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Role of Agroforestry in Carbon Sequestration

Chetan Bhanu Rathod*, Jagadish M R**,
* Ph.D. Scholar (Forestry), Department of Silviculture and Agroforestry, College of Forestry, Sirsi, UAS, Dharwad, Karnataka, India.
** Assistant Professor, Department of Silviculture and Agroforestry, College of Forestry, Sirsi, UAS Dharwad, Karnataka, India.
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Abstract

Climate change affects earth's entire environment and is considered as a one of the major global issues. Indian agriculture is highly prone to the risks due to climate change, especially to drought, because 2/3 rd. of the agricultural land in India is rain fed and even the irrigated system is dependent on monsoon. Agroforestry involves deliberate combination of trees crops and livestock in a single land use system. Agroforestry is often considered a cost-effective strategy for climate change mitigation. Thus, existing agroforestry systems have significant contribution in natural resources conservation, increase and stabilize agricultural yields and reduce soil erosion reduction of atmospheric CO_2 through carbon sequestration and hence agroforestry is a viable option for mitigation of climate change.

Introduction

The major global issues of the today's world are climate change, water resources, energy resources, food supply, globalization, habitat preservation, food security and deforestation. Climate change affects all of earth's environments and is considered as a one of the major global issues. A report from the Organization for Economic Cooperation and Development (OECD) found that droughts and extreme weather would intensify globally, leading to poor crop yield, water shortages and even desertification. Global warming is the increase in average temperature of the earth's surrounding air and ocean, which is believed to be caused mainly by the increase in atmospheric concentrations of the so-called greenhouse gases (GHGs). According to the IPCC (2007), these GHG emissions could rise by 25 – 90% by 2030 relative to 2000 and the earth could warm by 3 °C at the end of this century. Even with a temperature rise of 1-2.5 °C, the IPCC predict serious disastrous effects, including reduction in crop yields in tropical and subtropical areas leading to increased risk of food shortage, spread of climate responsive diseases such as malaria, and an increased risk of extinction of 20-30% of all biodiversity present on earth.

Oceans are the major sink for CO_2 removed from the atmosphere, causing acidification of ocean. Increased temperature and CO_2 in the atmosphere is a greater challenge for the human race and it is observed that the world's poor and developing countries will bear the heaviest burden of the climate change. Indian agriculture is highly prone to the risks due to climate change, especially to drought, because 2/3rd of the agricultural land in India is rainfed and even the irrigated system is dependent on monsoon (Pathak *et al*., 2015).

Since the pre-industrial era, anthropogenic GHG emissions have driven large increases in concentrations of CO_2, CH_4 and N_2O in the atmosphere. Among all GHGs, CO_2 is a major GHG, between 2000 and 2011 atmospheric concentration of CO_2 has increased from 369 to 391.5 ppm. India made ambitious commitments at the COP 26 climate summit in Glasgow 2021. The country announced a two-phased plan increasing non-fossil fuel capacity by 2030 and then targeting net-zero emissions by 2070. While net zero is a distant target, the 2030 commitments will require urgent intervention of the policy and investment front.

There are multiple scenarios with a range of technological and behavioural options having different characteristics and implications for sustainable development, which are consistent with different levels of mitigation. However, sequestering CO_2 from point sources or atmosphere through natural techniques (afforestation, reforestation, natural regeneration of forests and the adaptive agriculture) is more economically and ecologically sound in increasing the carbon storage capacity of the terrestrial ecosystems. The role of agroforestry in stabilizing the CO_2 levels and increasing the carbon sink potential has attracted considerable attention, especially after the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC).

Agroforestry v/s carbon sequestration

The actual aim of farmers and government institutions behind agroforestry was improving rural livelihood and meeting various needs, *viz*. food, fuel, timber, fodder of the farmers. But in recent era of climate change, agroforestry became economically and ecologically very attractive tool for mitigating harmful effect of GHGs. Since, the Kyoto Protocol allowed industrialized countries with a GHG reduction commitment so as to invest in mitigation projects in the developing and least developed countries under the Clean Development Mechanism (CDM) and there is an attractive opportunity for major practitioners of agroforestry, especially the resource poor farmers. IPCC (2007) also indicated in its special report that the conversion of wasteland and grassland to agroforestry has the best potential to soak up atmospheric CO_2 other than direct benefits. Since CO_2 is the major greenhouse gas, representing 77% of total anthropogenic GHG emissions, its reduction is very essential from the atmosphere. Carbon sequestration is the capturing atmospheric CO_2 and storing for long term through natural (soils/vegetation) and engineering techniques. Among all the natural techniques, agroforestry provides a win-win opportunity to achieve the objectives of carbon sequestration and climate change mitigation and adaptation (Dhyani *et al*. 2016).

