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Carbon sequestration potential of *Eucalyptus* spp.: A review

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ABSTRACT

Climate change has become an important and sensitive environmental issue that has captured the global attention of many intellectuals during the recent past. The increasing concentration of carbon dioxide in the atmosphere is believed to have contributed significantly to the climate change. Among all the available options, the use of perennial woody vegetation is an efficient, cost-effective and environmental friendly strategy for storing and sequestering the atmospheric carbon. According to the Kyoto Protocol, an international agreement, carbon sequestration through afforestation and reforestation by long-term rotational tree crops are potentially mitigation strategies as carbon credit for many countries to meet their commitments of green house gas emissions reduction. Besides, the wood production from agro-forestry plantations will reduce pressure from timber extraction in natural forests. Therefore, the tree like *Eucalyptus* spp. has been selected for the study to provide both the benefits not only for harvesting the year round and for mitigating the climate change to compensate green house gas emission but also for sequestering the atmospheric carbon. The study concluded that the *Eucalyptus* plantations have significant contribution in carbon sequestration potential.

Key words: Carbon sequestration, climate change, *Eucalyptus*, fast growing, short rotation

INTRODUCTION

Carbon sequestration (CS) through sink enhancement by way of integration of trees into landscapes is one of the cost effective mitigation strategies. Land-use, Land-use Change and Forestry (LULUCF), an approach that became popular in the context of the Kyoto protocol, allows afforestation and reforestation as greenhouse gas (GHG) offset activities (Nair et al., 2011). Climate change evident linked to human induced increase in GHGs concentrations is well documented (IPCC, 2001, 2007). The total global potential for afforestation and reforestation activities for the period 1995-2050 is estimated to be between 1.1 and 1.6 Pg C per year, of which 70% could occur in the tropics (IPCC, 2000). Afforestation and reforestation are seen as potentially attractive mitigation strategies, as wood production and carbon (C) storage can be combined. United Nations Framework Convention on Climate Change (UNFCCC) has recognized the importance of plantation forestry as a greenhouse gas mitigation option as well as the need to monitor, preserve and enhance terrestrial carbon stocks (Updegraff et al., 2004). However, there is a large variation in the carbon sequestration potential of different plantation species and there are varying estimates of the carbon sequestration rates of

common plantation species (FAO, 2003; Negi and Chauhan, 2002). Short rotation tree crops, either as farm forestry or agroforestry systems, are considered an effective means to mitigate the greenhouse effect, due to their ability to accumulate substantial quantities of carbon in vegetation in a limited period. In addition, production from plantation forests may relieve pressure on timber extraction from natural forests, and thus contribute to forest conservation (Prasad et al., 2012). Significant carbon stocks are stored in plantations in the tropical and temperate regions (Malhi et al., 2008). Short rotation tree plantations grow rapidly, give high yields and are a significant source of raw material for the industry. Fast growing species yield at least 10 m^3 ha^{-1}, usually a mean annual increment is between 20 and 30 m^3 ha^{-1} or even more. Plantations make good financial sense and the returns of investments on *Eucalyptus* plantations are generous (Bauhus et al., 2010). Carbon sequestration mitigates CO_2 emissions in the long term and in this way contributes to reducing the effects of climate change. Intensively managed forest plantations grow faster and simultaneously produce more biomass than many natural forests. Due to this fast growth rate a plantation have better potential for carbon sequestration than a native forest. Plantations also alleviate the pressure on harvesting of natural forests (Evans and Turnbull, 2004; IPCC, 2007; Kaul et al., 2010). High carbon sequestration potential is an important consideration in all tropical tree planting programmes. This is particularly significant in view of the rising CO_2 levels and the growing need to sequester it. The carbon storage is intricately linked with site quality, nature of land use, choice of species, silvicultural and other crop management practices adopted (Swamy et al., 2003; Mandal et al., 2013). Mandal et al. (2013) estimated current annual carbon increment (CACI) to be highest under a study undertaken at Shreepur public plantation in Mahottari district of Nepal with recommended sites following package of silviculture adopting right agronomical practices. The most recent Intergovernmental Panel on Climate Change (IPCC) assessment reports a net carbon sink of 1.4 + 0.7 Pg C per yr in the terrestrial ecosystems in the 1990s, offsetting about 20% of the global carbon emissions from fossil fuel combustion and cement production. Wood products have a potential role in the mitigation of greenhouse gas emissions, either acting as carbon pools and sinks or by substituting more energy intensive construction materials and fossil fuels (Burschel et al., 1993; Schlamadinger and Marland, 1996).

