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Agroforestry: a tool for mitigating global climate change

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Abstract
Agroforestry, which involves the incorporation of trees and perennial woody plants within agricultural systems, is a time-honoured land management practice with profound implications for rural communities and the environment. This comprehensive review explores the multifaceted role of agroforestry in addressing contemporary challenges, particularly climate change. Climate change is an unprecedented global threat, exacerbating food insecurity, poverty, and environmental degradation. Developing countries, already facing critical development needs, will bear the brunt of its impact. This review examines the adaptation and mitigation functions of agroforestry systems, reevaluates the concept of sustainability, and investigates how agroforestry can enhance resilience and reduce vulnerability among smallholder farmers, particularly in tropical regions. Agroforestry contributes to carbon storage, biodiversity conservation, soil and water conservation, and diversified income sources. The review goes on to explore the capacity for carbon storage in agroforestry systems in both tropical and temperate.

Keywords: agroforestry, climate change, food security and poverty

Introduction

Agroforestry has been practised as a conventional use of land and livelihood alternative since time immemorial as a comprehensive and holistic land management system using perennial woody plants within farming systems. Agroforestry practises have a direct impact on the lives of a million rural people since they are linked to the majority of agricultural fields. Governments and international organisations must address the pressing issues of severe scarcity, squalor of the atmosphere, and environment change, both individually and together. Under increasing time constraints, there's a critical need to design an approach to deal with either these urgent regional as well as a long-term global concern [1]. Developing countries will be bearing the weight of global warming and suffering most severely from its adverse effects. Global agreements are ineffective in halting the growth in environmental greenhouse gas, or GHG, emissions and we now recognise that the fundamental forces of environmental degradation are unstoppable. As a result, mitigation initiatives will individually deliver a fractional easing of the possessions of environment change. Climates and earthly ecosystems will alter locally, endangering biology and social livings. Nonetheless, smooth as the climate changes, nourishment and grit manufacture, ecological facilities, and countryside lives must recover rather than simply remain stable. In the developing world, the status quo is unacceptable. Developing countries face critical development demands, such as improving nutrition security, reducing scarcity, and providing an appropriate standard of alive for rising peoples [2]. Agroforestry, or the mixing of plants and shrubs with yearly crop production and livestock, is a time-honoured managing approach used through farmers for its numerous of profits. It provides a consistent source of nutrition during the time, prevents soil resource dilapidation and maintains soil productiveness, expands farm income sources, rises and stabilises revenue, improves soil nutrient use productivity [3]. Agroforestry is crucial in climate change adaption because it protects livelihoods and revenue sources, increases agricultural output, and mitigates weather-related losses to production, and all of which enhance a region's resistance to climatic effects on farming systems. The following are the harmful effects of climate change on agriculture and forestry: hazard of natural resources; proliferation of pests, illnesses, and aggressive species; agriculture and forestry destruction; and high levels of nutrition scarcity. Agroforestry adaptation affects climate change via growing tree protection open-air of forests, improving woodland carbon stocks, protecting biodiversity, minimising hazards and destruction intensity, sustaining health and strength, and grading up numerous advantages [4]. Agroforestry has enormous potential in India. There is a vast hectare available in the shape of boundaries, bunds, and wastelands where this system can be implemented. This approach is suitable for growing the right tree species in areas where most annual crops flourish. Even in the most severe conditions, agroforestry ensures long-term sources of increased income. Recognising the scope of the problem, and the All India Coordinated Research Project on Agroforestry was initiated in 1983 and has subsequently expanded to encompass a substantial number of universities and research institutes. Due to its efficient land management that doesn't deplete soil fertility, agroforestry yields higher production and significantly contributes to the national economy. Consequently, a promising future for agroforestry in India is inevitable [5].

Potential for carbon storage in agroforestry systems in both tropical and temperate regions

