7. Agroforestry as Answer to Rising Carbon Emission in Agriculture

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Abstract:

Carbon emission is a major threat to the ecosystem as it triggers the global warming resulting in rise of the atmospheric temperature, contributing towards climate change. IPCC explains five key sectors as industry, buildings, energy, transportation, and AFOLU responsible for maximum release of carbon emission. Agroforestry is a critical component in mitigating the negative effects of changes in the climate. Agroforestry offers a unique chance to meet the mitigation as well as adaptation goals for climate change. Agroforestry systems lower greenhouse gas emissions from soils by storing carbon in soils and woody biomass. Recent research in various agroforestry systems in various ecological conditions has highlighted the need of agroforestry in restoring carbon stocks in biomass above ground and soil, as well as enhancing economic stability and diminishing vulnerability to climate change.

Keywords:

Agro-forestry, Climate Change, Carbon emission, Diminishing, Vulnerability

7.1 Introduction:

Agroforestry is an integrated approach to growing trees with agricultural practices. It is the cultivation and utilization of forest trees with crops, including livestock rearing, in an agricultural system. American economic geographer J. Russell Smith first formally described agroforestry in his book entitled "Tree Crops: A Permanent Agriculture"(1929)[1]which he saw as a solution to the destructive erosion that frequently followed the cultivation of sloping lands[2] It is a dynamic, ecologically oriented bio-resource management strategy that diversifies and maintains productivity while also building social institutions via the inclusion of woody perennials within farms and agricultural landscapes [3]. Carbon Emissions for a specific duration represent the total carbon equivalent greenhouse gas emissions associated with the consumption of energy during that period, represented in metric tonnes of equivalent carbon dioxide.

Carbon emissions are the most significant contributors to greenhouse gas (GHG) emissions, which trigger environmental degradation [4]. They are frequently assigned to the five primary sectors defined by the IPCC as industry, buildings, energy, transportation, and AFOLU [5].

7.2 Current Scenario Under Agroforestry:

Agroforestry has been utilized in India as a means of existence and a source of income from time immemorial. Boosted agricultural forestry in the entire nation can help to solve certain of the most serious difficulties brought on by climate change (Dhyani*etal* 2016, CAFRI Vision 2015) [6][7]. Aside from its environmental benefits, crop forest cultivation meets around fifty percent of the necessities for fuel wood, 65 percent for small timbers, 70-80 percent for plywood, 60 percent raw material for paper pulping and 9-11 percent for green fodder for cattle (NRCAF 2013) [8].

The ultimate objective of agroforestry for climate change is to enhance and sustain the standard of living of impoverished rural economy of farmers. Tree-crop integration can benefit the farming community by providing consistent revenues, diversifying land use and local skills, increasing nutritional and livestock security, and improving ecological health [9]. In the Haridwar and Yamuna Nagar areas of North India, agri-silviculture exhibited a B: C ratio of 3.85 with a net return of 1.97 lakhs ha-^{1}[10]. In the coastal states of the country, *Casuarina equisitifolia* has become a significant fast-growing tree species that is highly suitable for agroforestry. Groundnut + *Casuarina*-based system generated around 89,000 net annual returns per hectare, (Saravanan and Vijayaraghavan 2014)[11].

The versatile *Melia azedarach* tree species is well-known for its insecticidal and curative properties and is frequently grown along bunds and canals in irrigated areas, and the leaves are fed to goats. *Melia azedarach* grown with a soybean crop generated a net return that was 19% greater than that of a soybean crop alone [12][13]. Likely, sorts of agroforestry systems are improving farmer livelihoods, particularly in rainfed areas. Agroforestry systems can improve farmers' socioeconomic scenario while also contributing to the region's overall expansion. This is evident in terms of higher revenue and the creation of new job possibilities (Dhyani et al 2003) [14]. Agroforestry provides a unique opportunity to fulfil both climate change and mitigation as well as adaptation aims. Agroforestry systems minimize greenhouse gas emissions from soils by storing carbon in soils and woody biomass [15]. Recent investigation regarding different agroforestry activity systems in multiple ecological conditions has drawn attention to the significance of agroforestry systems for generating and storing carbon stocks in aboveground biomass and soil, as well as in boosting income and reducing risk to climate change. Agroforestry has the largest potential of any land use assessed for reducing carbon from the earth's atmosphere.

India recently declared voluntary commitments to the United Nations Framework Convention on Climate Change (UNFCCC) for climate change mitigation measures in the form of Intended Nationally Determined Contributions (INDCs). India plans to reduce GDP emissions by 33-35% by 2030 compared to 2005 levels. The aim will be met by expanding forest cover through afforestation and agroforestry, along with increasing the share of sources of renewable energy such as biodiesel, bioenergy, and solar energy [16].