Agroforestry and its potential for carbon sequestration:

Agroforestry is often considered a cost-effective strategy for climate change mitigation. Majority of the agroforestry systems have the potential to sequester carbon, which may vary according to tree species. Agroforestry is a viable option to prevent and mitigate the climate change, increase and stabilize agricultural yields and reduce soil erosion.

Carbon sequestration potential of agroforestry in world:

Area under agroforestry globally is of about 1023 m ha. The carbon sequestration potential of agroforestry systems is estimated to be between 12 and 228 Mg C/ha. (Albrecht and Kandji, 2003). Of all the land uses analysed in the Land-Use, Land-Use Change and Forestry report of the IPCC, agroforestry offered the highest potential for carbon sequestration in non-Annex I countries. And it is estimated that 630 m ha of unproductive cropland and grasslands could be converted to agroforestry representing 5, 86,000 Mg C/ha by 2040.

Carbon sequestration potential of agroforestry in India:

According to Pandey (2002) carbon sequestration in Indian agro forests varies from 19.56 Mg C/ha/yr in north Indian state of Uttar Pradesh to a carbon pool of 23.46–47.36 Mg C/ha/yr in tree-bearing arid agro-ecosystems of Rajasthan.

The CSP of trees varies with species, structure, age and spatial distribution. For the most common tree density in the range of 312–800 trees/ha (usually preferred by the farmers in planted AFS), the CSP varied in the range of 0.25 to 19.14 Mg C/ha/yr. (Nair *et al.*,2010) have also reported world scenario of carbon stored in AFSs ranged from 0.29 to 15.21 Mg C/ha/yr in above ground, and 30–300 Mg C/ha up to a depth of 1 m in the soil (the age varied from 4 to 35 years).

Rizvi *et al.* (2018) have estimated that area under agroforestry India: 25.32 m ha *i.e*., 8.2% of total geographical area (TGA). A total of 53.32 m ha (17.57 % TGA) could be used potentially under agroforestry in future. In India carbon sequestration potential of agroforestry systems is estimated between 0.25 – 19.14 and 0.01 to 0.60 Mg C/ha/yr for tree and crop component, respectively. The contribution of agroforestry in soil carbon sequestration varied between 0.003 to 3.98 Mg C/ha/yr.

Different agroforestry system

1. **Agri-silvicultural systems**: Arable crops are combined with tree crop. The carbon sequestration in mono cropping of trees and food crops were less than agri-silviculture indicating that agroforestry systems have more potential to sequester carbon. In an agri-silvicultural system, *Dalbergia sissoo* at age 11 years was able to accumulate 48-52 t/ha of biomass.

Fig 1. Different Agri-silvicultural systems

2. **Silvipastoral systems**: Silvipastoral systems have a great potential to sequester carbon due to high biological productivity, and availability of larger areas under grazing management. Proper rotational grazing and fertilizer application may also help enhance carbon sequestration. Carbon sequestration potential is about 26.43 t ha^{-1}.

Fig 2. Different silvipastoral system

3. **Windbreak:** Windbreaks are designed with one or more rows of trees or shrubs planted across crop or grazing areas to reduce wind speed and enhance microclimate for crop.

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Carbon sequestration potential of windbreaks depends on species which is used. It is estimated that 85 million ha under windbreaks having sequestration potential of 4 Tg C year (Giga ton of carbon).


Fig 3. Different windbreak system

4. **Shelterbelts:** Depending on the species and the spacing, trees in shelterbelts can increase soil organic carbon. It can contribute to the improvement of soil conditions and indirectly enhance carbon sequestration by improving crop productivity and reducing erosion induced soil losses.


Fig 4. Different shelterbelt system

5. **Home gardens:** Home gardens are land use system involving the management of multipurpose tree and shrubs in association with annual and perennial agriculture crops. These are also called as multitier system. These are found extensively in high rainfall areas. Average aboveground standing Carbon stocks ranged from 16 to 36 Mg ha−1.

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Fig 5. Different Home gardens

Conclusion: The importance of agroforestry systems as a carbon sink has recently been recognized as a need of climate change mitigation. Higher biomass of ecosystems is associated with higher diversity and higher species diversity leads to greater carbon sequestration. The management of agricultural lands will therefore play an important role in enhancing carbon sinks and in turn reducing emissions. Agroforestry provides the best example of promoting mitigation and adaptation synergy in addressing climate change. Thus, existing agroforestry systems have significant contribution in natural resources conservation, reduction of atmospheric CO_2 through carbon sequestration and hence agroforestry is a viable option for mitigation of climate change.

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