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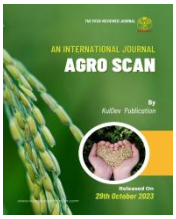

Review Article

An overview of agroforestry's potential to mitigate climate change via carbon sequestration

Samir K Shaikh

Department of Agriculture, Kohinoor Arts, Commerce and Science College, Khultabad-431209, India

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ABSTRACT

It is well acknowledged that human activity is now having a greater impact on changes in the global climate. Forest degradation and deforestation and result in increased carbon emission. On the other hand, this may be controlled by managing the land and forests sustainably. Therefore, this review article is to provide the collected research on potential to agroforestry in mitigating climate change by sequestering carbon. Enhancing forest carbon stores by agroforestry was one of the primary way to lower atmospheric greenhouse gas concentration. Agroforestry is a novel, wide-ranging practice that combines livestock and agricultural components with woody plants. Consequently, agroforestry's contribution to mitigating climate change has drawn a lot of attention in recent decades. Therefore, agroforestry's biggest contribution to combating climate change is its ability to absorb carbon from the environment, therefore reducing CO2 emissions. Since monocrop agriculture has less potential than agroforestry practices to promote carbon sequestration in regions dominated by agriculture.

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Introduction

We can all understand that the repercussions of climate change are a global problem that affect every country. Above all, worry about climate change will spread across the world. Developing countries will bear a disproportionate amount of the brunt of climate change's consequences. Mitigation efforts will only partially lessen the effects of climate change. It is well known that human activity significantly influences changes in the Earth's climate [1]. The livelihoods of humans and all other biota were at risk due to changes in the terrestrial ecology and local climate. Some of the potential negative impacts of climate change include an increase in sea level, a rise in the frequency and intensity of tropical storms, floods, droughts, and wildfires; modifications to the amount, timing, and distribution of rain; disturbance of coastal marine and other ecosystems; and more [2]. Agricultural systems with deteriorated land and resource bases, coupled with unsustainable management methods, are the most vulnerable to the effects of climate change. Following the removal of aboveground biomass for harvesting, decomposition, burning, and soil loss occurred.

* Corresponding author.
E-mail address: samirshaikh22@gmail.com (Samir K Shaikh)

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And carbon as CO_2 and erosion of soil carbon were the major ways that agricultural activities reduce carbon stocks. Deforestation in the tropics is responsible for up to 27% of global net yearly CO_2 emissions [3]. The concentration of CO_2 in the atmosphere now at 388 parts per million and is expected to rise to between 470 and 578 parts per million by the year 2055 [4]. Trees have a significant role in lowering vulnerability, boosting agricultural systems' resilience, and protecting homes from threats associated with climate change [5]. Globally, forestry has emerged as a key strategy for reducing CO2 emissions and mitigating climate change. On the other hand, by implementing mitigation and adaptation measures, agriculture and plantations may also be able to address climate change [5]. Effectively managed agroforestry techniques enable this [6].

Agroforestry, which integrates forestry and agriculture was sustainable and promising method of land use in developing nations where farms are mostly supported by trees [7]. It enable to farmer to concurrently produce fodder, fuel, food and fibre from the same unit of land, offering an integrated solution to land-use issues. There are interactions between the many components of an agroforestry system on both an ecological and economic level [8, 9]. Because some agroforestry techniques may absorb CO_2 from the atmosphere and store in plant along the soil and they have drawn more attention to their net carbon sequestration impact [10]. Therefore, the goal of this review study is to provide the collected research on the contribution of agroforestry to the mitigation of climate change via carbon sequestration (Table 1).

Table 1: Carbon sequestration potential of different agroforestry system.

Agroforestry System	Carbon Accumulation
Taungya agroforestry system	174MgC ha^{-1}
Mixed multistory/multistery system	162MgC ha^{-1}
Falcata-coffee multistorey system	92MgC ha^{-1}

Techniques

This work is only a review. Every piece of information was gathered from secondary sources. All of the information in this article was gathered from papers, including Google Scholars, as well as books, reports, dissertations, and conference proceedings. Additionally, other studies were found by doing a manual Google search. The reference lists of the papers that were obtained were also searched for further articles. Regarding the technique, research participants, or publishing year, no restrictions were placed. The "adaptation," "Carbon Sequestration" "agroforestry," "Climate change" and "mitigation" were the main search phrases.

