border plantings, and windbreaks are also created, particularly in cases where pests or diseases are dispersed by air (Ratnadass et al., 2012, & Sileshi et al., 2008). Many studies demonstrate that AFS, especially those that have a considerable variety of crops, often have greater biological enemy populations (Letourneau et al., 2011, & Smith et al., 2013b) and more conflict between pests and non-pest organisms (Stamps & Linit, 1997, & Smith et al., 2013b). Besides minimizing pests, Agroforestry Systems (AFS) have been demonstrated to lessen the ecological impact of pesticides. AFS reduces the discharge of pesticides, and the microbial communities within these systems are capable of breaking down pesticides (Wilson & Lovell, 2016). (Chaplin-Kramer et al., 2011) discovered that in contrast to monocultures, insect populations and injury to plants did not correlate with landscape complexity, such as AFS. Additionally, some research indicates that AFS has fewer pests and less crop harm (Letourneau et al., 2011). But there isn't much data, in a single meta-analysis, for instance, more than 80% of the publications focused on only two kinds of crops (Pumariño et al., 2015). To better understand how various AFS affect pests, especially in temperate zones, more varied study is needed (Martin-Chave et al., 2019). Additionally, it was suggested by (Iverson et al., 2014) that effective AFS supervision is necessary to create a "win-win" relationship between crop yield and biological control, this is something that is not sufficiently taken into consideration in most research. (Smith et al., 2013b) proposed that effective agroforestry system (AFS) management could include strategies such as supplying food sources for adult parasitoids, creating locations for mating, egg-laying, and resting, ensuring host plants are distributed intermittently to make it harder for insects to find them, employing "trap-crop" species to shield additional crops from herbivorous organism attacks, and incorporating trees that repel herbivores (Smith et al., 2013b). (Stamps & Linit, 1997) and (Iverson et al., 2014) concurred that a reduction in the host plant apparency might be advantageous for controlling pests. Studies examining the impact of AFS on disease of plants have been conducted substantially less often than those examining pests of plants, despite data suggesting that agroforestry decreased plant diseases considerably (Pumariño et al., 2015, & Ratnadass et al., 2012). Only two publications out of the 40 included in a meta-analysis by (Pumariño et al., 2015), on the impact of AFS on diseases and pests, dealt with diseases of plants, and both of those studies were for tropical AFS (Beule et al., 2019) agreed that there aren't enough data on how AFS affects disease control, especially in temperate zones. Similar to controlling pests, controlling AFS properly is crucial for preventing sickness. (Beule et al., 2019) propose that plant pathogens may be suppressed using numerous AFS diversification techniques. Crop rotation, intercropping, planting a variety of crop kinds, and alley cropping are a few of them. (Tilman et al., 2002) verified this viewpoint, arguing that since current intensive agroecosystems have been simplified too much, they are more susceptible to crop loss from diseases and pests (Tilman et al., 2002). Similar to managing pests, decreasing the density of host crops may lower the frequency of diseases of crops, especially those caused by sprayed- and soil-dispersed pathogens. When opposing organisms reduce diseases, soil microbiology may have a beneficial effect (Ratnadass et al., 2012, & Beule et al., 2019). Furthermore, decreased wind velocity and microclimatic effects brought on by increased tree density might lessen the spread of infections. Additionally, studies in temperate AFS showed that tree shade decreased the prevalence of diseases and pests while improving disease resistance (Ratnadass et al., 2012, & Artru et al., 2017). Nevertheless, (Schroth et al., 2000) discovered in a study of tropical AFS that the degree of disease and pest assaults in such systems differs depending on the kind of pest or disease and its environmental needs.

Table 1: Summary of Ecological Benefits of Agroforestry Systems

Aspect	Key Points
Biodiversity and Habitat Creation	* Essential for preserving threatened species and reducing species decline * Supports the EU's Biodiversity Strategy for 2030 * Crucial for understanding how agroforestry affects biodiversity trends * May improve habitat and landscape variability, enhance structural complexity, and aid in species preservation * Limited knowledge on how agroforestry micro-habitats impact biodiversity dynamics.
Improved Soil Health and Fertility	* Varies depending on crop type, temperature, and location * Trees play a vital role in nutrient cycling due to their deep roots * Helps retain and store carbon in the soil * Increases field capacity, organic matter, available potassium, phosphorus, and soil carbon stocks * Reduces bulk density * Improves water retention * Enhances microbial diversity and reduces soil erosion.
Mitigation and Adaptation to Climate Change	* Stores carbon in the soil and biomass * Lowers greenhouse gas emissions * More efficient than single cropping systems for sequestering carbon * Reduces temperatures and controls climatic conditions
Pest and Disease Control	* Creates a more complex habitat that disrupts pest life cycles * Provides habitat for natural enemies of pests * Reduces reliance on synthetic pesticides * May decrease plant diseases * Effective management is crucial for maximizing benefits.

3. Socioeconomic Benefits of Agroforestry Systems

3.1 Increased Agricultural Productivity:

(Mead & Willey, 1980) introduced the notion of the land equivalent ratio (LER), which can be described as the sum of the comparative yields of different species in a mix compared to the yields of a monoculture (van der Werf et al., 2021). According to (Malézieux et al., 2009), it is the most often used metric for evaluating yield in the form of biomass or other outputs. It is also an effective way to evaluate the production system when thinking about converting traditional agricultural land to AFS (Lovell et al., 2018). Several studies have revealed indications of increased production in agroforestry systems. In Denmark, the land equivalent ratio (LER) for systems combining food and energy production ranged from 1.14 to 1.34. According to (Xu et al., 2019), agroforestry provided agricultural and tree production that needed 14–34% less area or resources in terms of sunlight, nutrients, and water than single cropping. This is a major benefit that opens up opportunities for sustainable intensification to increase output while lowering input requirements. Five agroforestry systems with different crop, tree, and grass varieties were examined in recent research in various pedo-climatic areas along with management techniques. The LER values of these systems varied from 1.36 to 2.00, indicating better production in a variety of AFS (Lehmann et al., 2020).

Similarly, silvoarable agroforestry systems at Europe's oldest and best-documented agroforestry research area have LER values between 1.3 and 1.6 (Lovell et al., 2018). Modeling has been utilized in other research to assess the efficiency of various agricultural systems. The yields of crops and wood produced in a silvoarable system were calculated to need 1.28 hectares of distinct forests and arable systems spread over 30 years (García de Jalón et al., 2018). (Sereke et al., 2015) examined 14 distinct agroforestry techniques and found that, on average, the AFS was more efficient than either arable systems or separate forestry (12 of the 14 alternatives, land equivalent ratio = 0.95–1.30). Farmers, who believe that AFS is unproductive and hence not financially feasible, are disproved by several studies showing the increased productivity of AFS (Sereke et al., 2015). This perspective is echoed in several other studies evaluating farmers' perceptions of obstacles to the implementation of AFS, where farmers often express anxiety about the risk to their finances (Smith et al., 2012, García de Jalón et al., 2018, Trozzo et al., 2014, & Rois-Díaz et al., 2018). With population growth and changing consumption patterns driving up food demand, high-yielding agroforestry is a viable means of contributing to yield increases that will meet the demand for a significant rise in food production by 2050 (Hall et al., 2017).

3.2 Enhanced Income Opportunities for Farmers:

The way that agroforestry incorporates plants that resemble trees into the system sets it apart from other methods of managing land. Implementing this kind of tree-based farming may strengthen financial resilience by diversifying products, according to economic concepts (Amare et al., 2019). In particular, using multifunctional trees may improve the economic feasibility of agroforestry since they may provide a range of benefits, such as food (wild edible fruits), fodder, or additional income streams when resources are few for rural populations (Gebru et al., 2019). In addition, certain trees with greater financial importance may bring in more money for the community than just the money from the yearly harvests. For example, studies on Indonesian teak-agroforestry (Tectona grandis) systems, regardless of their quicker recycling (due to a slowing development season), may yield up to 12% of total family income (Roshetko et al., 2013). Agroforestry may also lead to a higher benefit-to-cost relation. Cultivating trees and shrubs that need little input (chemical fertilizers, insecticides, etc.) is one method that may reduce the cost of cultivation and increase farmers' revenue (do Carmo Martinelli et al., 2019, Maia et al., 2021). The outcome may be greatly influenced by the farmers' proficiency with the method, particularly in selecting the finest trees and plants for their system. Certain trees may thrive when grown alongside crops that complement them. In contrast, improper crop or tree component selection may result in nutrient competition, which lowers productivity and, ultimately, farmer profit (Reynolds et al., 2007).

In rural regions, agroforestry adoption may provide new jobs for off-farm operations like grain drying, tree cutting, furniture manufacture, etc (ISKANDAR et al., 2016). More work opportunities for women might also benefit them since they could be involved directly in industrial processes, which would gender parity in rural communities (Kiptot et al., 2014). Furthermore, employment assimilation in rural regions might help boost the rural economy by halting the outflow of rural residents (Laudares et al., 2017), (Ollinaho & Kröger, 2021). However, industrial locations near natural forests or nature preserves should be developed with prudence since there is a chance that humans would trespass into these protected areas, which might harm the ecology (Ollinaho & Kröger, 2021).

