Int. J. Agriworld, Vol. 1[1] August 2020
©2020 SVPSS, India
Online ISSN: 2582-7537
Journal's URL:http://www.svpss.in
Received 14.01.2020 Revised 11.03.2020 Accepted 17.06.2020
REVIEW ARTICLE **OPEN ACCESS**

Agroforestry Intervention for Combating Climate Change, Natural Resources Conservation and Livelihoods

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Abstract

This paper is an attempt to review the agroforestry system at global context. Agroforestry have tremendous potential to serve as a tool in combating climate change, protecting people and livelihoods, and creating a foundation for more sustainable economic and social development. Agroforestry continues to play an integral role in enlightening the competitive position of the agricultural sector. The main issue for optimizing production in agroforestry systems is rational utilization of resource by maximizing positive interactions and minimizing negative ones. Climate change, caused by global warming, is a phenomenon partly resulting from abundance of carbon dioxide in the atmosphere. Traditional resource management adaptations such as agroforestry systems may potentially provide options for improvement in livelihoods through simultaneous production of food, fodder and firewood as well as mitigation of the impact of climate change Agroforestry systems have the potential for improving water use efficiency by reducing the unproductive components of the water balance. Adaptation strategies that promote sustainable management and community based practices have the potential to not only protect land and people from some of the harmful effects of rising global temperatures, but also to provide opportunities for greater, more sustainable rural development and poverty reduction. Dominance of many traditional agroforestry systems in India offers opportunity worth reconsidering for carbon sequestration, livelihood improvement, biodiversity conservation, soil fertility enhancement and rural employment.

Keywords: *Agroforestry, Climate Change, Livelihoods, Sustainable Management, Potential & Adaptation*

Introduction

Agroforestry means land-use systems and practices, where woody perennials are deliberately integrated with crops and/or animals on the same land management unit. The trees may be single or in groups inside parcels (silvoarable agroforestry, silvopastoralism, grazed or intercropped orchards) or on the limits between parcels (hedges, tree lines) (EURAF 2012).Climate change is a change in the long-term weather patterns that characterize the regions of the world. Scientists state unequivocally that the earth is warming. Natural climate variability alone cannot explain this trend. Human activities, especially the burning of coal and oil, have warmed the earth by dramatically increasing the concentrations of heat-trapping gases in the atmosphere. The more of these gases humans put into the atmosphere, the more the earth will warm in the decades and centuries ahead. There is increasing acceptance that even very ambitious greenhouse gas mitigation which would go beyond the current international climate agreements, would not be sufficiently effective to halt the increase of atmospheric greenhouse gas concentrations in the medium term and that therefore adaptation measures are as needed as mitigation measures. The impact of climate change will be affecting developing countries more severely than developed countries not the least because of their generally low adaptive capacities (IPCC, 2003). In these countries, the agricultural sector will be among the most vulnerable putting rural population at large risks. At the same time, the risk of climate change is yet an additional threat to urgent rural development demands including livelihood security and poverty reduction. Much effort will be needed to integrate what is known about climate change response measures into national development planning.

The global climate change intensified the interest and concern towards green economy. According to Planning Commission report “Greening India”, that 33% forest cover can only be achieved through agroforestry. In the context of global change and sustainable development, land management activities play a key role through mitigation of climate change. However, forests are also affected by climate change and their contribution to mitigation strategies may be influenced by stresses possibly resulting from it. Agroforestry can make a very significant contribution to a low-cost global mitigation portfolio that provides synergies with adaptation and sustainable development. However, only a small portion of this potential being realized at present. The carbon mitigation potentials from reducing deforestation, forest management, afforestation, and agro-forestry differ greatly by activity, regions, system boundaries and the time horizon over which the options are compared.

Globally, millions of households depend on goods and services provided by forests. This underlines the importance of assessing forest sector activities aimed at mitigating climate change in the broader context of sustainable development and community impact. Forestry mitigation activities can be designed to be compatible with adapting to climate change, maintaining biodiversity, and promoting sustainable development. There is robust evidence that agroforestry systems have the potential for improving water use efficiency by reducing the unproductive components of the water balance.

A new land-use options that increase livelihood security and reduce vulnerability to climate and environmental change are necessary. Traditional resource management adaptations such as agroforestry systems may potentially provide options for improvement in livelihoods through simultaneous production of food, fodder and firewood as well as mitigation of the impact of climate change (Anitha, S. & R. Sathya Priya, 2012). One of the potential alternative energy sources which actively caters to the mitigation and adaptation of climate change and rehabilitation of marginal land is bamboo based agroforestry system.