7.3 Impact of Carbon Emission on Agriculture and Forestry:

A direct significant adverse impact of carbon emission has been observed on agriculture and forestry worldwide. Global CO2 emissions from fossil fuel burning are higher than ever, having grown 1000 times over the previous two centuries. Approximately 270 (30) Pg C was emitted towards the earth's atmosphere as carbon dioxide in an outcome of combustion of fossil fuels and cement manufacturing from 1858 to 1998.

Land-use change, including as forest loss, biomass burning, and soil cultivation, on the other hand, has emitted around 136 (55) PgC [17]. The CO_2 emissions generated by land-use change include soil and biotic pool depletion. With roughly 1550 Pg of SOC as well as 750 Pg of soil inorganic carbon (SIC) to a depth of one meter , global soils are the third largest of the 5 global C pools (after oceanic and geologic pools)[18].Thus, at a one-meter depth, the total soil C pool is 2300 Pg, representing 41 times the amount of the biotic pool (560 Pg) and threefold the atmospheric pool (760 Pg). The SOC pool is highly reactive, acts as the primary site of action for the bulk of pedological and edaphological operations, and is susceptible to both natural and human perturbations. As a result, the transformation of ecosystems to agricultural habitats reduces the SOC pool. The drop is driven by disruptions in C and other element cycles (for example, N, P, S), as well as components of hydrologic and energy budgets. A drop in energy restored to the soil, an increase in mineralization rate due to modifications to moisture in the soil and temperature regimes, as well as an elevation in losses due to leaching and erosion all contribute to a rapid decline in the SOC pool within agricultural ecosystems. The majority of farming soils have reduced by 50% to two-thirds of their original SOC pool. Soils with high antecedent pools lose more than soils with low antecedent pools, and soils in warm and dry climates lose more than soils in cool and moist climates, and practices of low-input subsistence agriculture lead to soil fertility mining rather than science-based or commercial agricultural systems that maintain a positive nutrient balance in soil. Soil erosion is responsible for 19-32 Pg (26 9 Pg) of the anthropogenic depletion from the soil C pool[19]. SOC pools in the majority of agricultural soils are now lower than their maximum capacity due to historic loss induced by historical agricultural practices and soil management practices. The process of taking CO_2 from the atmosphere and preserving it in long-lasting carbon reservoirs is known as carbon sequestration. Chemical reactions underpin abiotic C sequestration methods such as chemical scrubbing, capture and injection into geological formations and deep oceans, and natural creation of secondary carbonates (Halmannand Steinberg, 1999; DOE, 1999) [20][21]. The biotic C sequestration methods are biological reactions that collect atmospheric C and store it in long-lived pools (e.g., biotic, soil, and oceanic). The primary biotic mechanism that finally transports C into the biotic, soil, and marine pools is photosynthesis. Photosynthate and biosolids are transferred into the soil C pool by humification, aggregation, and eluviation into the subsoil, where they are shielded from human disruption. The exchange of organic C into humus through metabolic and physical mechanisms in the pedosphere is known as soil C sequestration.

The aim is to restore greater biomass to the soil that can be mineralized, to transfer C to the subsoil away from the region of disturbance, and to encourage the formation of organometal aggregates or solid micro and macro aggregates. Enhancing the SOC pool in farm and damaged soils can boost soil health and crop yield while also being environmentally friendly.

When the SOC pool in a soil has been depleted by prior land uses, the SOC pool typically responds linearly to carbon restoration [22][23][24][25]. Carbon storage in soil is a win-win method that boosts productivity, improves environmental management, and reduces global warming[26].

7.4 Sustainable Measures to Mitigate Carbon Emission:

Optimum utilization of available resources with a minimal disturbance to the ecosystem should be carried out to mitigate the carbon emission including the following-

A. **Afforestation and reforestation:** A component of a forest restoration and afforestation programme is the planting of forest trees in agricultural areas. As a result, by accumulating carbon in trees as they develop (carbon stock), the effort serves to lower the concentration of green house gases in the environment.

B. **Reducing the use of Nitrogenous fertilizers:** To increase crop yields, food industry depends on N fertilizer, yet this practice is unsustainable. The synthetic N fertilizer supply chain was predicted to emit 1.13 $GtCO_2e$ in 2018, making up 10.6% of crop-related emissions and 2.1% of overall emissions. N fertilizer manufacturing generated 38.8% of the overall synthetic N fertilizer-related emissions, with field emissions accounting for 58.6% and transportation accounting for 2.6%. 62% of worldwide emissions were attributed to India, China, the US, & the European Union. In regional food production, historical trends demonstrate a large disparity in general and individual N consumption. Reducing total N fertilizer output and usage, as well as changing to organic crop production, provides enormous reduction potential as well as in many cases, achievable emission reduction potential [27].