3.3 Improved Food Security and Nutrition:

One of the largest obstacles to global food security is the need to almost quadruple food production in the years to come, mostly because of the fast increasing demand from developing nations (McGuire, 2015, Godfray et al., 2010, Kiers et al., 2008, Foresight, 2011, & Baulcombe et al., 2009). The success of genetic modification, automation, and chemical inputs in recent years (with Africa being a notable exception) has made their usage customary to attain yield improvements (Pretty & Bharucha, 2014, Foresight, 2011, & Baulcombe et al., 2009). This means that there is now general agreement that, under the broad heading of ecological growth, we must go beyond the current, limited concentration on production and toward a more "multifunctional" farming which additionally maintains (and ideally promotes) larger socioeconomic and environmental objectives (Godfray et al., 2010, Pretty & Bharucha, 2014, Foresight, 2011, & Baulcombe et al., 2009).

Agroforestry contributes to the community's increased supply of food in the vicinity of the woods. In instance, (Ickowitz et al., 2016) used geographical data to clarify micronutrient intake in Indonesian children aged one to five. At the country level, they identified a connection between agroforestry and increased use of legumes. On a regional basis, their research revealed a connection between the existence of agroforestry and higher intake of fruits and green vegetables that are high in vitamin A. Additionally, agroforestry systems were linked to increased meat consumption, especially among individuals who employed silvopastoral techniques (Ickowitz et al., 2016). Increased food availability after the introduction of agroforestry was shown by increased food yield and variety among farmers with low incomes who had participated in agroforestry training (Pratiwi & Suzuki, 2019). Agroforestry adoption and community availability of food have been positively correlated, according to studies carried out in a number of South Asian, Latin American, and Sub-Saharan African countries (Kiptot et al., 2014, Mbow et al., 2014, & Sharma et al., 2016a).

4. Biofertilizer Benefits of Agroforestry Systems

In an agroforestry system based on Ficus benghalensis, which occurs frequently in the southern dry agro-climatic region of Karnataka, the residue of trees above as well as below the soil surface is utilized as litter in agroforestry, providing various kinds of fertilizer elements when the litter decomposes. According to research, the mass decomposition of agroforestry litter based on Ficus benghalensis in a field showed a slightly greater speed of decomposition in below the surface soil after an entire year of decomposition rotation compared to surface soil. The pace at which litter decomposes has been discovered to be influenced by the local climate and soil (Dhanya et al., 2013). Likewise, in the Mandya region, the rate of decomposition of agroforestry litter was examined, and it was shown to account for approximately 60% of the overall litter fall of F. benghalensis inside the agroforestry system (Dhanya, 2011). The foundation of ecosystems, microbial biodiversity, provides humans with food, fiber, and non-timber forest products. In agroforestry, phosphate-mobilizing microorganisms, disease-preventive endophytic bacteria, and symbiotic and non-symbiotic nitrogen fixers all perform important functions. An agroforestry system may benefit from managing the composition of microbial diversity via crop and tree variation (Sridhar & Bagyaraj, 2017). The rate of litter decomposition in tropical regions of the plantation was greater than in temperate parts due to the increased sunshine requirements for this process.

Table 2: Summary of Socioeconomic Benefits of Agroforestry Systems

Aspect	Key Points
Increased Agricultural Productivity	* Values range from 1.14 to 2.00, indicating higher productivity compared to monoculture systems. * Requires 14-34% less area and resources (sunlight, nutrients, water) than traditional single cropping methods. * Various agroforestry systems show enhanced yields, supporting sustainable intensification of agriculture.
Enhanced Income Opportunities	* Multifunctional trees provide additional products like food (fruits), fodder, and timber, enhancing financial resilience. * Trees requiring fewer inputs reduce cultivation costs, increasing overall revenue for farmers. * Generates new rural employment opportunities in tree-related activities such as harvesting and processing.
Improved Food Security and Nutrition	* Higher yields and crop diversity support food security in local communities. * Agroforestry systems promote higher intake of essential nutrients through diverse crop and fruit production.
Biofertilizer Benefits	* Agroforestry systems enhance nutrient cycling through the decomposition of tree litter, which releases essential nutrients into the soil. * By relying on natural processes for nutrient cycling, agroforestry reduces the need for chemical fertilizers and pesticides. * Continuous input from decomposing litter and microbial activity improves soil structure, fertility, and resilience against erosion. * Biofertilizers contribute to sustainable agricultural practices by minimizing environmental impact compared to chemical inputs.

5. Case Studies:

Asia is the biggest and most populated continent, making up 30% of the globe's total surface and home to 60% of all people on the earth (Ortega-Castillejos, 2018). Agroforestry activities have been used throughout South and Southeast Asia for a long time under a variety of agroecological settings, earning the area the title "cradle of agroforestry" (Kumar, 2012). A study project led by (Wicke et al., 2013) investigated the potential of agroforestry systems in salt-affected soils across South Asia. The results showed that over 24 mg ha of carbon could be sequestered in the country of Bangladesh, 6 mg ha-1 in Haryana, an Indian state, and 96 mg ha-1 in Pakistan's Punjab province by these systems, which included intercropping and already-existing compact tree plantings. In Ethiopia, Africa, agroforestry practices have been shown to remove greenhouse gases and sequester between 8.34 and 43.64 Mg ha^{-1} of tree carbon, as well as 71.69 to 112.74 Mg ha^{-1} of soil carbon (Manaye et al., 2021). (Somarriba et al., 2013) examined the capacity of agroforestry in the United States to sequester carbon. Based on his research, he calculated that the carbon locking potential of various plants such as Theobroma cacao, Cordia alliodora, Bactris gasipaes, palms, bananas, etc., was around 49.2 mg ha^{-1} of tree carbon and 51.0 mg ha^{-1} of soil carbon. (Gama-Rodrigues, 2011) conducted research on the role that Brazilian agroforestry systems play in sequestering carbon. Theobroma cacao L.-based agroforestry system absorbed 302 Mg ha^{-1} of carbon in total, and it was determined that farmers might potentially benefit financially from this potential carbon sequestration. When (Kay et al., 2019b) assessed the capacity of suitable agroforestry systems to store carbon throughout the EU, he found that silvopastoral and silvoarable systems were able to do so at rates ranging from 0.09 to 7.29 Mg ha-1 yr-1. Agroforestry systems in low-rainfall regions of Australia were found to have an average carbon storage rate of 9.5 Mg ha-1 yr-1, according to study done there (Neumann, 2011).

Comparable studies were carried out for several agroforestry systems in Java, Sri Lanka, Central Sulawesi, Spain, Argentina, Indonesia, Peru, Canada, Costa Rice, Mexico, and Colombia (Aryal et al., 2019), (Aynekulu et al., 2020, Beer et al., 1990, Ehrenbergerova et al., 2016, Häger, 2012, Indrajaya et al., 2014, & Siarudin et al., 2021), and the amount of carbon stored by crops, trees, and soil was ascertained. Tanzania has a long history of using agroforestry, where it is practiced in a number of traditional systems (Lulandala, 2011). According to a research by (Banzi et al.), Tanzania's adoption of agroforestry boosted the supply of food from crops including cassava, bananas, beans, and maize while also dramatically increasing maize yields. In the eastern part of Tanzania, different research by (Mkonda & He, 2017), observes that areas where agroforestry is implemented have superior socio-economic and environmental growth. The National Agroforestry Planning, which seeks to reach 4 million agricultural families by 2025, highlights the importance of agroforestry in Tanzania. It outlines a plan to utilize agroforestry to raise the standard of living for 60% of Tanzania's low-income families (URT, 2009).

The capacity of agroforestry systems (AFS) in India to sequester carbon is projected to range from 0.25 to 19.14 megagrams of carbon per hectare annually (Mg C/ha/yr) for the tree parts and from 0.01 to 0.6 Mg C/ha/yr for the crop components (Dhyan et al., 2016). At the country level, the agroforestry systems' carbon sequestration capacity was calculated to be 0.21 Mg C/ha/yr, which is comparable to 0.77 Mg CO2/ha/yr in terms of CO2 mitigation (Ajit et al., 2017b). Agroforestry systems based on Quercus leucotrichophora in the Central Himalaya (Uttarakhand) have the capacity to store 36.94–51.14 Mg of carbon at elevations of 1400–2200 m, according to research by (Kumar et al., 2021). (Ajit et al., 2017a) and (Ajit et al., 2017b) worked in the Himalaya area and carried out similar investigations. Many researches were conducted in North-East India to find out how much carbon different agroforestry systems might store (Choudhary et al., 2014), (Kalita et al., 2016a, Nath & Das, 2012, Singh et al., 2018a, & Singh et al., 2018). In the Terai area (Uttarakhand and West Bengal), plantations and agrihorticultural systems absorb a significant quantity of carbon, which ultimately aids in the mitigation of climate change (Banga et al., 2017, Gera, 2012, Koul et al., 2011, & Yadava, 2010). According to research done in Madhya Pradesh by (Rizvi et al., 2019) An agroforestry system based on Acacia nilotica, Azadirachta indica, Leucaena leucocephala, etc. is expected to have a carbon storage capability of 0.11 to 0.15 Mg ha^{-1} yr^{-1}. comparable research was carried out in

Chattisgarh and Uttar Pradesh (Balloli et al., 2018), (Chandra & Singh, 2018), (Ajit et al., 2017a, Ajit et al., 2017b, Newaj et al., 2016, & Ramnewaj & Dhyani, 2008).