Agroforestry holds significance as a carbon sequestration strategy due to its diverse plant species and soil's carbon storage potential. Additionally, its adaptability for agricultural lands and reforestation makes it a valuable approach. The potential seems substantial, but it has not been adequately acknowledged, let alone fully utilized. Well-designed and well-managed agroforestry practices have the potential to serve as effective carbon sinks. Like other land-use systems, the extent of carbon sequestration will depend on the amount of carbon in standing biomass, the persistent carbon retained in the soil, and the carbon stored in wood products. Agroforestry practices have been estimated to sequester 9, 21, 50, and 63 Megagrams of carbon per hectare (Mg C ha^{-1}) in semiarid, subhumid, humid, and temperate environments, respectively. The potential carbon sequestration rates in tropical smallholder agroforestry systems vary between 1.5 to 3.5 Megagrams of carbon per hectare per year (Mg C ha^{-1} yr^{-1}). Agroforestry can also indirectly impact carbon sequestration by alleviating pressure on natural forests, which act as the primary storehouse of terrestrial carbon. Another indirect method of carbon sequestration is the application of agroforestry techniques to enhance soil conservation, which has the potential to enhance carbon storage in both trees and the soil. Agroforestry systems that incorporate perennial crops could function as substantial carbon storage sites, whereas agroforestry systems through annual crops under intensive management resemble conventional agricultural practices in terms of carbon sequestration. To harness the substantial, yet untapped, the potential for carbon sequestration through agroforestry in both tropical and temperate regions., it is imperative to implement forward-thinking policies rooted in well-researched findings [6].

The potential for carbon storage in agroforestry systems in temperate regions

Alley cropping

Alley cropping involves the arrangement of sparsely planted rows containing one or more varieties of trees and/or shrubs, alongside the cultivation of agronomic crops within the alleys. This approach is aimed at enhancing environmental quality, microclimate conditions, carbon sequestration, economic gains, and providing benefits to wildlife. The choice of perennial companion vegetation is contingent on the landowner's goals and the appropriateness of the site. Within these systems, the arrangement of tree/shrub and crop rows, variations in carbon input into the soil, decomposition rates, past management practices, and the presence of soil microfauna collectively influence carbon sequestration [7].

Riparian buffers

The definition of riparian areas varies based on their intended use and geographical context. However, they are typically described as intricate terrestrial ecosystems comprising plants and various organisms located in proximity to aquatic environments. In general, carbon sequestration potential and storage tend to be greater in the above-ground component of riparian buffer systems when compared to row crops or upland forests. In North American riparian ecosystems, the tree density and basal area are often higher than or similar to those observed in upland areas, thereby contributing to carbon sequestration [8].

Silvopastoral system

The term used to describe a system in which trees, livestock and fodder are managed concurrently is recognized as a "silvopastoral system." In North America, this organization exhibits a range of variations. These include systems predominantly associated with agriculture, where trees are planted near pastures and utilized for orchard grazing. Furthermore, there are integrated systems that combine agriculture and forestry, like the combination of pine forests, pastures, and cattle in the southeastern region. Lastly, there are systems exclusively dedicated to forestry, exemplified by managed forest rangelands. In the southeastern United States, traditional silvopastoral agroforestry practices involve the simultaneous cultivation of pine trees and the grazing or pasturing of pecan trees. Numerous agroforestry experiments in this region have emphasized the utilization of cool-season forage plants as supplements. This is due to the fact that warm-season forages tend to wither or go into hibernation during the cold months, leading to a shortage in forage availability [9].

Shelterbelts/Windbreaks

Shelters, sometimes known as windbreaks, offer a mostly appealing option for mitigating greenhouse gas emissions through carbon storage on agricultural lands (Schoeneberger 2009). The reason behind this is that windbreaks, which occupy a relatively small portion of the land (3 - 5%) (Brandle *et al*. 2009), offer a multitude of services valued by both landowners and society. These services include increased production to compensate for the land allocated to windbreaks, Furthermore, windbreaks, in addition to the co-benefits of carbon sequestration and emissions reduction (Schoeneberger 2009). Windbreaks are essentially linear arrangements of trees and shrubs, designed to serve as barriers for reducing wind speed (Rosenberg 1983, Brandle *et al*. 2009), as described by Buck *et al*. in 1999. Windbreaks have the capacity to decrease evapotranspiration, as noted by Caborn in 1957 and Brandle *et al*. in 2009. Additionally, they contribute to the reduction of wind erosion and soil separation caused by raindrops, as highlighted in Brandle *et al*. 1992b. Windbreaks also contribute to carbon sequestration in both crop and livestock production systems while concurrently reducing energy consumption in farm operations. This reduction stems from a decreased reliance on fossil fuels for heating and cooling homesteads and barns (Brandle *et al*. 1992b, Kort and Turnock 1999) [10].