Potential carbon sequestration by agroforestry system

In India, evidence is now emerging that agroforestry systems are promising land use system to increase and conserve aboveground and soil C stocks to mitigate climate changes. The average potential of agroforestry has been estimated to be 25 t C / ha over 96 m ha (Sathaye and Ravindranath, 1998). In this way the total potential of agroforestry in India to store C is about 2400 m.t. In other estimate, the under agroforestry is 8.2% of total reported geographical area (305.6 m ha) and it contribute 19.3 % of total C stock under different land uses (2755.5 m. t C).In agroforestry, the potentially higher productivity could be due to the capture of more growth resources *e. g.* light or water or due to improved soil fertility. Several studies in different parts of the country suggested that agroforestry is more profitable to farmers than agriculture or forestry for a particular area of land (Tokey, 1997 and Samra *et al.,* 1999). According to the recent projections, in India the area under agroforestry will increase substantially in the near future (NRCAF, 2006). The amount of carbon sequestration of different agroforestry system depends on practices to be followed. The carbon storage potential differed from 12 to 228 Mg C ha $^{-1}$ in various part of the world (Ram Newaj and S. K. Dhyani, 2008).

Agroforestry as a tool in combating climate change, protecting people and livelihoods

Agroforestry have tremendous potential to serve as a tool in combating climate change, protecting people and livelihoods, and creating a foundation for more sustainable economic and social development. Sustainable forest management provides the framework for international and national level planning of how best to confront this ever changing and ever challenging obstacle that we all face. At the same time, agroforestry do have the potential to contribute to national adaptation strategies. Adaptation strategies that promote sustainable management and community based practices have the potential to not only protect land and people from some of the harmful effects of rising global temperatures, but also to provide opportunities for greater, more sustainable rural development and poverty alleviation through income generation and employment opportunities. These systems enable farmers to diversify production, reduce farm risk, contribute to food security, and generate much-needed income. They also meet commercial needs for timber and improve environmental conditions. In rural areas 70-80% energy comes through biomass from trees and shrubs. Due to the agroforestry initiatives large amount of woods are now being produced from outside the conventional forest lands. The fuel wood potential of indigenous (*Acacia nilotica, Azadirachtaindica, Melia azadiracht, Leucaenaluecocephala, Casuarina equisetifolia, Dalbergiasissoo, Prosopis cineraria* and *Ziziphusmauritiana*) and exotic (*Acacia auriculiformis, A. tortilis, Eucalyptus camaldulensis*and *E. tereticornis*) trees revealed that calorific values ranges from 18.7 to 20.8 MJ/ kg for indigenous tree species and 17.3 to19.3 MJ/kg for exotics. Species such as *C. equisetifolia, Prosopisjuliflora, Leuceana leucocephala* and *Calliandra calothyrsus* have become prominent due to their potential for providing wood energy at the highest efficiency, shorter rotation and also their high adaptability to diverse habitats and climates. In India the energy demand is expected to grow at 4.8%. Further, increasing gap between demand and domestically produced petroleum the dependence on import of oil will increase in the near future (Anitha, S. & R SathyaPriya 2012).

Carbon pool in different agroforestry system

Climate change, caused by global warming, is a phenomenon partly resulting from abundance of carbon dioxide in the atmosphere. It is the most pressing environmental problem of the world today. It persists, and it cannot be stopped but it can be mitigated. Agroforestry systems as land use can reduce the atmospheric concentration of carbon dioxide. According to recent projections, the area of the world under agroforestry will increase substantially in the near future. Undoubtedly, this will have a great impact on the flux and long-term storage of C in the terrestrial biosphere (Dixon, 1995). Agro-ecosystems play a central role in the global C cycle and contain approximately 12% of the world terrestrial C (Smith *et al.*, 1993; Dixon et al., 1994; Dixon, 1995).Carbon is accumulating in the atmosphere at a rate of 3.5 Pg (Pg = 1015 g or billion tons) per annum, the largest proportion of which resulting from the burning of fossil fuels and the conversion of tropical forests to agricultural production (Paustian *et al.*, 2000). Current evidence suggests that increased atmospheric Carbon flux could have some positive effects such as improved plant productivity (Schaffer *et al.*, 1997). However, negative changes in the global climate (rising temperatures, higher frequency of droughts and floods) are often the most consequential processes associated. Land-use management such as agroforestry systems or the combination of production of trees with agricultural crops plays a very important role in climate change mitigation by absorbing excess carbon dioxide which is used in the process of photosynthesis by the trees. Carbon is stored in tree biomass and in soil that helps protect natural carbon sinks through the improvement of land productivity and the provision of forest products on agricultural lands (Albrecht & Kandji 2003).