In Pakistan, agroforestry combines quickly growing trees with agricultural crops that have many advantages, including high revenue, food, raw materials, and little negative effects on the crops (Zubair & Garforth, 2006). In regions with waterlogging and aridity, agrisilviculture, windbreaks, and shelterbelts using plants like Populous, Morus, and Salix are employed (Foroughbakhch et al., 2009). Agroforestry approaches such as the Agrisilvi system (50.5%), Agrosilvopastoral system (45.5%), and Agro-pastoral system (4%), were observed in District Dir Lower, Pakistan. Based on these practices, the majority of farmers received profits in Pakistani currency, ranging from 20,000 to 40,000, from their wood trees (Hayat et al., 2020). Pakistan's firewood demands, which are 22.15 million m³, are mostly met by agroforestry methods, the remaining 19.94 million m³ originate through plants that are not in forests (Zaman & Ahmad, 2011). Major tree species grown on farmlands include Ficus carica, Juglans regia, Salix tetrasperma, Fimus alba, Populus nigra, Platanus orientalus, and Acacia modesta. Additionally, the planting of trees along nation borders serves the economic goal of generating cash from the sale of fruits such as Prunus domestica, Citrus species, and Juglans regia (Hayat et al., 2020).

Since the Maldives is a seaside country, coconuts are an important plant and are essential to the national economy. A popular approach is to grow fruit trees, fodder, and fuelwood atop the bunds of agricultural fields (Dhyani et al., 2021). In the nation, coconut is used in agroforestry techniques, such as homegrown coconut gardens, coconut plantations coupled with vegetables, yearly crops like cassava, and coconuts combined with trees that produce fruit like mangoes and custard apples. Similarly, it's common to use windbreaks, pastoral pairings with coconut, etc. Before, coconut monoculture was used in the Maldives. However, with the development of technology and agroforestry models, coconut-based agroforestry is now used to get many advantages from a single piece of land (Paudel & Shrestha, 2022).

In Nepal, it is traditional to plant trees, cultivate crops, and rear animals on the same area of soil. In Nepal, many agroforestry techniques are used, in the terai and mid-hills, traditional agroforestry systems are most prevalent. Modern, commercial agroforestry is the predominant activity in Terai. Trees that provide wood, such as poplar, eucalyptus, and teak, are particularly favored for Sissoo. Similarly, the mid-hills are home to fruit and fodder as well as a few agri-based commercial activities like cardamom, tea, and coffee, whereas the high mountain areas are mostly home to pastoral cattle husbandry (Dhakal & Rai, 2023). There are 12 agroforestry systems and 41 agroforestry techniques that are used in Nepal, according to a research that was carried out in 44 districts of the Terai and mid-hills (Amatya et al., 2018). There are many popular agroforestry techniques used in Nepal, including home gardens, agrisilviculture, aquasilviculture, intercropping, silvi-pastoral systems, and agro-Silvopastoral systems. Even though agricultural shifting is becoming less common, it is still practiced in many of the nation's upland areas (Amatya et al., 2018).

6. Challenges and Considerations

Agroforestry has been shown to have several advantages in various studies; nonetheless, many developing nations have not quickly shifted to this kind of tree-based agriculture. The perception of agroforestry as a strategy that contradicts the central thesis "a monoculture system that has significant output" could be one of the causes (Ollinaho & Kröger, 2021). Agroforestry uses a more intricate system made up of various components (livestock, crops, and/or tree species), and it relies on the cooperation of these elements to provide the best potential outcomes for the environment and the economy. Good agricultural practices (GAP) awareness in communities will thus determine the effect, whether favorable or bad. For example, nutrient or light conflict between the varieties brought into the agroforestry system might lead to reduction in the yield or harvestable portions of crops or trees (Wu et al., 2020). Moreover, certain tree and agricultural species have high water and nutrient requirements, which may lead to soil mining and the loss of water resources (Wu et al., 2020, & Kröger, 2013). hus, among the essential knowledge that rural populations require to successfully implement agroforestry is agronomy. For the purpose of transferring knowledge to the local people, it is thus essential to have a bigger workforce (from NGOs, government agencies, and scientific organizations).

The legislative sector presents another obstacle to implementation since agroforestry is hardly included in the national agenda that promotes the shift to environmentally friendly farming. The lack of a clear definition for the word "agroforestry" in comparison to other, more well-known methods like organic agriculture may be the root of this problem. Several tree-based systems may provide distinct results depending on the kind of components they include, even if they are all included under the general category of agroforestry. Furthermore, despite decades of research on the effects of agroforestry, most of it focuses on the farms and mainly looks at one particular variable either financial, social, or environmental while there are relatively few thorough studies on higher levels, like the national or even continental scope (Ollinaho & Kröger, 2021). As a result, it is challenging to come to an agreement about the effects of agroforestry, in part because legislators have less faith in the practice.

The implementation of the agroforestry system in India has been struck by a number of issues, including a lack of knowledge on the part of the cultivators, their inability to locate certified and registered growing materials, seed varieties, and most significantly, difficulties finding the right price for their produce when it was ready to be sold. The majority of the planting stuff is not guaranteed to meet quality standards, with just approximately 10% or so being of exceptional quality (Verma et al., 2017).

Roughly 20 million hectares of land in Europe are covered by AFS, with 90% of them being silvopastoral systems (Mosquera-Losada et al., 2016) in the Mediterranean Region (Mosquera-Losada et al., 2012). According to estimates by (Aertsens et al., 2013) the European Union still has 50 million hectares of grazing land and 90 million hectares of arable land that might be used for agroforestry. In evaluating the AFS, it is important to consider its many functions, which include the supply of environmental services, product variety, increased biodiversity, minimized GHG emissions, and weather-related resistance (Kay et al., 2019a, Marsden et al., 2020, & Marais et al., 2019). AFS have difficulties for a variety of reasons. Therefore, we outline some of the major obstacles to implementation, such as the expense of establishing agroforestry systems, the shortage of economic incentives, advertising, and public awareness/education.

Implementing innovative agricultural methods and production systems is sometimes hampered by high expenses (Long et al., 2016). The EU has given farmers financial assistance to encourage the deployment of agroforestry through a number of required and optional policy tools during the past ten to fifteen years (Mosquera-Losada et al., 2016, Panagos et al., 2016, & Hernández-Morcillo et al., 2018). Producers and managers of farms who are thinking about using agroforestry are still quite concerned about its low earnings (Hernández-Morcillo et al., 2018, & Graves et al., 2017). Since AFS are manpower-intensive, those who are thinking of adopting them may be greatly discouraged by the expensive cost of manpower in the EU (Eichhorn et al., 2006). The primary source of higher yields among the AFS constituents is complementarity in the temporal and geographical usage of nutrients, water, and radiation; if this complementarity is not adequately managed, competition among the AFS components may result in lower yields and monetary risk (Rois-Díaz et al., 2018, & Graves et al., 2017). (García de Jalón et al., 2018) carried out a study to evaluate the environmental effects of agroforestry, forestry, and arable farming across Europe. The findings revealed that agroforestry systems (AFS) ranked second in biodiversity richness. Financial incentives contributed significantly to their economic value, equating to EUR 364 per hectare per year for AFS, compared to EUR 559 per hectare per year for arable farming. Conversely, with the inclusion of grants, the forestry system's economic value was significantly lower, amounting to only EUR 194 per hectare per year.

The amount of money provided in return for the ecological benefits provided by agroforestry is insufficient (Graves et al., 2017). Under the concept of "payment for environmental services," farmers and other land managers who safeguard and restore ecosystems are paid for their efforts (Milder et al., 2010). While the European Union supports agroforestry through the Common Agricultural Policy's Pillars I and II, this assistance is limited to the creation of new agroforestry systems and does not extend to those already in place, (Hernández-Morcillo et al., 2018), thereby discouraging the continued use of existing systems for those who already implement agroforestry practices. Moreover, the EU Emissions Trading System does not presently permit the exchange of carbon credits for land-use or forestry operations (Van Vooren et al., 2016). Therefore, even though AFS has a great potential for sequestering carbon, farmers cannot profit from selling carbon credits (Aertsens et al., 2013, & Mosquera-Losada et al., 2011). Landowners who currently practice agroforestry may be able to reduce some of the monetary hazards and be incentivized to sustain AFS over time by receiving grants and incentives for environmental benefits (Hernández-Morcillo et al., 2018).

Due to the development and modernization of agriculture, many conventional AFS in Europe vanished in the 20th century (Quinkenstein et al., 2009). As a consequence, farmers in the continent lost their basis of knowledge (Mosquera-Losada et al., 2012). One of the biggest obstacles to the deployment of agroforestry systems is the lack of expertise and guidance assistance (Gómez et al., 2009). The financial success of AFS is dependent on the varieties of crops and trees chosen, as well as the understanding of how well they complement one another in terms of resource use (Palma et al., 2007). Training and knowledge exchange may be helpful in assisting farmers in selecting varieties that jointly increase production without affecting the primary crop (Palma et al., 2007, Hernández-Morcillo et al., 2018, & Graves et al., 2017). For instance, planting trees on agricultural land may be a profitable opportunity due to the growing demand for premium wood from hardwood production in Europe (Eichhorn et al., 2006, Hernández-Morcillo et al., 2018). Currently, there is a lack of knowledge among farmers about the benefits of agroforestry. To overcome this and promote practical learning, farmers and other people in the community have to share ideas (Rois-Díaz et al., 2018).

