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REVIEW ARTICLE

Role of Agroforestry in Carbon Sequestration

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ABSTRACT

Agroforestry is the practice of the purposeful growing of trees and crops, and/or animals, in interacting combinations, for a variety of benefits and services. Agroforestry is a viable alternative to prevent and mitigate climate change. Agroforestry was recognized by IPCC (Intergovernmental Panel on Climate Change) as having high potential for sequestering C as part of climate change mitigation strategies. The average C storage by agroforestry practices has been estimated as 9, 21, 50 and 63 Mg ha^{-1} in semi-arid, sub-humid, humid and temperate regions, respectively. Agroforestry trees improve land cover in agricultural fields in addition to providing C inputs (root biomass, litter and prunings) to the soil. This has often reduced soil erosion, which is crucial process in the soil C dynamics.

Keywords: Agroforestry, climate, carbon sequestration and global warming

INTRODUCTION

Carbon dioxide is the largest human-made greenhouse gas that is causing global warming and forcing climate change. The present concentration of carbon dioxide in the atmosphere is 390 mg kg^{-1} (Blassing, 2012) with an increase of 39.5 % since the industrial revolution (1750). The other important greenhouse gases are methane (1871 ppb), nitrous oxide (323 ppb), CFC-11 (241 ppt) and CFC-12 (534 ppt). According to the findings by the Netherlands Environmental Assessment Agency, India's carbon dioxide emissions increased from 1.86 Gt in 2010 to 1.97 Gt in 2011, an up tick of about 6 %. The primary source of the increase in the atmospheric CO_2 is from the combustion of fossil fuels. According to the International Energy Agency report, CO_2 emission from fossil fuel combustion hit 31.6 Gt in 2011. Anthropogenic activities including deforestation, biomass burning, conversion of natural to agricultural ecosystems, land use change pattern, drainage of wetlands and soil cultivation have increased emissions from carbon global stocks.

Global warming and Climate change

The greenhouse effect is neither new nor necessarily bad because without it life would probably not exist on earth. It maintains the surface temperature of the earth at 15° C, rather than at -18° C, which would be the temperature in the absence of the greenhouse effect. About 50 % of the sun energy reaching the earth's surface is reflected back into space or adsorbed in the upper atmosphere. The other 50 % is absorbed by the earth's land and water masses, which then emits a less intense form of energy at longer wavelengths as a result of heating. The greenhouse gases absorb the longer wavelengths or reflect back to the surface. Like a blanket, the greenhouse gases trap the radiated energy, converting it to heat which results in warming of the earth's atmosphere popularly known as Global Warming. Climate change is the change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. Climate change is the result of a great many factors including the dynamic processes of the earth itself, external forces including variations in sunlight intensity, and more recently exacerbated by anthropogenic

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activities such as deforestation, agriculture, industries, automobiles, and the burning of fossil fuels, are contributing to greenhouse gas (GHG) emission, a major cause of global warming. Climate change has a variety of impact on the world *viz.*, rising temperature, changing precipitation pattern, rising sea level brought about by melting icecaps and warming oceans, extreme events like drought, flood, storms, hurricanes and heat waves.

Carbon sequestration

The term "carbon sequestration" is used to describe both natural and deliberate processes by which CO_2 is either removed from the atmosphere or diverted from emission sources and stored in different sinks. It is considered to be a strategy for mitigating climate change. Reducing CO_2 emissions is necessary to prevent the mentioned negative impacts of climate change. There are various sinks where carbon can be sequestered. They are: ocean (ocean sequestration), underground (geological sequestration), in plants and soil (terrestrial sequestration) and as solid material (still in development). Agricultural soils are among the planet's largest reservoirs of carbon. The total soil carbon pool is four times the biotic and three times the atmospheric pool (Lal, 2004) and holds potential for expanded carbon sequestration. Soil organic carbon is the prime decider of soil health and soil quality. In agricultural system, maintenance of soil organic carbon (SOC) has long been recognised as a strategy to reduce soil degradation, improve soil fertility, water availability, soil productivity and overall sustain soil health. Depletion of the SOC pool has major adverse economic and ecological consequences, because the SOC pool serves numerous on-site and off-site functions of value to human society and well being (Lal, 2004). Principal on-site functions of the SOC pool are:

1. Source and sink of principal plant nutrients (e.g., N, P, S, Zn, Mo);
2. Source of charge density and responsible for ion exchange;
3. Absorbent of water at low moisture potentials leading to increase in plant available water capacity;
4. Promoter of soil aggregation that improves soil tilth;
5. Cause of high water infiltration capacity and low losses due to surface runoff;

Role of Agroforestry in carbon sequestration

Agroforestry is the practice of the purposeful growing of trees and crops, and/or animals, in interacting combinations, for a variety of benefits and services (Nair *et al*. 2009). Globally 700 million ha of land might be available for C conservation and sequestration programs (345 million ha for plantation and Agroforestry, 138 million ha for slowed tropical deforestation and 217 million ha for natural and assisted regeneration of tropical forests (Brown 1999). Agroforestry is a viable alternative to prevent and mitigate climate change and have higher potential for sequestering C as part of climate change mitigation strategies. Agroforestry was recognized by IPCC as having high potential for sequestering C as part of climate change mitigation strategies (Watson *et al*. 2000). Agroforestry is ideal option to increase productivity of wastelands, increase tree cover outside the forest, and reduce human pressure on forests under different agro-ecologial regions of India.