C. **Shifting to Battery Electric Vehicles (BEV):** Modern automobiles are significant contributors to carbon emissions. The pollution emitted by motor vehicles hurts the global ecology. According to researchers, BEVs are a vital technology for lowering GHG emissions and fulfilling the goal of reducing the carbon content of the energy sector [28].

D. **Maximum utilization of renewable energy:** In both the immediate and long-term, renewable energy cuts CO_2 emissions. However, the combustion of petroleum and natural gas increases CO_2 emissions. The usage of renewable energy improves environmental quality significantly by lowering CO_2. The optimal use of renewable energies such as wind power, solar power, water energy, and so on over petroleum and coal has become crucial for lowering carbon emissions since they generate less pollution and so contribute to enhancing climatic quality by lowering pollution. In both the immediate and long-term, renewable energy cuts CO_2 emissions. However, the combustion of petroleum and natural gas increases CO_2 emissions. The usage of renewable energy improves environmental quality significantly by lowering CO_2. The optimal use of renewable energies such as wind power, solar power, water energy, and so on over petroleum and coal has become crucial for lowering carbon emissions since they generate less pollution and so contribute to enhancing climatic quality by lowering pollution [29][30].

E. **Recycle and reuse:** Natural aggregates produce the most CO2 due to the petroleum that's used in their distribution. By substituting 68% of all natural aggregate with recycled aggregates, CO2 emissions can be reduced by 53%. Construction is one of the commercial sectors that has the greatest environmental impact and contributes to warming temperatures because it consumes a large number of substances, supplies, and energy, almost all of which come from non-renewable sources. In this sense, the production of building materials accounts for about 10% of global energy consumption. Establishment and destruction phases contribute approximately 40% of solid waste generated in industrialized nations, while the construction goods operation phase emits roughly 40% of global glasshouse gases (GHG), establishing building manufacturing as one of the commercial sectors with the highest global energy consumption[31].Thus, recycling and reusing resources can help to reduce carbon emissions to a large extent.

7.5 Capturing Carbon in Tree Biomass:

The rate of biomass carbon stored in the silvi-pastoral system was 6.72 t C/ha/yr in 8 years, which is two times more than the rate of 3.14 tC/ha/yr from natural grassland, according to comparative studies conducted by NRCAF [32] on the generation of biomass from natural grassland and silvi-pastoral system composed of *Albizia amara, Dichrostachys cinerea,* and *Leucaena leucocephala* as woody perennial. Approximately 16,400 t/yr of carbon is stored annually in agricultural forestry, which includes species like *Eucalyptus sp*., *Populus deltoides, Tectona grandis,* and *Anthocephalus chinensis* trees [33].

In a natural grassland in semi-arid Uttar Pradesh, introduced species of *Albizia procera, Eucalyptus tereticornis*, *Albizia lebbeck*, *Embilica officinalis*, and *Dalbergia sissoo* accumulated 8.6, 6.92, 6.52, 6.25, and 5.41 t/ha/yr of biomass [34]. Here, silvipasture held 1.89–3.45 tC/ha of the system's carbon while pure pasture held 3.94 t C/ha of it.

7.6 Potential of Carbon Sequestration at The Agro-Forestrial Scenario in India:

Only through switching from lower biomass land uses (such as grasslands, crop fallows, etc.) to tree-based systems like agroforestry, forests, and plantation forests will the atmosphere's CO_2 levels be reduced [35].

There is sufficient evidence that an agroforestry system has a greater overall potential for (biomass) productivity, soil fertility to be enhanced, soil conservation, nutrient cycling, microclimate regulation, and carbon sequestration than an annual system[36].In Indian agro-forests, carbon sequestration ranges from 19.56 Mg C/ha/yr in Uttar Pradesh in the north to a carbon pool of 23.46–47.36 Mg C/ha/yr in Rajasthan's tree-bearing desert agro-ecosystems[37].

The biomass of above-ground plants, such as wood and fuel-wood, as well as the biomass of below-ground plants, such as roots and soil microbes, as well as all the forms of inorganic as well as organic C in soils, including the deep root zone, all contribute to the sequestration of carbon in terrestrial pools. Trees and crops are the two key elements in agro-forestry systems that primarily sequester CO_2. The overall amount sequestered in each component varies widely and is largely influenced by a number of variables, such as the system type (and its components' nature and plant age), site quality, and historical land-use [38].

7.7 Carbon Sequestration Through Crops:

Although trees sequester more carbon in agro-forestry systems, crops also fix and store a sizeable quantity of carbon. Crops enhance the soil's organic matter, a key contributor to the terrestrial C pool [39]. Adoption of suitable crop rotations, integrated soil fertility management [40], careful use of fertilizers and organic amendments [41], and the implementation of conservation agriculture can all result in an increase in the soil's carbon pool. One of the key characteristics of Indian agriculture is the diversity of agricultural systems. The variety of soil and climatic factors that affect the total agro-ecological conditions for the growing of a crop or group of crops identified the cropping system.