CONCLUSION

Agroforestry systems enhance the diversity of habitats by increasing biodiversity, sequestering carbon, enhancing soil health, and also by integrating trees and shrubs within agricultural lands, among others. In this realm, the economic benefits of diversified income sources and improved resilience to climate change play an anchor role in promoting sustainable land use. However, there are many barriers yet to be overcome in successful agroforestry, such as the establishing of enabling policy frameworks, training of farmers, and access to financial resources. Tailored research is, therefore, crucial for optimizing practices under specific local conditions and for accurately quantifying long-term benefits. Agroforestry has an enormous potential to respond to global challenges like food security, climate change, and loss of biodiversity. Those potentials for contributing to more sustainable agricultural practices and greater environmental conservation have underlined its significance as a multidimensional solution to contemporary environmental and socioeconomic challenges.

Acknowledgement:
I would like to sincerely thank my co-authors for their support and kind gesture to complete this manuscript in time.

Funding: NIL.

Conflict of Interest:
There is no such evidence of conflict of interest.

Author Contribution:
All authors have participated in critically revising of the entire manuscript and approval of the final manuscript.

REFERENCES

ABBASI SURKI, A., NAZARI, M., FALLAH, S., IRANIPOUR, R., & MOUSAVI, A. (2020). The competitive effect of almond trees on light and nutrients absorption, crop growth rate, and the yield in almond–cereal agroforestry systems in semi-arid regions. *Agroforestry Systems, 94*, 1111-1122.

AERTSENS, J., DE NOCKER, L., & GOBIN, A. (2013). Valuing the carbon sequestration potential for European agriculture. *Land use policy, 31*, 584-594.

AJIT, DHYANI, S. K., HANDA, A. K., NEWAJ, R., CHAVAN, S. B., ALAM & B., E. A. (2017b). Estimating carbon sequestration potential of existing agroforestry systems in India. *Agroforestry Systems, 90*, 1101–1118.

AJIT, HANDA, A. K., DHYANI, S. K., BHAT, G. M., MALIK, A. R., DUTT, V., MASOODI, T. H., UMA, & JAIN & A. (2017a). Quantification of carbon stocks and sequestration potential through existing agroforestry systems in the hilly Kupwara district of Kashmir valley in India. *Current Science, 113*, 782-785.

AMARE, D., WONDIE, M., MEKURIA, W., & DARR, D. (2019). Agroforestry of smallholder farmers in Ethiopia: practices and benefits. *Small-scale Forestry, 18*, 39-56.

AMATYA, S. M., CEDAMON, E., & NUBERG, I. (2018). *Agroforestry systems and practices in Nepal*.

ANSELL, DEAN, FREUDENBERGER, DAVID, MUNRO, NICOLA, GIBBONS & PHILIP (2016). The cost-effectiveness of agri-environment schemes for biodiversity conservation: A quantitative review. *Agriculture, Ecosystems & Environment, 225*, 184-191.

ARTRU, S., GARRÉ, S., DUPRAZ, C., HIEL, M.-P., BLITZ-FRAYRET, C., & LASSOIS, L. (2017). Impact of spatio-temporal shade dynamics on wheat growth and yield, perspectives for temperate agroforestry. *European Journal of Agronomy, 82*, 60-70.

ARYAL, D. R., GÓMEZ-GONZÁLEZ, R. R., HERNÁNDEZ-NURIASMÚ, R., & MORALES-RUIZ, D. E. (2019). Carbon stocks and tree diversity in scattered tree silvopastoral systems in Chiapas, Mexico. *Agroforestry systems, 93*, 213-227.

AYNEKULU, E., SUBER, M., VAN NOORDWIJK, M., ARANGO, J., ROSHETKO, J. M., & ROSENSTOCK, T. S. (2020). Carbon storage potential of silvopastoral systems of Colombia. *Land, 9*, 309.

BALLOLI, S.S., RAO, G.R., VENI, V.G., KUMARI, V.V., & OSMAN, M. (2018). Carbon sequestration potential in agroforestry systems. *Central Research Institute for Dryland Agriculture*, pp92-98.

BANDOLIN, T., & FISHER, R. (1991). Agroforestry systems in North America. *Agroforestry Systems, 16*, 95-118.

BANGA, A., YADAVA, A., & SAH, V. (2017). Growth, biomass and carbon sequestration potential of different poplar (Populus deltoides Bartr.) clones in agroforestry system with wheat (Triticum aestivum) varieties in tarai belt of Uttarakhand. *G-Journal of Environmental Science and Technology*, *5*, 32-36.

BANZI, F., OTSYINAº, R., & ASENGA, D. (15). Soil fertility improvement and maize yields following woodlots of 107 three different tree species in Shinyanga, Tanzania E.

BAULCOMBE, D., CRUTE, I., DAVIES, B., DUNWELL, J., GALE, M., JONES, J., PRETTY, J., SUTHERLAND, W., & TOULMIN, C. (2009). *Reaping the benefits: science and the sustainable intensification of global agriculture*, The Royal Society.

BEER, J., BONNEMANN, A., CHÁVEZ, W., FASSBENDER, H., IMBACH, A., & MARTEL, I. (1990). Modelling agroforestry systems of cacao (Theobroma cacao) with laurel (Cordia alliodora) or poro (Erythrina poeppigiana) in Costa Rica: V. Productivity indicies, organic materialmodels and sustainbility over ten years. *Agroforestry systems, 12*, 229-249.

BEER, L., & THEUVSEN, L. (2020). Factors influencing German farmer's decision to grow alley cropping systems as ecological focus areas: a regression analysis. *International Food and Agribusiness Management Review*, *23*, 529-545.

BÉLIVEAU, A., LUCOTTE, M., DAVIDSON, R., PAQUET, S., MERTENS, F., PASSOS, C. J., & ROMANA, C. A. (2017). Reduction of soil erosion and mercury losses in agroforestry systems compared to forests and cultivated fields in the Brazilian Amazon. *Journal of environmental management*, *203*, 522-532.

BENTRUP, G., HOPWOOD, J., ADAMSON, N. L.. & VAUGHAN, M. (2019). Temperate agroforestry systems and insect pollinators: A review. *Forests*, *10*, 981.

BEULE, L., LEHTSAAR, E., RATHGEB, A., & KARLOVSKY, P. (2019). Crop diseases and mycotoxin accumulation in temperate agroforestry systems. *Sustainability*, *11*, 2925.

BIANCHI, F. J., BOOIJ, C., & TSCHARNTKE, T. (2006). Sustainable pest regulation in agricultural landscapes: a review on landscape composition, biodiversity and natural pest control. *Proceedings of the Royal Society B: Biological Sciences*, *273*, 1715-1727.

BOINOT, SÉBASTIEN, POULMARC'H, JOUANEL, MÉZIÈRE, DELPHINE, LAURI, PIERRE-ERIC, SARTHOU & JEAN-PIERRE (2019). Distribution of overwintering invertebrates in temperate agroforestry systems: Implications for biodiversity conservation and biological control of crop pests. *Agriculture, Ecosystems & Environment*, *285*, 106630.

BUENO, A. S., & PERES, C. A. (2019). Patch-scale biodiversity retention in fragmented landscapes: Reconciling the habitat amount hypothesis with the island biogeography theory. *Journal of Biogeography*, *46*, 621-632.

CALLENDAR, G. S. (1938). The artificial production of carbon dioxide and its influence on temperature. *Quarterly Journal of the Royal Meteorological Society*, *64*, 223-240.

CAO, L., WANG, S., PENG, T., CHENG, Q., ZHANG, L., ZHANG, Z., YUE, F., & FRYER, A. E. (2020). Monitoring of suspended sediment load and transport in an agroforestry watershed on a karst plateau, Southwest China. *Agriculture, Ecosystems & Environment, 299,* 106976.

CHANDRA, K., & SINGH, A. K. (2018). Carbon stock appraisal of naturally growing trees on farmlands in plain zone districts of Chhattisgarh, India. *Tropical ecology*, *59*, 679-689.

CHAPLIN-KRAMER, R., O'ROURKE, M. E., BLITZER, E. J., & KREMEN, C.

(2011). A meta-analysis of crop pest and natural enemy response to landscape complexity. *Ecology letters, 14*, 922-932.

CHATTERJEE, N., NAIR, P. R., CHAKRABORTY, S., & NAIR, V. D. (2018). Changes in soil carbon stocks across the Forest-Agroforest-Agriculture/Pasture continuum in various agroecological regions: A meta-analysis. *Agriculture, ecosystems & environment, 266*, 55-67.

CHOUDHARY, V., SINGH, S., DIXIT, A., ARUNACHALAM, A., & BHAGAWATI, R. (2014). Biomass and carbon sequestration potential of agroforestry trees in Arunachal Pradesh, North East India. *Climate Change and Environmental Sustainability, 2*, 48-54.

DHAKAL, A., & RAI, R. (2023). Potential of Agroforestry Systems for Food Security, Climate Change Mitigation, Landscape Restoration and Disaster Risk Reduction in Nepal. *Agroforestry for Sustainable Intensification of Agriculture in Asia and Africa.* Springer.

DHANYA, B. (2011). *Integrated study of a Ficus based traditional agroforestry system in Mandya district, Karnataka.* PhD thesis. Forest Research Institute Deemed University, Dehradun, India, 211p.

DHANYA, B., VISWANATH, S., & PURUSHOTHAMAN, S. (2013). Decomposition and nutrient release dynamics of Ficus benghalensis L. litter in traditional agroforestry systems of Karnataka, Southern India. *International Scholarly Research Notices, 2013*, 524679.