Based on findings from several international research the contribution of agroforestry to climate change mitigation along carbon sequestration were outline in this study. This section discusses the idea of an agroforestry system, carbon sequestration, and agroforestry's ability to mitigate climate change.

Definition and fundamental ideas

The integration of woody plant with agricultural and animal components is a novel and large practice known as agroforestry [3, 11]. As a result agroforestry role in adapting and mitigating to climate change has garnered lot of attention in recent decade [12]. Among the noteworthy practices in tropical environments are the following: better fallow management; domestication of new and underutilised tree species utilisation of appropriate tree and shrub species to intensify agriculture on incorporation and smallholder farms of fast-growing, nitrogen-fixing trees and shrubs in agricultural fields to improve soil fertility [11]. Measures to reduce the amount or pace of long-term global warming and its associated impacts are referred to as climate change mitigation [2]. Reducing greenhouse gas emissions from human activity (anthropogenic) is a common strategy for mitigating climate change [3]. Reforestation is one method of boosting carbon sink capacity, which may also be used to mitigate [3]. Policies for mitigation may significantly lower the hazards related to global warming caused by humans [4].

"Climate change is an instance of the 'tragedy of the commons,' while mitigation serves the public good." As noted in International collaboration and emissions trading, individual, institutional and national actions motivated by self-interest will not lead to effective mitigation of climate change [13]. Collective action

is thus necessary. Carbon dioxide was most common greenhouse gas. Carbon sequestration has the process of removing and storing carbon dioxide from the atmosphere. It is one strategy for lowering atmospheric carbon dioxide levels in an attempt to mitigate global climate change [14].

Using agroforestry to mitigate climate change by sequestering carbon

Agroforestry means mitigating climate change along agriculture and climate change are closely related. This is especially true in underdeveloped nations where farming, particularly rain-fed agriculture, is the primary source of income [5]. Various writers, including [5,11,15–16], have detailed their research on the degree to which agricultural systems are particularly susceptible to climate change. Due to a lack of resources, smallholder farmers in tropical regions are especially susceptible to climate change when it comes to subsistence farming [11]. One of the innovative and promising approaches to addressing climate change is the use of enhanced farming practices in conjunction with trees. Indeed, in many regions of the globe today, agroforestry is likely to be a "bright sector" in the fight against climate change.

Agroforestry is regarded as a cost-effective strategy as well. Agroforestry systems have the potential to provide significant mitigation choices, even if they need proper management that influences the amount of carbon stored [17]. Based on his findings, agroforestry in Africa may help smallholder farmers adapt to climate change and perhaps cut down on greenhouse gas emissions into the environment. Most research indicates that of all agricultural land management systems advocated for greenhouse gas reduction in Africa, agroforestry techniques have been utilized and studied the most [18]. [19] The study under consideration provided an explanation of agroforestry as a means of mitigating the adverse impacts of climate change and a special opportunity to combine the objectives of adaptation and mitigation. As stated by him, agroforestry may increase the system's ability to withstand the adverse consequences of climate change. Agroforestry systems have the potential to assist smallholder farmers in sub-Saharan Africa and other tropical regions in general in adapting to predicted changes in the climate, according to studies carried out in Kenya.

This conclusion makes agriculture one of the high priority sectors since it indicates that million of smallholder farmer who depend on the agricultural industry for their livelihoods are at danger as a result of climate change. Next, make use of any nearby agroforestry systems to assist local populations in adapting to and become more robust to the impacts of climate change [11]. More study conducted in Ethiopia by [5] found that trees have a significant role in lowering vulnerability, boosting agricultural systems' resilience, and protecting families from dangers associated with climate change. The greatest "no regrets" strategies for assisting communities in adapting to and becoming more robust to the effects of climate change are thought to use agroforestry treatments. The tree component of agroforestry systems may be a significant carbon sink on land used for agriculture. This might thus suggest that many stakeholders should work together to promote agroforestry. Agroforestry mitigates climate change by supplying wood products from farms, which lessens the demand for deforestation, and by enhancing soil quality and preserving fertility and excellent nutritional balance, which lessens the need for fertilisers [20].