The average C storage by agroforestry practices has been estimated as 9, 21, 50 and 63 Mg ha^{-1} in semi-arid, sub-humid, humid and temperate regions, respectively. For small holder agroforestry systems in the tropics, potential carbon sequestration ranges from 1.5-3.5 Mg ha^{-1} (Montagnini and Nair 2004). AFS_S are believed to have a higher potential to sequester C (ranges from 0.29 to 15.21 Mg ha^{-1} yr^{-1} aboveground, and 30 to 300 Mg C ha^{-1} up to 1m depth in soil) than pastures or field crops. On an average, the soil and aboveground parts are estimated to hold major portions, roughly 60 and 30%, respectively, of the total C stored in tree based land use systems (Lal 2008). Estimates of aboveground CS potential (CSP) are based on the assumption that 45-50% of branch and 30% of foliage dry weight constitute C (Schroth *et al*. 2002). Agroforestry trees improve land cover in agricultural fields in addition to providing C inputs (root biomass, litter and prunings) to the soil. This has often reduced soil erosion, which is crucial process in the soil C dynamics.

C is sequestered in soils in two ways:

- **Direct soil CS**
- **Indirect soil CS**

Direct soil CS occurs by inorganic chemical reactions that convert CO_2 into soil inorganic C compounds such as calcium and magnesium carbonates.

Indirect plant CS occurs as plants photosynthesize atmospheric CO_2 in to plant biomass. Some of this plant biomass is then sequestered as soil organic carbon (SOC) during decomposition process. The amount of soil C sequestered at a site reflects the long term balance between C uptake and release mechanism. Because those flux rates are large, changes such as shifts in land cover and/ or land use practices that affect pools and fluxes of SOC have large implications for the C cycle and the earth's climate system.

CS occurs in two major segments of the AF ecosystem:

- Aboveground
- Belowground

The former in to specific plant parts like stem, leaves etc. of trees and herbaceous components. The latter in to living biomass such as roots and other belowground plant parts, soil organisms and C stored in various soil horizons.On an average, the soil and aboveground parts are estimated to hold major portions, roughly 60% and 30% respectively, of the total C stored in tree-based land-use systems.

ABOVEGROUND (VEGETATION) CARBON SEQUESTRATION Aboveground C storage is the incorporation of C into plant matter either in the harvested product, or in the parts remaining on site in a living form. The amount of biomass, and subsequently C, that is stored depend up on apart from nature of plant itself, but also on properties of soil on which it grows, with higher conc. of organic matter, nutrients, and good soil structure , leading to greater biomass production.

BELOWGROUND (SOIL) CARBON SEQUESTRATION

Soils play a vital role in the global C cycle.The soil C pool comprises SOC estimated at 1550 Pg and soil inorganic C about 750 Pg both to 1m depth. This total soil C pool of 2300 Pg is three times the atmospheric pool of 770 Pg and 3.8 times the vegetation pool of 610 Pg. Loss of organic C from tropical soils not only increases the atmospheric CO_2 content, but also reduces the fertility of those soils that are generally nutrient poor. Soil organic matter (SOM) contains more reactive organic carbon than any other single terrestrial pool. SOM plays a major role in determining carbon storage in ecosystems and in regulating atmospheric CO_2 concentration.

Problems and Benefits of Carbon Sequestration

- **High Price of Installing Carbon Capture Systems -** Coal Power Plants who use carbon capture technology require 30 per cent more energy than power plants that don't use carbon capture technology.
- **Reduced Emissions -** However, Coal Power Plants which use sequestration reduced their emissions by as much as 85 per cent.
- **Installing Carbon Capture Technology -** Power Plants which are retrofitted with carbon capture and the ability to sequester it spent 50 per cent more than plants that were built with carbon capture already installed.

Some Effective and Cost Efficient Activities to Increase Carbon Sequestration:

- Increase productivity of forest land
- Increase area of forest land
- Increase agroforestry
- Increase carbon in durable wood products through efficient utilization of raw material

CONCLUSION

Carbon sequestration through agroforestry is a potential viable option to add to the trees on the farm lands, alone or in association with crops, because our present forest cover is 20.5 per cent of the total geographical areas and target fixed to increase tree cover to the extent of 25 per cent by 2007 and 33 per cent by 2012 can only be achieved by the plantation of tree in agricultural field through agroforestry systems. Choosing species with large deep root system is desirable for increasing C inputs. Land use change from cropland to forest or grassland has been estimated to have a high global sequestration rate. Substitution of fossil fuel with bio-fuel and ethanol has greatest mitigating potential in long term. These approaches involves extending the production of bio-diesel through cultivation of tree bearing oilseed species like jatropha, neem, karang etc. and diversify in to the co-production of ethanol by the sugar industries.

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