DHYAN, S., RAM, A., & DEV, I. (2016). Potential of agroforestry systems in carbon sequestration in India. *Dhyani, SK, Ram, A., Dev, I*, 1103-1112.

DHYANI, S., MURTHY, I. K., KADAVERUGU, R., DASGUPTA, R., KUMAR, M., & ADESH GADPAYLE, K. (2021). Agroforestry to achieve global climate adaptation and mitigation targets: Are South Asian countries sufficiently prepared? *Forests, 12*, 303.

DO CARMO MARTINELLI, G., SCHLINDWEIN, M. M., PADOVAN, M. P., VOGEL, E., & RUVIARO, C. F. (2019). Environmental performance of agroforestry systems in the Cerrado biome, Brazil. *World Development, 122*, 339-348.

DUDLEY, N., & ALEXANDER, S. (2017). Agriculture and biodiversity: a review. *Biodiversity, 18*, 45-49.

EHRENBERGEROVA, L., CIENCIALA, E., KUČERA, A., GUY, L., & HABROVÁ, H. (2016). Carbon stock in agroforestry coffee plantations with different shade trees in Villa Rica, Peru. *Agroforestry systems, 90*, 433-445.

EICHHORN, M. P., PARIS, P., HERZOG, F., INCOLL, L., LIAGRE, F., MANTZANAS, K., MAYUS, M., MORENO, G., PAPANASTASIS, V. P., & PILBEAM, D. (2006). Silvoarable systems in Europe–past, present and future prospects. *Agroforestry systems, 67*, 29-50.

EVJU, M., & SVERDRUP-THYGESON, A. (2016). Spatial configuration matters: a test of the habitat amount hypothesis for plants in calcareous grasslands. *Landscape Ecology, 31*, 1891-1902.

FAGERHOLM, N., TORRALBA, M., BURGESS, P. J., & PLIENINGER, T. (2016). A systematic map of ecosystem services assessments around European agroforestry. *Ecological Indicators, 62*, 47-65.

FAHAD, S., CHAVAN, S. B., CHICHAGHARE, A. R., UTHAPPA, A. R., KUMAR, M., KAKADE, V., PRADHAN, A., JINGER, D., RAWALE, G., & YADAV, D. K. (2022). Agroforestry systems for soil health improvement and maintenance. *Sustainability, 14*, 14877.

FAHRIG, L. (2013). Rethinking patch size and isolation effects: the habitat amount hypothesis. *Journal of biogeography, 40*, 1649-1663.

FAHRIG, L. (2021). What the habitat amount hypothesis does and does not predict: A reply to Saura. *Journal of Biogeography, 48*, 1530-1535.

FERNANDEZ-CORNEJO, J., NEHRING, R. F., NEWCOMB SINHA, E., GRUBE, A., & VIALOU, A. (2009). Assessing recent trends in pesticide use in US agriculture.

FORESIGHT, U. (2011). The future of food and farming. *Final Project Report, London, The Government Office for Science*.

FOROUGHBAKHCH, P., PINERO, J., VÁZQUEZ, M., & AVILA, M. (2009). Use of multipurpose trees and shrubs in forestry and agroforestry systems in northeastern Mexico. *Handbook on Agroforestry: Management Practices and Environmental Impact*, 37-95.

FRISON, E. A., CHERFAS, J., & HODGKIN, T. (2011). Agricultural biodiversity is essential for a sustainable improvement in food and nutrition security. *Sustainability, 3*, 238-253.

GAMA-RODRIGUES, E. F., GAMA-RODRIGUES, A. C., & NAIR, P. K. R. (2011). Soil carbon sequestration in cacao agroforestry systems: a case study from Bahia, Brazil. *Springer.*, pp85–99.

GARCÍA DE JALÓN, S., BURGESS, P. J., GRAVES, A., MORENO, G., MCADAM, J., POTTIER, E., NOVAK, S., BONDESAN, V., MOSQUERA-LOSADA, R., & CROUS-DURÁN, J. (2018). How is agroforestry perceived in Europe? An assessment of positive and negative aspects by stakeholders. *Agroforestry Systems, 92*, 829-848.

GARRETT, H., JONES, J., KURTZ, W., & SLUSHER, J. (1991). Black walnut (Juglans nigra L.) agroforestry–its design and potential as a land-use alternative. *The forestry chronicle, 67*, 213-218.

GEBRU, B. M., WANG, S. W., KIM, S. J., & LEE, W. K. (2019). Socio-ecological niche and factors affecting agroforestry practice adoption in different agroecologies of southern Tigray, Ethiopia. *Sustainability, 11*, 3729.

GERA, M. (2012). Poplar culture for speedy carbon sequestration in India: a case study from Terai region of Uttarakhand. *Envis Forestry Bulletin, 12*, 75-83.

GERBER, P. J., STEINFELD, H., HENDERSON, B., MOTTET, A., OPIO, C., DIJKMAN, J., FALCUCCI, A., & TEMPIO, G. (2013). *Tackling climate change through livestock: a global assessment of emissions and mitigation opportunities*.

GODFRAY, H. C. J., BEDDINGTON, J. R., CRUTE, I. R., HADDAD, L., LAWRENCE, D., MUIR, J. F., PRETTY, J., ROBINSON, S., THOMAS, S. M.. & TOULMIN, C. (2010). Food security: the challenge of feeding 9 billion people. *science, 327*, 812-818.

GÓMEZ, J. A., GUZMÁN, M. G., GIRÁLDEZ, J. V., & FERERES, E. (2009). The influence of cover crops and tillage on water and sediment yield, and on nutrient, and organic matter losses in an olive orchard on a sandy loam soil. *Soil and Tillage Research, 106*, 137-144.

GRAHAM, J. B., & NASSAUER, J. I. (2019). Wild bee abundance in temperate agroforestry landscapes: Assessing effects of alley crop composition, landscape configuration, and agroforestry area. *Agroforestry systems, 93*, 837-850.

GRAVES, A. R., BURGESS, P. J., LIAGRE, F., & DUPRAZ, C. (2017). Farmer perception of benefits, constraints and opportunities for silvoarable systems:

Preliminary insights from Bedfordshire, England. *Outlook on agriculture, 46*, 74-83.

GRAVES, A. R., BURGESS, P. J., PALMA, J., KEESMAN, K., VAN DER WERF, W., DUPRAZ, C., VAN KEULEN, H., HERZOG, F., & MAYUS, M. (2010). Implementation and calibration of the parameter-sparse Yield-SAFE model to predict production and land equivalent ratio in mixed tree and crop systems under two contrasting production situations in Europe. *Ecological Modelling, 221*, 1744-1756.

HADDAD, N. M., GONZALEZ, A., BRUDVIG, L. A., BURT, M. A., LEVEY, D. J., & DAMSCHEN, E. I. (2017). Experimental evidence does not support the Habitat Amount Hypothesis. *Ecography, 40*, 48-55.

HÄGER, A. (2012). The effects of management and plant diversity on carbon storage in coffee agroforestry systems in Costa Rica. *Agroforestry systems, 86*, 159-174.

HAGGAR, J., PONS, D., SAENZ, L., & VIDES, M. (2019). Contribution of agroforestry systems to sustaining biodiversity in fragmented forest landscapes. *Agriculture, Ecosystems & Environment, 283*, 106567.

HAILU GEBRU, H. G. (2015). A review on the comparative advantage of intercropping systems.

HALL, C., DAWSON, T., MACDIARMID, J., MATTHEWS, R., & SMITH, P. (2017). The impact of population growth and climate change on food security in Africa: looking ahead to 2050. *International Journal of Agricultural Sustainability, 15*, 124-135.

HANSKI, I. (2015). Habitat fragmentation and species richness. *Journal of Biogeography, 42*, 989-993.

HAYAT, M., ZHA, T., NIZAMI, S. M., GULZAR, S., KHAN, A., IQBAL, S., & KHAN, M. S. (2020). Productive role of agroforestry system in context of ecosystem services in district dir lower, Pakistan. *Pak. J. Bot, 52*, 1411-1419.

HERNÁNDEZ-MORCILLO, M., BURGESS, P., MIRCK, J., PANTERA, A., & PLIENINGER, T. (2018). Scanning agroforestry-based solutions for climate change mitigation and adaptation in Europe. *Environmental Science & Policy, 80*, 44-52.

HERZOG, F. (1997). Agroforestry, an alternative form of land use for Europe-conceptual considerations.

ICKOWITZ, A., ROWLAND, D., POWELL, B., SALIM, M. A., & SUNDERLAND, T. (2016). Forests, trees, and micronutrient-rich food consumption in Indonesia. *PloS one, 11*, e0154139.

INDRAJAYA, Y., SIARUDIN, M., & HANDAYANI, W. (2014). Karbon tersimpan dalam biomassa agroforestry jabon-kapulaga dan rumput gajah di Kecamatan Pakenjeng, Garut, Jawa Barat. *Jurnal Penelitian Agroforestry, 2*, 67-74.

ISKANDAR, J., ISKANDAR, B. S., & PARTASASMITA, R. (2016). Responses to environmental and socio-economic changes in the Karangwangi traditional agroforestry system, South Cianjur, West Java. *Biodiversitas Journal of Biological Diversity, 17*.

IVERSON, A. L., MARÍN, L. E., ENNIS, K. K., GONTHIER, D. J., CONNOR-BARRIE, B. T., REMFERT, J. L., CARDINALE, B. J., & PERFECTO, I. (2014). Do polycultures promote win-wins or trade-offs in agricultural ecosystem services? A meta-analysis. *Journal of Applied Ecology, 51*, 1593-1602.