Agroforestry enhances agricultural resilience by yielding more crops and giving farm animals better homes [21]. Moreover, depending on the kind of crop, it may alter the microclimate in a manner that increases agricultural output by 6% to 56%. By reducing soil erosion brought on by wind and water and enhancing the physical health and fertility of the soil as a result of stable tree cover and a variety of biological niches, agroforestry effectively buffers climate fluctuation. The two most crucial elements of an agroforestry system are the creation of habitat and the maintenance of biodiversity, which includes pollinators and beneficial insects. Agroforestry has the potential to promote soil fertility and ecological stability via enhanced microclimate creation, reduced erosion, and increased carbon input from trees, as shown by studies [20 and 22]. Along with offering a greater variety of ecosystem goods and services, such as high biodiversity and carbon sequestration, it may also repair damaged areas. Sequestering carbon using agroforestry systems: Carbon emissions increase as a result of deforestation [10]. However, this might be managed by practicing sustainable land and forest management. One of the main ways to reduce the concentrations of greenhouse gases in the atmosphere is via agroforestry's capacity to build forest carbon storage.

For example, using fossil fuels generates almost 26% of the world's CO_2 emissions in the United States [23]. Perhaps agroforestry's most significant contribution to combating climate change is its ability to effectively absorb carbon from the atmosphere, hence reducing CO_2 emission. From an agroforestry perspective, [24] states that the main processes in carbon sequestration were the intake of atmospheric CO_2 during photosynthesis and the fixed carbon transfer into plant, detritus and soil pools for "secure" storage [23]. Agroforestry is a technique for mitigating greenhouse gas emissions on agricultural lands by storing carbon in biomass and soils and lowering GHG emissions overall, particularly via avoided emissions from reduced energy consumption and fuel use. Adopting agroforestry practices offers a higher potential than monocrop agriculture to promote carbon sequestration in landscapes dominated by agriculture [25].

The study's findings demonstrated that there is convincing evidence of variations in carbon sequestration across different land use systems. Researchers used a technique that was almost identical to determine the amount of carbon stored in various plant components or in another pool. Trees are measured at their diameter breast height (dbh), and soil, litter, and herbaceous plant samples are taken in order to determine the carbon content and conduct farmer interviews [26, 27]. Agroforestry techniques helped restore 37 % of the original carbon stock of the destroyed forest in the tropics, compared to crops and pastures, which only contributed 12% of the total. Compared to cropland management systems, which can only sequester 100Mt C/year by 2040, agroforestry systems can sequester 605 Mt C/year (Figure- 1). According to carbon stock assessment research done in the Philippine [28], carbon buildup in agroforestry systems occurs in the following order:

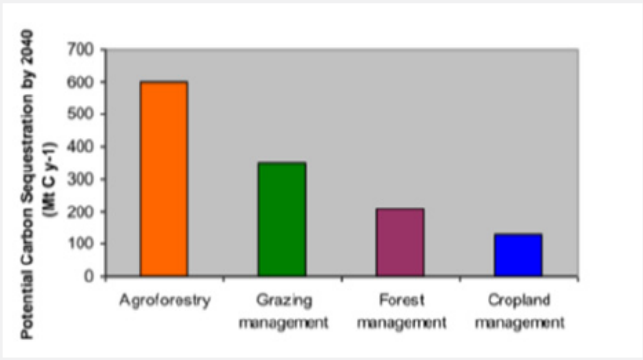

Figure 1: Carbon sequestration potential of different land use system [42].