Contribution in soil conservation and underground water recharge potential

Planting trees and their sustainable management can aid in the protection of soil and land against detrimental impacts of flooding. In addition, agroforestry can be used to rehabilitate degraded land and maintain water quality by trapping sediments, taking up nutrients, and immobilizing toxic substances. Agroforestry systems have potential of Hydraulic lift, the transfer of water from relatively wet deeper layers to drier soil higher in the profile. This has been described for both natural tree–grass mixtures and agroforestry systems (Richards and Caldwell, 1987; Dawson, 1993; Caldwell *et al.,* 1998; Midwood *et al.,* 1998; Norton and Hart, 1998; Zou *et al.,* 2005; Hawkins *et al.,* 2009). Shoot and root pruning effect of *Alnusa cuminata* and *Sesbania sesban* on terrace risers increased water content in the cropping area (Siriri *et al.* 2013). The hydraulic redistribution could have positive effects on transpiration and plant growth during regular dry seasons. Agroforestry systems are a better climate change mitigation option than oceanic and other terrestrial options because of the secondary environmental benefits such as food security, secured land tenure, increasing farm income, restoring and maintaining the above-ground and below-ground biodiversity, maintaining watershed hydrology and soil conservation (Pandey D.N, 2002))

Soil amelioration & fertility improvement through agroforestry

Carbon sequestration in degraded agricultural soils in developing countries to mitigate atmospheric greenhouse gas concentrations is increasingly promoted as a potential strategy (Petra Tschakert, 2004). It is apparent from the studies that the agroforestry systems, which promote the use of legumes as fertilizer or shade trees, may increase N_2O emissions compared to unfertilized systems. The significance of different variables on GHG production and soil C sink capacity was investigated by Mondini *et al*., by monitoring CO2 and N2O fluxes from amended soils under laboratory conditions and reported that the C conservation efficiency of organic residues, calculated by the combined loss during composting and after land application was higher for the less transformed organic materials Lal R. (2005). Samra and Singh (2000) observed in increase in soil organic carbon status of surface soil 0.39 %to 0.52 % under *Acacia nilotica* + *Saccharum munja* and 0.44% to 0.55% under *Acacia nilotica* + *Eulaliopsis binata* after 5 years and suggested that *Acacia nilotica* + *Eulaliopsis binata* are conservative but more productive and less competitive with trees and suitable for eco- friendly conservation and rehabilitation of degraded lands of Shivalik foot hills of sub-tropical northern India. Ram Newaj *et al.* (2008) observed that in agri-silviculture growing of *Albizia procera* with different pruning regimes, the organic carbon of the soil increased by 13-16 % from their initial values under different pruning regimes which was 5 to 6 times higher than growing of either sole tree or sole crop. Soil fertility can also be regained in shifting cultivation areas with suitable species. For instance, field experiment to study N_2 fixation efficiency suggests that planting of stem-cuttings and flooding resulted in greater biological N_2 fixation, 307 and 209 kg N ha–1 by *Sesbania rostrata* and *S. cannabina* respectively. Thus, *S. rostrata* can be used as a green manure by planting the stem-cuttings under flooded conditions (Patel *et al.,* 1996). Within the terrestrial ecosystems, the soil is the main provider of environmental services. The soil is a living system essential to sustain biological productivity, air and water quality, and plant, animal and human health. Unfortunately, soil degradation is a severe problem for food production in rural areas, particularly in developing countries. Therefore, it is necessary to contemplate strategies for land management representing the best possible communion between generations of multiple services while preserving the natural capital (Lavelle 2008).

Livelihood security through adoption of agroforestry

Agroforestry provide a wide range of benefits beyond those related to climate change. Accounting for approximately thirty percent of the world's land mass, forests provide economic, social, cultural and environmental services. Adoption of diversified agriculture production system that is complementary in economic and/or ecological dimensions involving crops, trees, livestock and post-harvest processing. More than one billion people depend on agroforestry and use resources for fuel, timber, food, medicine and income; of these, 70 million are indigenous peoples living in remote areas that depend largely on agricultural resources for their livelihoods. Expanding market opportunities for smallholders particularly in niche markets and high value products is critical to the success of agroforestry innovations (Russell and Franzel, 2004). Agroforestry just not an answer of self-increase profits, but also special pleasure collecting or growing non-timber forest products as part of their cultural and family tradition. Many high-value specific crops can be cultivated or grown under the protection of existing cropping system. It is a way of utilizing tree resources for short-term income while high-quality trees are being grown for wood products. Traditional agroforestry has progressively been replaced by more simplified production systems. Agroforestry has been modernized over the last years. It is no longer focused on single species plantation. It is now a side by side cohabitation of local field and forest species. The most commonly grown agroforestry crops are: edible flowers, sap products, medicinal plants, ornamental &decorative plants, short-term energy coppice and wood products like charcoal, Fuelwood etc. In addition, forests contribute significantly to a wide range of forest products, recreational opportunities as well as environmental services such as protection of the watershed. Clearly, the potential contribution of agroforestry to the mitigation of climate change is just one of many benefits for local communities and urban populations, as well as a large number of business enterprises. Economic benefits of agroforestry adoption can be beneficial and significant (Dragana *et al* 2013).