KALITA, R. M., DAS, A. K., & & NATH, A. J. (2016a). Carbon stock and sequestration potential in biomass of tea agroforestry system in Barak Valley, Assam, North East India.

International Journal of Ecology and Environmental Sciences, *42*, 107-114.

KANZLER, M., BÖHM, C., MIRCK, J., SCHMITT, D., & VESTE, M. (2019). Microclimate effects on evaporation and winter wheat (Triticum aestivum L.) yield within a temperate agroforestry system. *Agroforestry systems*, *93*, 1821-1841.

KAY, S., GRAVES, A., PALMA, J. H., MORENO, G., ROCES-DÍAZ, J. V., AVIRON, S., CHOUVARDAS, D., CROUS-DURAN, J., FERREIRO-DOMÍNGUEZ, N., & DE JALÓN, S. G. (2019a). Agroforestry is paying off–Economic evaluation of ecosystem services in European landscapes with and without agroforestry systems. *Ecosystem services*, *36*, 100896.

KAY, S., REGA, C., MORENO, G., DEN HERDER, M., PALMA, J. H., BOREK, R., CROUS-DURAN, J., FREESE, D., GIANNITSOPOULOS, M., & GRAVES, A. (2019b). Agroforestry creates carbon sinks whilst enhancing the environment in agricultural landscapes in Europe. *Land use policy*, *83*, 581-593.

KHAN, N., JHARIYA, M. K., RAJ, A., BANERJEE, A., MEENA, R. S., BARGALI, S. S., YADAV, S. K., & KUMAWAT, A. (2021). Agroforestry and its services for soil management and sustainability. *Sustainable intensification for agroecosystem services and management*, 353-377.

KIERS, E. T., LEAKEY, R. R., IZAC, A.-M., HEINEMANN, J. A., ROSENTHAL, E., NATHAN, D., & JIGGINS, J. (2008). Agriculture at a crossroads. *American Association for the Advancement of Science*.

KING, K. (1987). The history of agroforestry. *Agroforestry: a decade of development*, 1-11.

KIPTOT, E., FRANZEL, S., & DEGRANDE, A. (2014). Gender, agroforestry and food security in Africa. *Current Opinion in Environmental Sustainability*, *6*, 104-109.

KOUL, D., SHUKLA, G., PANWAR, P., & CHAKRAVARTY, S. (2011). Status of soil carbon sequestration under different land use systems in Terai Zone of West Bengal. *Environ. We Int. J. Sci. Technol*, *6*, 95-100.

KRÖGER, M. (2013). *Contentious agency and natural resource politics*, Routledge.

KUMAR, B. M., SINGH, A.K., & DHYANI, S. K. (2012). South Asian agroforestry: traditions, transformations, and prospects. *Dordrecht: Springer*, *Netherlands*, pp359–389.

KUMAR, S., BIJALWAN, A., SINGH, B., RAWAT, D., YEWALE, A. G., RIYAL, M. K., & THAKUR, T. K. (2021). Comparison of carbon sequestration potential of Quercus leucotrichophora–based agroforestry systems and natural forest in Central Himalaya, India. *Water, Air, & Soil Pollution*, *232*, 350.

KURUKULASURIYA, P., & ROSENTHAL, S. (2003). Climate change and agriculture: A review of impacts and adaptations.

LACOMBE, S., BRADLEY, R. L., HAMEL, C., & BEAULIEU, C. (2009). Do tree-based intercropping systems increase the diversity and stability of soil microbial communities? *Agriculture, Ecosystems & Environment*, *131*, 25-31.

LANGENBERG, J., & THEUVSEN, L. (2018). Agroforstwirtschaft in Deutschland: Alley-Cropping-Systeme aus ökonomischer Perspektive. *Journal of Cultivated Plants/Journal für Kulturpflanzen*, *70*.

LAUDARES, S. S. D. A., BORGES, L. A. C., ÁVILA, P. A. D., OLIVEIRA, A. L. D., SILVA, K. G. D., & LAUDARES, D. C. D. A. (2017). Agroforestry as a sustainable alternative for environmental regularization of rural consolidated occupations. *Cerne, 23*, 161-174.

LEE, H., & CHEONG, H. W. (2018). Effects of carbon dioxide and clouds on temperature. *Procedia computer science, 139*, 95-103.

LEHMANN, L. M., BORZĘCKA, M., ŻYŁOWSKA, K., PISANELLI, A., RUSSO, G., & GHALEY, B. B. (2020). Environmental impact assessments of integrated food and non-food production systems in Italy and Denmark. *Energies, 13*, 849.

LETOURNEAU, D. K., ARMBRECHT, I., RIVERA, B. S., LERMA, J. M., CARMONA, E. J., DAZA, M. C., ESCOBAR, S., GALINDO, V., GUTIÉRREZ, C., & LÓPEZ, S. D. (2011). Does plant diversity benefit agroecosystems? A synthetic review. *Ecological applications, 21*, 9-21.

LI, X. A., GE, T. D., CHEN, Z., WANG, S. M., OU, X. K., WU, Y., CHEN, H., & WU, J. P. (2020). Enhancement of soil carbon and nitrogen stocks by abiotic and microbial pathways in three rubber-based agroforestry systems in Southwest China. *Land Degradation & Development*, *31*, 2507-2515.

LINDSEY, R. (2020). Climate change: Atmospheric Carbon Dioxide.

LONG, T. B., BLOK, V., & CONINX, I. (2016). Barriers to the adoption and diffusion of technological innovations for climate-smart agriculture in Europe: evidence from the Netherlands, France, Switzerland and Italy. *Journal of cleaner production, 112*, 9-21.

LORENZ, K., & LAL, R. (2014). Soil organic carbon sequestration in agroforestry systems. A review. *Agronomy for Sustainable Development, 34*, 443-454.

LOSEY, J. E., & VAUGHAN, M. (2006). The economic value of ecological services provided by insects. *Bioscience, 56*, 311-323.

LOVELL, S. T., DUPRAZ, C., GOLD, M., JOSE, S., REVORD, R., STANEK, E., & WOLZ, K. J. (2018). Temperate agroforestry research: considering multifunctional woody polycultures and the design of long-term field trials. *Agroforestry Systems, 92*, 1397-1415.

LULANDALA, L. (2011). Agroforestry concepts, systems, practices, potentials, constraints, research and training needs. MSc. *MNRSA Lecture Notes, Sokoine University of Agriculture, Morogoro*, 1-15.

MAIA, A. G., DOS SANTOS EUSEBIO, G., FASIABEN, M. D. C. R., MORAES, A. S., ASSAD, E. D., & PUGLIERO, V. S. (2021). The economic impacts of the diffusion of agroforestry in Brazil. *Land use policy, 108*, 105489.

MALÉZIEUX, E., CROZAT, Y., DUPRAZ, C., LAURANS, M., MAKOWSKI, D., OZIER-LAFONTAINE, H., RAPIDEL, B., DE TOURDONNET, S., & VALANTIN-MORISON, M. (2009). Mixing plant species in cropping systems: concepts, tools and models: a review. *Sustainable agriculture*, 329-353.

MANAYE, A., TESFAMARIAM, B., TESFAYE, M., WORKU, A., & GUFI, Y. (2021). Tree diversity and carbon stocks in agroforestry systems in northern Ethiopia. *Carbon Balance and Management, 16*, 14.

MARAIS, Z. E., BAKER, T. P., O'GRADY, A. P., ENGLAND, J. R., TINCH, D., & HUNT, M. A. (2019). A natural capital approach to agroforestry decision-making at the farm scale. *Forests*, *10*, 980.

MARSDEN, C., MARTIN-CHAVE, A., CORTET, J., HEDDE, M., & CAPOWIEZ, Y. (2020). How agroforestry systems influence soil fauna and their functions-a review. *Plant and Soil, 453*, 29-44.

MARTIN-CHAVE, A., BÉRAL, C., & CAPOWIEZ, Y. (2019). Agroforestry has an impact on nocturnal predation by ground beetles and Opiliones in a temperate organic alley cropping system. *Biological Control, 129*, 128-135.

MATEO-SAGASTA, J., ZADEH, S. M., TURRAL, H., & BURKE, J. (2017). Water pollution from agriculture: a global review. Executive summary.

MBOW, C., VAN NOORDWIJK, M., LUEDELING, E., NEUFELDT, H., MINANG, P. A., & KOWERO, G. (2014). Agroforestry solutions to address food security and climate change challenges in Africa. *Current Opinion in Environmental Sustainability, 6*, 61-67.

MCGUIRE, S. (2015). FAO, IFAD, and WFP. The state of food insecurity in the world 2015: meeting the 2015 international hunger targets: taking stock of uneven progress. Rome: FAO, 2015. *Advances in Nutrition, 6*, 623-624.

MEAD, R., & WILLEY, R. (1980). The concept of a 'land equivalent ratio'and advantages in yields from intercropping. *Experimental agriculture, 16*, 217-228.

MELO, G. L., SPONCHIADO, J., CÁCERES, N. C., & FAHRIG, L. (2017). Testing the habitat amount hypothesis for South American small mammals. *Biological Conservation, 209*, 304-314.

MILDER, J. C., SCHERR, S. J., & BRACER, C. (2010). Trends and future potential of payment for ecosystem services to alleviate rural poverty in developing countries. *Ecology and Society, 15*.