Moreover, the carbon stored in the various pools was found to be arranged as follows: soil (78-94%) > trees (7.1-27%) > herbaceous plants and litter (1.5%). A research conducted in India by [28] found that agroforestry systems capacity to store carbon is influenced by environmental and social factor. Agroforestry systems which include windbreaks, silvopastures, home gardens, and alley cropping, have the capacity to sequester more than 75 Mg/ha in humid tropical environments. This is based on a meta-analysis of 427 soil C stock data pairs, which was conducted in the top 25 cm. The investigation included AF alterations as well as adjacent control pasture or crops. The average soil carbon storage in AF were measured to be 129 Mg C•ha−1, 24 percent more than those in pasture or crops, at 1.56 mt depth. The highest soil C reserves were found in subtropical household gardens, AF with younger trees and top soil (0.5–21 cm). Increased soil C stocks in AF were less than aboveground C stocks in the majority of AF system with the exception of alley cropping. The largest concentration of C was found in home gardens, particularly in the subsoil (25–101 cm), both above and below ground. AF has the potential to store an extra 5.3 × 111 Mg of carbon in soil on 972 Mha worldwide, mostly in the tropics and subtropics. According to a 14 year old Ontario, Canada alley-cropping system's scientific evaluation [30], compared to sole-cropping plots, the system's C content ranged from 12.4 % to 42.7 % higher, depending on the kind of tree.

If implemented over greater distances, AF systems might significantly increase soil C sequestration globally. Accordingly, [31] examined the possibility of storing carbon in household gardens as well as their contribution to lowering the atmospheric concentration of CO_2. According to the study's findings, home gardens can sequester more carbon than monospecific production systems, and doing so at a cheaper cost than reducing emissions or sequestering carbon via other methods. Furthermore, [32] described how the agroforestry system in home gardens has a great potential for sequestering carbon in its soil and variety of plant species, particularly wood perennial plants. By reducing the strain on natural forests, this system aids in the conservation of carbon stock in existing forests. Additionally, [33] states that a home garden agroforestry system may be beneficial in minimizing C substitution by promoting the production of wood fuel and lowering the consumption of fossil fuels. According to the majority of studies, adding a significant amount of the comparatively high quantity of plant materials generated in a system would raise the soil's C stock.

As such, it seems reasonable to believe that home gardens will play a major role in helping to sequester C [31, 34]. There are two ways that agroforestry systems may store carbon: aboveground and belowground. Carbon is stored in both above ground biomass, stem, branch, leaf, soil and roots in agroforestry system. The significant aboveground biomass and deep tree root systems of agroforestry systems in particular have attracted increased interest for climate change adaptation and mitigation [35]. The factors influencing the final amount sequestered in each compartment include the ecoregion, type of system (including the age and composition of perennials like trees), site quality, and prior land use. About two thirds of the total carbon stored in land use systems based on trees is thought to be held by the soil, which includes living biomass such as roots, and the aboveground portions of the soil [36]. based on the idea that adding trees to pastures and croplands would increase the amount of net carbon stored both above and below ground [37, 38].

Agroforestry systems are believed to have a higher capacity to store carbon than pastures or field crops grown in similar ecological conditions [39, 40]. The rate at which soil sequesters carbon is influenced by temperature, soil aggregations and structures, and the quantity of dead organic matter that plants contribute [21]. There's evidence that deeper soil layers retain more carbon, even if tree-based agroforestry systems are superior than treeless pastures in this regard [11, 15]. Agroforestry, for example, is thought to store between 0.30 and 14.38 mg C/ha/year above ground, and between 30-300 mg C/ha down to a depth of 1 m in the soil [23]. Agroforestry systems can sequester 27 t.ha-1 of carbon on average across 98 million hectares, according to studies by [41, 42], albeit there is a lot of regional variation. His findings indicate that agroforestry systems provide villagers income, employment opportunities, and a stable source of food.

In summary

This review study demonstrates how carbon sequestration by agroforestry offers a viable and alternative method of lowering and mitigating CO_2 emissions from the atmosphere. Establishing agroforestry systems might significantly decrease the quantity of carbon emissions generated by human activity. As a result, carbon can be sequestered in two ways via agroforestry systems: aboveground and belowground. Thus, in agroforestry systems, carbon is sequestered in both aboveground biomass—such as stem, branch, and foliage—and belowground biomass—such as soil and roots. Although agroforestry systems need correct management that affects the amount of carbon stored, they have the potential to provide substantial mitigation alternatives.

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