The potential for carbon storage in agroforestry systems in tropical regions

Potential of agroforestry for carbon sequestration

A large portion of the available estimates for carbon sequestration potential in agroforestry systems primarily concentrate on tropical regions. After conducting an initial assessment of national and global terrestrial carbon sinks, Dixon (1995) identified two main advantageous characteristics of agroforestry systems with regard to carbon sequestration: (1) The immediate storage of carbon in trees and soils over the short to long term, ranging from decades to centuries; and (2) The potential to potentially offset the immediate greenhouse gas emissions associated with deforestation and subsequent shifting cultivation [11]. Nonetheless, enhancing carbon stocks within a specific time frame represents only one aspect; what truly determines sequestration is the fate of these accumulated stocks. In agroforestry systems, carbon sequestration is a dynamic process that can be classified into various phases. During the initial establishment phase, many of these systems are likely to function as sources of greenhouse gases, mainly due to carbon and nitrogen loss from vegetation and soil [12]. Afforestation and reforestation of deteriorated natural forests have been widely acknowledged as valuable practices for mitigating climate change by capturing carbon. Agroforestry, on the other hand, presents several unique benefits [13]. Carbon sequestration in terrestrial reservoirs comprises the biomass found aboveground, encompassing elements like timber and fuelwood, as well as the belowground biomass, including roots, soil microbes, and the comparatively enduring organic and inorganic carbon forms within soils and deeper subsurface settings [14]. Considering the observed scale of alterations in carbon stocks, the prospect for swift carbon sequestration in humid tropical regions primarily lies within the vegetation, with a relatively smaller impact in the topsoil. However, there is less information available regarding the potential carbon changes in deeper soil layers [15].

Soil carbon

The selection of tree species and their arrangement within different agroforestry systems will influence both the quantity and the quality of biomass that gets reintegrated into the soil. While polycultures tend to accumulate more carbon in the soil, it's worth noting that soil carbon stocks can also rise in monoculture tree systems, contingent upon the specific tree species involved (Russell *et al*., 2004). Roots show a crucial part in the carbon balance of the soil since they store substantial amounts of carbon within it. More than one-third of the carbon absorbed by the plant is eventually transferred below the ground through processes such as root growth and turnover, the release of organic substances via root exudates, and the deposition of litter [16]. In numerous tropical regions, consistent incorporation of pruned vegetation and the cycling of root materials over time have played a character in enhancing the gathering of soil organic matter (SOM) and nutrient reserves in the soil, as documented by studies like Lehmann *et al*. (1998), Rao *et al*. (1998), and Kumar *et al*. (2001). In a 12-year high-input (HI) experimental conducted on a Nigerian Alfisol, the combination of *G. sepium* and *Leucaena leucocephala* led to a 15% increase in surface soil organic carbon (SOC), which amounted to 2.38 megagrams of carbon per hectare, in comparison to sole crop systems (Kang *et al*., 1999). Similarly, a 12% boost in SOC, equivalent to 0.23 megagrams of carbon per hectare, was observed after 5 years of high-input agroforestry involving Inga edulis in a Typic Paleudult located in Peru (Alegre and Rao, 1996) [17]. The soil carbon (C) reservoir consists of soil organic carbon (SOC) projected at 1550 petagrams (Pg) and soil inorganic carbon, approximately 750 Pg, together extending to a depth of 1 meter (Batjes, 1996). This combined soil carbon pool amounts to 2300 Pg, which is 3 times the size of the atmospheric carbon pool (770 Pg) and 3.8 times the size of the vegetation carbon pool (610 Pg). It's worth emphasizing that a decrease in the soil carbon pool by 1 petagram (Pg) is equivalent to an increase of 0.47 parts per million by volume (ppmv) of CO_2 in the atmosphere (Lal, 2001) [18].

Biodiversity

Several authors have examined the mechanisms by which agroforestry systems promote biodiversity. These studies include works by authors such as Schroth *et al*. (2004), McNeely (2004), McNeely and Schroth (2006), Harvey *et al*. (2006), and Jose (2009). In a broader context, agroforestry serves five significant roles in biodiversity conservation:

- **Habitat Provision:** Agroforestry systems provide habitat for species that can tolerate a certain level of disturbance.
- **Germplasm Preservation:** Agroforestry contributes to the preservation of genetic resources of sensitive species.
- **Habitat Conservation:** By offering a more productive and sustainable alternative to traditional agricultural systems that might require clearing natural habitats, agroforestry aids in lowering the rates of natural habitat conversion.
- **Connectivity:** Agroforestry establishes corridors between remaining habitat areas, promoting connectivity that enhances the preservation of area-sensitive flora and fauna and maintains the integrity of these remnants.
- **Ecosystem Services:** Agroforestry contributes to the conservation of biological diversity by delivering vital ecosystem services such as erosion control and water recharge. Consequently, this aids in averting the degradation and loss of the surrounding habitat [19]. Current research in tropical fragmented landscapes suggests that small, isolated fragments of less than 100 hectares in size (with most of the area being forest edge) are predominantly inhabited by common and invasive species while lacking in rare and endemic species [20]. Agroforestry practices have often shown their capacity to enhance levels of wildlife diversity on agricultural land. Additionally, it is suggested that these practices can play a complementary role in conserving biodiversity within the remnants of natural habitat that are interspersed with farmland in tropical land use mosaics [21]. Agroforestry holds significant promise for biodiversity conservation due to the fact that 43% of the world's agricultural land already incorporates a minimum of 10% tree cover, as noted by Zomer *et al*. in 2016 [22]. Applying this concept to agroforestry systems implies two key points:

- Agroforestry systems possess attributes that facilitate the restoration of biodiversity to levels similar to those observed in the original land use system before land conversion disturbances occurred.
- The management practices within agroforestry systems are gentle enough to prevent irreversible changes during their operational lifespan. This idea was explored by Tittonell (2014) in the context of tropical agroecosystems in Africa, incorporating the concept of resilience [23]. Lastly, it's important to note that biodiversity associated with forests is often regarded as the most vulnerable and imperiled in tropical forest ecosystems [24].

Soil and water conservation

Conservation of soil and water has been a global priority in this millennium. Soil conservation is defined as the practice of maintaining soil fertility by controlling erosion, preserving organic matter, managing soil physical properties, ensuring nutrient balance, and preventing toxicities, as outlined by Young in 1989. Soil and water conservation involves minimizing soil loss from runoff and increasing the rate of water infiltration into the soil. Relying solely on crops may not be sufficient to reduce runoff velocity. However, when trees are cultivated alongside crops, they enhance soil stability and permeability, resulting in improved water conservation [25]. soil and water conservation are integral components of the broader objective of conserving natural resources. This overarching goal encompasses the preservation of not only soil and water but also other critical resources, such as vegetation (forests and pastures) and wildlife [26]. This review offers an overview of various agroforestry systems concerning soil conservation and soil health. Agroforestry systems play a crucial role in enhancing soil quality and improving soil health in diverse agroecosystems [27].

Improved Livelihoods

The concept of sustainable livelihood has gained prominence in humanitarian and international development organizations aiming to assess and build sustainable livelihoods for agroforestry producers. But, measuring, analysing, and visualising data on enhancing livelihoods from agroforestry (AF) is difficult [28]. Agroforestry has been proposed as a potential livelihood strategy to bolster resilience in the face of an uncertain future, as highlighted by several researchers (Kandji *et al*., 2006; Lin, 2011; Mbow, Smith, Skole, Duguma, & Bustamante, 2014; McCord, Cox, Schmitt-Harsh, & Evans, 2015; Simelton, Viet Dam, & Catacutan, 2015; Thorlakson & Neufeldt, 2012; Verchot *et al*., 2007). Agroforestry encompasses a variety of mixtures involving plants, crops, and animals within the landscape, with diverse spatial configurations and temporal sequences (Sinclair, 1999). Although there has been a suggestion that agroforestry enhances livelihood resilience, there is a limited number of comprehensive empirical studies that explore these connections. Instead, prior research has primarily centred on the indirect benefits of agroforestry [29]. One of the outcomes of adopting agroforestry is an increase in crop yield, primarily attributed to soil enhancement. The products derived from agroforestry plants play a substantial character in enhancing the economic well-being of households. These agroforestry tree products serve as sources of income and revenue for the households [30]. In one way or another, the practice of agroforestry serves as a means for farmers to access both food and cash. In the study area, the primary agricultural activities carried out on farms include vegetable production, tree crop cultivation, and livestock husbandry [31]. Nevertheless, traditional agroforestry has been a time- honoured practice for countless generations among agrarian societies worldwide [32]. The effects of livelihood strategies on the well-being of woodlands and individual species can differ significantly [33]. Enhancing livelihoods will require the adoption of new approaches and the acquisition of financial support [34].