MKONDA, M. Y., & HE, X. (2017). The potentials of agroforestry systems in East Africa: a case of the eastern arc mountains of Tanzania.

MONDAL, S., ANGON, P. B., & ROY, A. R. (2023). Ecological Advancements and Developments of Agroforestry. *Turkish Journal of Agriculture-Food Science and Technology, 11*, 2476-2480.

MONTAGNINI, F., & METZEL, R. (2017). *Integrating landscapes: agroforestry for biodiversity conservation and food sovereignty,* Springer.

MONTEITH, J., ONG, C., & CORLETT, J. (1991). Microclimatic interactions in agroforestry systems. *Forest Ecology and management, 45*, 31-44.

MOSQUERA-LOSADA, ROSA, M., MCADAM, H, J., ROMERO-FRANCO, ROSA, SANTIAGO-FREIJANES, JAVIER, J., RIGUEIRO-RODRÓGUEZ & A (2009). Definitions and components of agroforestry practices in Europe. *Agroforestry in Europe: current status and future prospects*, 3-19.

MOSQUERA-LOSADA, M. R., FREESE, D., & RIGUEIRO-RODRÍGUEZ, A. (2011). Carbon sequestration in European agroforestry systems. *carbon sequestration potential of agroforestry systems: opportunities and challenges*, 43-59.

MOSQUERA-LOSADA, M. R., MORENO, G., PARDINI, A., MCADAM, J., PAPANASTASIS, V., BURGESS, P., LAMERSDORF, N., CASTRO, M., LIAGRE, F., & RIGUEIRO-RODRÍGUEZ, A. (2012). Past, present and future of agroforestry systems in Europe. *Agroforestry-The future of global land use*, 285-312.

MOSQUERA-LOSADA, M. R., SANTIAGO FREIJANES, J. J., PISANELLI, A. R., M., SMITH, J. D. H., M.; MORENO, G., MALIGNIER, N. M., J., & LAMERSDORF, N. E. A. (2016). Extent and Success of Current Policy Measures to Promote Agroforestry across Europe.

NAIR, P. K. R., NAIR, V. D., MOHAN KUMAR, B., & SHOWALTER, J. M. (2010). Carbon Sequestration in Agroforestry Systems. A. Sparks ed.: Academic Press.

NAIR, P. R. (2011). Agroforestry systems and environmental quality: introduction. *Journal of environmental quality*, *40*, 784-790.

NAIR, P. R., NAIR, V. D., KUMAR, B. M., & SHOWALTER, J. M. (2010). Carbon sequestration in agroforestry systems. *Advances in agronomy*, *108*, 237-307.

NATH, A. J., & DAS, A. K. (2012). Carbon pool and sequestration potential of village bamboos in the agroforestry system of northeast India. *Tropical Ecology, 53,* 287-293.

NEUMANN, C. R., HOBBS, T. J., & TUCKER, M. (2011). Carbon sequestration and biomass production rates from agroforestry in lower rainfall zones (300-650 mm) of South Australia: Southern Murray-Darling Basin Region. *Adelaide & Future Farm Industries Cooperative Research Centre*, *32*.

NEWAJ, R., CHAVAN, S., ALAM, B., & DHYANI, S. (2016). Biomass and carbon storage in trees grown under different agroforestry systems in semi arid region of central India. *Indian Forester*, *142*, 642-648.

OECD (2009). Cost-effective actions to tackle climate change.

OLLINAHO, O. I., & KRÖGER, M. (2021). Agroforestry transitions: The good, the bad and the ugly. *Journal of Rural Studies*, *82*, 210-221.

ORTEGA-CASTILLEJOS, D. K. A. (2018). The Asian Continent: Its Origin and Evolution BT - Practical Aspects of Hair Transplantation in Asians. *Tokyo: Springer Japan*, pp3-6.

PALACIN, C., & ALONSO, J. C. (2018). Failure of EU Biodiversity Strategy in Mediterranean farmland protected areas. *Journal for Nature Conservation*, *42*, 62-66.

PALMA, J., GRAVES, A. R., BURGESS, P. J., VAN DER WERF, W., & HERZOG, F. (2007). Integrating environmental and economic performance to assess modern silvoarable agroforestry in Europe. *Ecological Economics*, *63*, 759-767.

PANAGOS, P., IMESON, A., MEUSBURGER, K., BORRELLI, P., POESEN, J., & ALEWELL, C. (2016). Soil conservation in Europe: wish or reality? *Land Degradation & Development*, *27*, 1547-1551.

PAUDEL, Y., & SHRESTHA, S. (2022). Agroforestry practices prevailing in SAARC countries: A review. *Indonesian Journal of Social and Environmental Issues (IJSEI), 3*, 10-18.

PAVLIS, S, E., TERKENLI, S, T., KRISTENSEN, BP, S., BUSCK, G, A., COSOR & L, G. (2016). Patterns of agri-environmental scheme participation in Europe: Indicative trends from selected case studies. *Land Use Policy*, *57*, 800-812.

PIMENTEL, D., ACQUAY, H., BILTONEN, M., RICE, P., SILVA, M., NELSON, J., LIPNER, V., GIORDANO, S., HOROWITZ, A., & D'AMORE, M. (1992). Environmental and economic costs of pesticide use. *BioScience, 42,* 750-760.

PLASS, G. N. (1956). The carbon dioxide theory of climatic change. *Tellus*, *8*, 140-154.

PRATIWI, A., & SUZUKI, A. (2019). Reducing agricultural income vulnerabilities through agroforestry training: evidence from a randomised field experiment in Indonesia. *Bulletin of Indonesian Economic Studies, 55*, 83-116.

PRETTY, J., & BHARUCHA, Z. P. (2014). Sustainable intensification in agricultural systems. *Annals of botany, 114*, 1571-1596.

PUMARIÑO, L., SILESHI, G. W., GRIPENBERG, S., KAARTINEN, R., BARRIOS, E., MUCHANE, M. N., MIDEGA, C., & JONSSON, M. (2015). Effects of agroforestry on pest, disease and weed control: A meta-analysis. *Basic and Applied Ecology, 16*, 573-582.

QUINKENSTEIN, A., WÖLLECKE, J., BÖHM, C., GRÜNEWALD, H., FREESE, D., SCHNEIDER, B. U., & HÜTTL, R. F. (2009). Ecological benefits of the alley cropping agroforestry system in sensitive regions of Europe. *Environmental science & policy*, *12*, 1112-1121.

RAMNEWAJ & DHYANI, S. K. (2008). Agroforestry for carbon sequestration: scope and present status. *Indian Journal of Agroforestry, 10*, 1-9.

RAO, M., NAIR, P., & ONG, C.(1997). Biophysical interactions in tropical agroforestry systems. *Agroforestry systems, 38*, 3-50.

RATNADASS, A., FERNANDES, P., AVELINO, J., & HABIB, R. (2012). Plant species diversity for sustainable management of crop pests and diseases in agroecosystems: a review. *Agronomy for sustainable development, 32*, 273-303.

REYNOLDS, P. E., SIMPSON, J. A., THEVATHASAN, N. V., & GORDON, A. M. (2007). Effects of tree competition on corn and soybean photosynthesis, growth, and yield in a temperate tree-based agroforestry intercropping system in southern Ontario, Canada. *Ecological engineering*, *29*, 362-371.

RICHARD, R., CAHON, T., LLANDRES, A. L., LE LEVIER, L., PROUDHOM, G., & CASAS, J. (2020). Alley cropping agroforestry mediates carabid beetle distribution at a micro-habitat scale. *Agroforestry Systems, 94*, 309-317.

RIZVI, R., NEWAJ, R., CHATURVEDI, O., PRASAD, R., HANDA, A., & ALAM, B. (2019). Carbon sequestration and CO 2 absorption by agroforestry systems: An assessment for Central Plateau and Hill region of India. *Journal of Earth System Science, 128*, 56.

ROIS-DÍAZ, M., LOVRIC, N., LOVRIC, M., FERREIRO-DOMÍNGUEZ, N., MOSQUERA-LOSADA, M., DEN HERDER, M., GRAVES, A., PALMA, J. H., PAULO, J., & PISANELLI, A. (2018). Farmers' reasoning behind the uptake of agroforestry practices: evidence from multiple case-studies across Europe. *Agroforestry Systems, 92*, 811-828.

ROSAS-RAMOS, N., BAÑOS-PICÓN, L., TRIVELLONE, V., MORETTI, M., TORMOS, J., & ASÍS, J. D. (2019). Ecological infrastructures across Mediterranean agroecosystems: Towards an effective tool for evaluating their ecological quality. *Agricultural systems, 173,* 355-363.

ROSHETKO, J. M., ROHADI, D., PERDANA, A., SABASTIAN, G., NURYARTONO, N., PRAMONO, A. A., WIDYANI, N., MANALU, P., FAUZI, M. A., & SUMARDAMTO, P. (2013). Teak agroforestry systems for livelihood enhancement, industrial timber production, and environmental rehabilitation. *Forests, Trees and Livelihoods, 22*, 241-256.

ROSSMAN, A. Y. (2009). The impact of invasive fungi on agricultural ecosystems in the United States. *Ecological Impacts of Non-Native Invertebrates and Fungi on Terrestrial Ecosystems*, 97-107.

SANTOS, P. Z. F., CROUZEILLES, R., & SANSEVERO, J. B. B. (2019). Can agroforestry systems enhance biodiversity and ecosystem service provision in agricultural landscapes? A meta-analysis for the Brazilian Atlantic Forest. *Forest ecology and management, 433*, 140-145.