There is numerous researches on CSP of crops and cropping systems accessible in published literature. However, there is a significant impact on soil organic carbon stocks due to the selection of crop species, cropping system, the timing of fallowing, and both the quantity and quality of residue returned to the soil [42]. There are reportedly more than 250 double cropping systems in use across the nation. However, 30 significant cropping systems were recognized in each district of the nation based on the rational distribution of crops. In an experiment at the ICAR-Indian Institute of Soil Science in Bhopal, evaluated the ability of various crops to store carbon [43]. They found that maize, sorghum, and pearl millet were more capable of doing so than rice, finger millet, and soybean.

The potential for carbon sequestration of various cropping systems in Indian agriculture was examined through various long-term experiments (LTEs) in various agroclimatic zones of India. The C-sequestration rate ranged from 0.02 Mg C/ha/yr (in NPK treatment for soybean-wheat cropping systems over the 28-year period at Jabalpur in Madhya Pradesh) to 1.2 Mg C/ha/yr [44].

This review unequivocally shows that long rotation agro-forestry systems, including windbreaks, shelterbelts, woodlots, boundary plantations, agri-horticulture, silvi-pasture, home landscapes, and multi-storied systems, have a significant capacity to store carbon in biomass. (ii) The potential for soil carbon sequestration is great in short rotation systems (agri-silviculture). (iii) Tropical bamboos and fast-growing hardwoods like *Eucalyptus, Poplar, Melia, Casuarina,* and *Leucaena* have a greater potential for biomass than slow-growing species. (iv) the potential for soil carbon sequestration is comparable for both types (long as well as short rotation AFS).

As a result, there is strong evidence that agro-forestry is advantageous for maintaining farm revenue as well as for its positive effects on climate change adaptation and mitigation. Along with providing food, fuel, fodder, and lumber, crops combined with trees help keep atmospheric CO_2 levels within tolerable ranges. Except for forests, agro-forestry systems have the highest potential for sequestering carbon. However, the CSP of an agro-forestry system varies depending on factors like tree species, system age, crop/variety, type of agro-climate, etc. Different agro-forestry systems are represented by the various agro-climatic zones in India, and their aboveground and belowground (soil) CSP range from 0.25 to 19.14 Mg C/ha/yr and 0.003 to 3.98 Mg C/ha/yr, respectively. Agro-forestry systems have the capacity to store and sequester carbon, but they also provide the one-of-a-kind chance to boost India's tree cover to a level of 33%.

7.8 Future Prospects:

Nature-based solutions are the only long-term answers to ecological concerns. Only sustainable practices, such as agroforestry has the potential to reverse man-made ecological problems. Agroforestry implies more revenue and less danger from unpredictable weather conditions for farmers since trees have very high climatic resilience. It also frees up the farmer's time off the farm to pursue related or alternative work for additional revenue.

The farmer might start small rural processing businesses using wood and other tree raw materials. By storing emissions in soil and biomass, lowering fossil fuel use via fewer field equipment runs, enhancing the conservation of energy surrounding farm buildings, and boosting nitrogen fertilizer efficiency, agroforestry practices can decrease net greenhouse gas budgets. As a result, agro-forestry will plays vital role in supporting the environment in the future.

7.9 Conclusion:

In terms of emissions of carbon, agroforestry is vital to strengthening farmers' rural economy and ensuring global security. It can aid in preparing for and mitigating climate change by decreasing risks and enhancing agricultural landscape adaptability, as well as promoting species migration to more favorable circumstances, carbon sequestration, and glasshouse gas emissions reduction. Due to it being a greenwood-plant-based method that increases useful variety at many scales, agroforestry as stands out as an agricultural management substitute under climate change. By establishing microclimates, perennial components can benefit crops and livestock. It may be used to make forest corridors or paths in agricultural areas, which would improve habitat connectivity. It offers comprehensive and synergistic mitigation and adaptation benefits. By conserving emissions in soil and biomass, lowering fossil fuel use via reducing field equipment runs, enhancing energy savings near farm buildings, and boosting nitrogen fertilizer efficiency, agroforestry practices can decrease net greenhouse gas budgets. Agroforestry may give significant advantages from mitigation in exchange for the quantity of land utilized in the processes.

It provides an amazing chance to achieve the mitigation as well as adaptation goals for climate change. The release of carbon is among the more significant factor contributing to greenhouse gas (GHG) emissions, which promote environmental degradation, and agroforestry is one of the most important global warming remedies.

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