Potential of agroforestry as a climate-smart agriculture technology

The agricultural sector must embrace climate-smart practices to effectively tackle the intertwined challenges of food security and climate change. Agriculture, which includes forestry and fisheries, holds a central role in ensuring food security and rural livelihoods. It also provides essential resources such as energy, fiber, animal feed, and a wide range of ecosystem services. Climate-smart agriculture serves as a pathway to development and food security, and it is built upon three key pillars:

- Increasing productivity and income, enhancing livelihoods and ecosystem resilience, and reducing or eliminating greenhouse gas emissions from the environment.
- Climate-smart agriculture contributes to the attainment of various development objectives.
- Although there are abundant opportunities to leverage synergies among the pillars of climate-smart agriculture, there are also instances where trade-offs are inevitable [35].

Climate wise agriculture is any agricultural approach or practise that helps to the achievement of these pillars. Frequently, various techniques exhibit varying performance across the three pillars, necessitating their integration into a comprehensive Climate-Smart Agriculture (CSA) approach to complement each other and optimize their advantages (World Bank 2015, FAO 2015) [36].

Recent technological development in agroforestry and their adoption

Agroforestry research is tailored to specific sites and regions, resulting in agroforestry technologies that differ across various agro-climatic zones. The characterization of agroforestry systems for different agro-climatic zones is determined by the selection of promising tree species that are well-suited to each specific zone [35].

Poplar based agroforestry

Poplar is a highly preferred agroforestry species, especially in irrigated, fertile lands found in regions such as Punjab, Haryana, Western Uttar Pradesh, and the outer plains or valleys of Uttarakhand and Himachal Pradesh [37]. The total reported global area where poplar trees have been planted, either in block plantations for wood production, environmental purposes, or in agroforestry systems, covers 6.7 million hectares. Among these, 3.8 million hectares (56%) were primarily allocated for wood production, while 2.9 million hectares were designated for environmental purposes. Middlemen have a significant role in the sale of poplar wood, and they frequently take advantage of the growers. Farmers cultivating poplar trees often encounter frequent price fluctuations for poplar logs. The improvement in the price of poplar wood indicates that poplar cultivation has reached a mature stage in the country and has firmly entrenched itself in the national economy [38]. As the Indo-Gangetic Plain (IGP) is commonly known as the food bowl of India, integrating trees into farms, which can potentially reduce yields due to shading, might present a hurdle to the widespread adoption of agroforestry. Consequently, there is a need for additional research to establish standard tree-crop combinations and management practices to address this challenge [39].

Agroforestry

Teak based agroforestry

In India, poplar is the second greatest commonly established tree species after teak. With the exception of the northeastern states, poplar has been extensively planted on a large scale throughout the country. Agroforestry technology based on Eucalyptus is widely popular in the Indo-Gangetic plains of India. Eucalyptus is the favoured tree species for planting along the edges or bunds of agricultural fields in India, and it appears to be well integrated and widely accepted within the country's agroforestry practices. In agrosilviculture, a wide variety of crops can be cultivated with a spacing of 5 meters by 2 meters, allowing for intercropping for up to three years. In block plantations, the trees are spaced 3 meters apart within rows and 1.5 meters apart between rows, resulting in a density of 2222 plants per hectare. This configuration allows for intercropping during the first two years within a 4-year rotation period. During the initial years, intercrops like chilies, cotton, tobacco, black gram, and green gram are commonly cultivated alongside eucalyptus [35].

Eucalyptus based agroforestry

In India, it is the second most commonly cultivated tree species, following teak. Apart from the northeastern states, it has been extensively planted throughout the country. Eucalyptus-centered agroforestry practices are widely embraced in the Indo-Gangetic plains of India. Eucalyptus is the preferred tree species for planting along the perimeters or embankments of agricultural fields, and it is well-integrated and well-received in Indian agroforestry practices. In agrisilviculture, a spacing of 5 meters by 2 meters allows for intercropping with a variety of crops for up to three years. In block plantation, the trees are spaced 3 meters apart between rows and 1.5 meters apart within rows, resulting in 2222 plants per hectare. This setup enables intercropping during the first two years of the 4-year rotation cycle. Eucalyptus is often intercropped with crops like chilies, cotton, tobacco, black gram, and green gram during the initial years. The promotion of agroforestry and farm forestry by the private sector, particularly through clonal eucalyptus plantations, has proven beneficial to thousands of farmers. From 1992 to 2007, around 8 million hectares were planted with eucalyptus, as noted by Piare Lal in 2015. Increased yields, improved product quality, and reduced production costs have significantly boosted the profitability of clonal eucalyptus plantations. On average, farmers can anticipate net returns of up to ₹300,000 per hectare over a 4-year rotation period for irrigated clonal eucalyptus plantations, assuming a yield of 150 tons and the current farm gate price of ₹2,000 per ton for eucalyptus logs [35]. The agroforestry system centered around eucalypts is conducive to the cultivation of various crops, thanks to its open canopy and light penetration. With this in mind, the current study focuses on the evaluation of Eucalyptus-based agroforestry systems in the saline soils of the semi-arid regions of India [42]. Brazil holds the distinction of being the leading country in the world when it comes to eucalyptus planting, with a vast area of 10,52,000 hectares dedicated to eucalyptus plantations [43].