Mitigation of GHG emission through biomass substitution

Trees, soil and forests take in carbon at a rate that is determined by a number of factors including the type of forest, its location, and its age. Forests store large amounts of carbon in trees, under-story vegetation, and soil. Globally, they contain some 1.2 trillion tonnes of carbon, just over half the total in all terrestrial vegetation and soils (FAO). Wood substitution addresses climate change in several ways. Substituting wood for fossil fuel–intensive products also avoids the emissions from the substituted products, and what was forest carbon remains stored in the wood products. Trees remove carbon dioxide (CO2) from the atmosphere and store it in their roots, stems, trunks, and leaves through the process of photosynthesis. In addition, forested ecosystems store carbon in soil, forest floor, and down dead wood. As forests and their trees mature, their growth slows; however, some studies indicate that as tree growth slows, ecosystem storage of carbon may actually increase as a result of increases in other carbon pools (Zhou *et al.* 2006; Schulze *et al.* 2000).Total aboveground biomass accumulation was found maximum in *B. balcooa* followed *B. bambos* and *B. tulda* while minimum was in *B. asper* clumps after 4 years of age and ranged from 7.12 to 104 tons ha^{-1}(Pathak et al 2016). The production and use of biomass fuels and bio-based products is one way to reduce oil and gas imports and improve environmental quality. Biomass can be used as an offset for fossil fuels like coal, natural gas, gasoline, diesel oil, and fuel oil. At the same time, such uses can enhance domestic economic development by supporting rural economies and fostering new industries making a variety of renewable fuels, chemicals, and other bio-based products (California Biomass Collaborative 2005; English *et al.* 2006; J. R. Smith *et al.* 2007).

Agroforestry in microclimate development

Generally open land receives more sunlight in compare to cover land and temperature also follows similar trends. It has been proven from many researches that agroforestry system can perform better than sole cropping system in the areas where either there is scarcity of ground water or received less rain fall. Agroforestry is tool which is beneficial for shade loving as well low temperature crops. Role of agroforestry in development of microclimate have been studied through analysis of the energy and water balance for more than two decades (Monteith *et al., 1991;* Ong *et al., 1991;* Brenner, *1996*). Analysis by Ong *et al. (1991*) suggested that atmospheric interactions in hedgerow cropping in the semiarid tropics were positive but were of minor importance compared with below-ground, often competitive, interactions. Rao *et al. (1997*) concluded that the net positive effects of trees on crops were more likely in sequential rather than simultaneous agroforestry systems, as below-ground competition dominated tree–crop interactions for major food crops. Compared to open-field agriculture, all land-use systems with trees have reduced daily amplitude of air temperature, with a gradual decrease of the amplitude within the top layers of the soil. The temperature is restricted to a few multiples of tree height, depending on the solar elevation (Kohli and Saini, 2003). Similarly Hairiah *et al.* (2006) compared the effects of shading on the litter layer soil temperature and its spatial variability in open- and closed-canopy coffee agroforestry systems in Lampung, with a natural forest comparison. Significant effects of trees on temperature were reported in a study of urban trees in Bangalore (India), where street trees provided a maximum reduction in afternoon ambient air temperatures of 5.6°C, and of tarmac road surface temperatures of 27.5°C (Vailshery *et al*., 2013).

Conclusion

Agroforestry systems are land management strategy which concerned with other, may allow improved resilience of agro-ecosystems to climate change impacts. This review gave a description of a few agroforestry systems practiced in relation to their Carbon sequestration potential. Agroforestry offers the potential to develop synergies between efforts to combat climate change and efforts to help vulnerable populations adapt to the negative consequences of climate change. Agroforestry can very likely contribute to increasing the resilience of tropical farming systems. Agroforestry continues to play an integral role in improving the competitive position of the agricultural sector. Dominance of many traditional agroforestry systems in India offers opportunity worth reconsidering for carbon sequestration, livelihood improvement, biodiversity conservation, soil fertility enhancement and rural employment. Therefore, a systematic agroforestry system with sufficient management practices will be more beneficial towards the climate change mitigation and open up more opportunity for livelihood on a sustainable basis.

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CITATION OF THIS ARTICLE

Kumar, H., Umrao Rajiv and Agarwal Yogesh Kumar. Agroforestry intervention for combating climate change, natural resources conservation and livelihoods, *Int. J. Agriworld*, Vol. 1 [1] August 2020: 19-26