SAURA, S. (2021). The Habitat Amount Hypothesis implies negative effects of habitat fragmentation on species richness. *Journal of Biogeography, 48,* 11-22.

SAVARY, S., FICKE, A., AUBERTOT, J. N., & HOLLIER, C. (2012). Crop losses due to diseases and their implications for global food production losses and food security. *Food security, 4*, 519-537.

SCHROTH, G., & BURKHARD, J. (2002). Nutrient leaching. *Trees, Crops and Soil Fertility—Concepts and Research Methods; Schroth, G., Sinclair, FL, Eds*.

SCHROTH, G., KRAUSS, U., GASPAROTTO, L., DUARTE AGUILAR, J., & VOHLAND, K. (2000). Pests and diseases in agroforestry systems of the humid tropics. *Agroforestry systems, 50*, 199-241.

SEREKE, F., GRAVES, A. R., DUX, D., PALMA, J. H., & HERZOG, F. (2015). Innovative agroecosystem goods and services: key profitability drivers in Swiss agroforestry. *Agronomy for sustainable development*, *35*, 759-770.

SHARMA, N., BOHRA, B., PRAGYA, N., CIANNELLA, R., DOBIE, P., & LEHMANN, S. (2016a). Bioenergy from agroforestry can lead to improved food security, climate change, soil quality, and rural development. *Food and Energy Security, 5*, 165-183.

SHARMA, R., CHAUHAN, S. K., & TRIPATHI, A. M. (2016b). Carbon sequestration potential in agroforestry system in India: an analysis for carbon project. *Agroforestry systems, 90*, 631-644.

SIARUDIN, M., RAHMAN, S. A., ARTATI, Y., INDRAJAYA, Y., NARULITA, S., ARDHA, M. J., & LARJAVAARA, M. (2021). Carbon sequestration potential of agroforestry systems in degraded landscapes in West Java, Indonesia. *Forests, 12*, 714.

SILESHI, G., SCHROTH, G., RAO, M. R., & GIRMA, H. (2008). Weeds, diseases, insect pests and tri-trophic interactions in tropical agroforestry. *Ecological basis of agroforestry*, 73-94.

SINGH, LANABIR, S., SAHOO, KUMAR, U., GOGOI, ANUDIP, KENYE & ALICE (2018). Effect of land use changes on carbon stock dynamics in major land use sectors of Mizoram, Northeast India. *Journal of Environmental Protection*, *9*, 1262-1285.

SINGH, M., SRIDHAR, K. B., KUMAR, D., DWIVEDI, R. P., DEV, I., TEWARI, K. R, & C., O. P. (2018a). Agroforestry for doubling farmers' income: a proven technology for trans-gangetic plains zone of India. *Indian Farming, 68*, 33-35.

SMITH, J., PEARCE, B., & WOLFE, M. (2013a). Reconciling productivity with protection of the environment: Is temperate agroforestry the answer? Renew Agr Food Syst *28*, 80-92.

SMITH, J., PEARCE, B. D., & WOLFE, M. S. (2012). A European perspective for developing modern multifunctional agroforestry systems for sustainable intensification. *Renewable Agriculture and Food Systems*, *27*, 323-332.

SMITH, J., PEARCE, B. D., & WOLFE, M. S. (2013b). Reconciling productivity with protection of the environment: Is temperate agroforestry the answer? *Renewable Agriculture and Food Systems*, *28*, 80-92.

SOMARRIBA, E., CERDA, R., OROZCO, L., CIFUENTES, M., DÁVILA, H., ESPIN, T., MAVISOY, H., ÁVILA, G., ALVARADO, E., & POVEDA, V. (2013). Carbon stocks and cocoa yields in agroforestry systems of Central America. *Agriculture, ecosystems & environment, 173*, 46-57.

SÖNMEZ, O., TURAN, V., & KAYA, C. (2016). The effects of sulfur, cattle, and poultry manure addition on soil phosphorus. *Turkish Journal of Agriculture and Forestry*, *40*, 536-541.

SRIDHAR, K., & BAGYARAJ, D. (2017). Microbial biodiversity in agroforestry systems. *Agroforestry: Anecdotal to Modern Science*, 645-667.

STAMPS, W., & LINIT, M. (1997). Plant diversity and arthropod communities: implications for temperate agroforestry. *Agroforestry systems, 39*, 73-89.

STEPPLER, H. A., & NAIR, P. R. (1987). *Agroforestry: a decade of development*.

TILMAN, D., CASSMAN, K. G., MATSON, P. A., NAYLOR, R., & POLASKY, S. (2002). Agricultural sustainability and intensive production practices. *Nature, 418*, 671-677.

TORRALBA, MARIO, FAGERHOLM, NORA, BURGESS, J. P., MORENO, GERARDO, PLIENINGER & TOBIAS (2016). Do European agroforestry systems enhance biodiversity and ecosystem services? A meta-analysis. *Agriculture, ecosystems & environment, 230*, 150-161.

TROZZO, K. E., MUNSELL, J. F., & CHAMBERLAIN, J. L. (2014). Landowner interest in multifunctional agroforestry Riparian buffers. *Agroforestry Systems, 88*, 619-629.

TSONKOVA, P., MIRCK, J., BÖHM, C., & FÜTZ, B. (2018). Addressing farmer-perceptions and legal constraints to promote agroforestry in Germany. *Agroforestry Systems, 92*, 1091-1103.

TUBIELLO, F. N., SALVATORE, M., ROSSI, S., FERRARA, A., FITTON, N., & SMITH, P. (2013). The FAOSTAT database of greenhouse gas emissions from agriculture. *Environmental Research Letters, 8*, 015009.

UDAWATTA, R. P., RANKOTH, L. M., & JOSE, S. (2019). Agroforestry and biodiversity. *Sustainability, 11*, 2879.

URT (2009). *In:* (NAPA), M. F. T. C.-O. O. E. A. M. N. A. P. O. A. (ed.).

VAN DER WERF, W., ZHANG, L., LI, C., CHEN, P., FENG, C., XU, Z., ZHANG, C., GU, C., BASTIAANS, L., & MAKOWSKI, D. (2021). Comparing performance of crop species mixtures and pure stands. *Frontiers of Agricultural Science and Engineering, 8*, 481-489.

VAN VOOREN, L., REUBENS, B., BROEKX, S., PARDON, P., REHEUL, D., VAN WINSEN, F., VERHEYEN, K., WAUTERS, E., & LAUWERS, L. (2016). Greening and producing: An economic assessment framework for integrating trees in cropping systems. *Agricultural Systems, 148*, 44-57.

VARAH, A., JONES, H., SMITH, J., & POTTS, S. G. (2020). Temperate agroforestry systems provide greater pollination service than monoculture. *Agriculture, Ecosystems & Environment, 301*, 107031.

VERMA, P., BIJALWAN, A., DOBRIYAL, M. J., SWAMY, S., & THAKUR, T. K. (2017). A paradigm shift in agroforestry practices in Uttar Pradesh. *Current Science*, 509-516.

VERMEULEN, S. J., CAMPBELL, B. M., & INGRAM, J. S. (2012). Climate change and food systems. *Annual review of environment and resources, 37*, 195-222.

WATLING, J. I., ARROYO-RODRÍGUEZ, V., PFEIFER, M., BAETEN, L., BANKS-LEITE, C., CISNEROS, L. M., FANG, R., HAMEL-LEIGUE, A. C., LACHAT, T., & LEAL, I. R. (2020). Support for the habitat amount hypothesis from a global synthesis of species density studies. *Ecology letters, 23*, 674-681.

WICKE, B., SMEETS, E. M., AKANDA, R., STILLE, L., SINGH, R. K., AWAN, A. R., MAHMOOD, K., & FAAIJ, A. P. (2013). Biomass production in agroforestry and forestry systems on salt-affected soils in South Asia: Exploration of the GHG balance and economic performance of three case studies. *Journal of Environmental Management*, *127*, 324-334.

WILSON, M. H., & LOVELL, S. T. (2016). Agroforestry—The next step in sustainable and resilient agriculture. *Sustainability*, *8*, 574.

WIRSENIUS, S., HEDENUS, F., & MOHLIN, K. (2011). Greenhouse gas taxes on animal food products: rationale, tax scheme and climate mitigation effects. *Climatic change*, *108*, 159-184.

WU, J., ZENG, H., ZHAO, F., CHEN, C., LIU, W., YANG, B., & ZHANG, W. (2020). Recognizing the role of plant species composition in the modification of soil nutrients and water in rubber agroforestry systems. *Science of The Total Environment*, *723*, 138042.

XU, Y., LEHMANN, L. M., GARCÍA DE JALÓN, S., & GHALEY, B. B. (2019). Assessment of Productivity and Economic Viability of Combined Food and Energy (CFE) Production System in Denmark. *Energies*, *12*, 166.

YADAVA, A. K. (2010). Biomass production and carbon sequestration in different agroforestry systems in Tarai region of Central Himalaya. *Indian Forester*, *136*, 234-244.

ZAMAN, S., & AHMAD, S. (2011). Wood supply and demand analysis in Pakistan–key issues. *Pakistan Agricultural Research Council, Islamabad, Pakistan*.

ZUBAIR, M., & GARFORTH, C. (2006). Farm level tree planting in Pakistan: the role of farmers' perceptions and attitudes. *Agroforestry systems*, *66*, 217-229.