Sapota-teak based agroforestry system in hill zone

Sapota is a significant tropical fruit crop cultivated in the hilly and transitional regions of Karnataka, both in rainfed and irrigated conditions. Using wider spacing for this crop allows for intercropping opportunities in the initial years. This approach is well-suited for hilly areas and medium-depth soils with access to irrigation. The technology has been demonstrated in farmers' fields as part of the National Extension Technology Programs, specifically the ORP-II (Technology Extension Project on Agroforestry), covering an area of 50 hectares in total. In addition to teak, farmers are seeking information about other local timber tree species suitable for planting in orchards. Many farmers prefer to plant only one tree between two mango or sapota trees instead of the recommended three trees. This technology has been adopted by 5-10% of farmers engaged in cultivating plantations with sapota or mango.

Mitigation strategies

As we all comprehend, climate change is an extremely serious global environmental concern confronting all living organisms, including humans, because it disrupts natural ecosystems, agriculture, and health. Because of the changes in weather and climate patterns, agricultural output is no longer sustainable. In this case, agroforestry is a suitable mitigation approach. Climate change and global warming can be mitigated by absorbing Carbon sequestration reduces greenhouse gas emissions (CO2). As a result, agroforestry, a type of Climate Effective Agriculture, is a potential adaption choice for smallholder farmers worldwide. The manifold advantages of agroforestry's adaptability have been exemplified through case studies and scientific research conducted in developing nations across Asia, Africa, Central, and South America (Colin, 2013) [40].

- Enhancing our comprehension of how agroforestry practices contribute to both adaptation and mitigation of

environment change, as well as how climate change impacts agroforestry systems (AFS), is essential.
- The development of methods and strategies for scaling agroforestry technologies to achieve landscape-level impacts is a vital undertaking.
- Establishing suitable policies and institutional frameworks to encourage the adoption of agroforestry is essential [41].

Furthermore, the introduction of resistant plant varieties, mixed cropping, reforestation, and agroforestry practises are key corrective measures to mitigate climate change, which helps to improve people's socioeconomic position. Consequently, sustainable agroforestry has the potential to enhance resilience to environmental changes, support carbon sequestration, and generate income, ultimately leading to improved livelihoods for small and subsistence farmers (Buchman, 2008) [40].

Conclusion
In conclusion, agroforestry represents a crucial and multifaceted approach to tackling diverse global challenges, encompassing climate change, food security, and rural livelihoods. It has strong roots in traditional land use practices and provides a multitude of benefits that directly influence the well-being of countless individuals worldwide. Agroforestry systems, with their integration of woody perennials within farming systems, provide numerous advantages. They not only meet household needs for essential resources such as fuelwood, timber, fruit, and fodder but also contribute to economic stability by diversifying income sources. Climate change, recognized as one of the most significant global threats to humanity, is exacerbating existing challenges such as food insecurity, rural poverty, and environmental degradation. Agroforestry emerges as a key strategy to address these challenges, particularly in developing countries. It helps enhance agricultural productivity, mitigates weather-related production losses, and strengthens the resilience of farming systems. Agroforestry's ability to increase carbon stocks in vegetation, soils, and wood products is a valuable contribution to the global effort to reduce atmospheric carbon concentrations. Recent technological developments in agroforestry, such as poplar and teak-based systems, demonstrate the adaptability and economic potential of agroforestry in various regions. These innovations, along with ongoing research and policy support, continue to expand the scope and effectiveness of agroforestry practices. In conclusion, agroforestry is a versatile and effective approach that tackles numerous global challenges, making it an essential element of sustainable land management, climate change mitigation, and rural development. Its ability to provide environmental services, mitigate climate change, and improve livelihoods positions it as a valuable tool for building a more resilient and sustainable future for agriculture and the environment.

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