With an increasing concern for global climate changes resulting from more and more anthropogenic greenhouse gas, protecting carbon stocks in the existing forests and getting the new carbon stocks through afforestation and reforestation have become the important measures to enhance the carbon sequestration capacity in the terrestrial ecosystems and mitigate the increasing carbon dioxide concentration in the atmosphere (Lal, 2005). Pattnayak et al. had a comprehensive study on different forest types of world and their vegetation pattern which acts like a major carbon pool of terrestrial ecosystem. The growing or regenerated forest lands store and sequester more carbon through rapid growth of canopy cover and above ground biomasses. Global forest plantation cover was 187 million ha in 2005, about 1.4% of the total world available land area, of this planted area, 36% forest was located in the tropics and 64% in the non tropical regions. The tropical forest plantation area was more than doubled from 1995 to 2005 and on average, the growth rate of tropical forest plantations was 8.6% per year (FAO, 2006; Arias et al., 2011). Plantation forests are important sources of timber that alleviate the pressure on native forests for commercial forest products and are viewed as an effective means of short term carbon sequestration (Turner et al., 1999; Curlevski et al., 2010). Global warming risks from emissions of green house gases by anthropogenic activities have increased the need for the identification of ecosystems with high carbon sink capacity as an alternative mitigation strategy of terrestrial carbon sequestration. The plantation technology sector has received recent attention for its enormous potential carbon pools that reduce carbon emissions to the atmosphere. Global warming is among the most dreaded problems of the new millennium. The carbon emission is

supposedly the strongest casual factor for global warming. Trees are important sinks for atmospheric carbon i.e. CO_2, since 50% of their standing biomass is carbon itself (Ravindranath et al., 1997). Trees like *Eucalyptus* can be harvested year round and provide a living inventory of available biomass. The main goal of this paper is to assess the carbon sequestration potential of *Eucalyptus* under different land use systems.

EUCALYPTUS

Eucalyptus spp. belongs to Myrtaceae family is one of the most widely planted exotics in the tropics and an important fast growing and short rotation tree species of India. There are more than seven hundred species of *Eucalyptus* which are mostly native to Australia (Holidy, 2002) and some 170 species, varieties and provenance of *Eucalyptus* were tried in India (Bhatia, 1984). It is estimated that about 80 lakh hectares of land is under cultivation of *Eucalyptus* in the country (Surya Prakash, 2008). *Eucalyptus* is the most favored plantation trees in Indian subcontinent due to its fast growth, suitability to all types of soils, adoptability to varying climatic conditions and tolerance to water logging, salinity and sodicity (Singh et al., 2014) and for their economic, ecological values and high survival traits (Joshi et al., 2013). *Eucalyptus* can grow up to the soil pH of 11.0, 9.2 and 8.8 in sandy soil, clay and loamy soils respectively (Gupta et al., 1990).

Several pulp and paper mills and forest development corporations have embarked on raising *Eucalyptus* plantations on a large scale. Farmers are also taking up planting of *Eucalyptus* in farm lands in view of its short rotation period and high economic returns. At present, the total planted area in India is around 8 M ha and these plantations were mostly of seed origin (Aregowda et al., 2010). The new clonal *Eucalyptus* plantations started appearing on the horizon since 1992 covering nearly 2,50,000 ha of land so far (ICFRE, 2011). There is a high demand for the *Eucalyptus* wood in India for various purposes like timber, pulp wood, fire wood and poles (Saxena, 1991). Commercial *Eucalyptus* plantations are important global assets providing wood and wood fiber products to modern societies and offer a wide range of social, environmental and economic benefits to millions of people. Wood is mainly used as an excellent source of pulpwood. It is also used as poles, scaffolding, transmission lines and in construction industry. Again, wood has been tried as timber in construction and furniture industry. *Eucalyptus* plantations raised on a shorter rotation for production of pulpwood provide maximum return. Due to its multiple uses, demand of *Eucalyptus* wood is increasing day by day. The clonal *Eucalyptus* trees yield more, clear, straight and knot free timber in comparison to normal seed rooted *Eucalyptus* and fetches better market price of the wood.

CARBON SEQUESTRATION POTENTIAL IN *EUCALYPTUS* PLANTATION

Eucalyptus, an important short rotation tree species fixes the atmospheric CO_2 into biomass and sequester carbon at a faster rate as compared to other short rotation forestry species. Various authors worked on the carbon sequestration aspect of *Eucalyptus* which is summarized for the better understanding. The contribution of trees outside forests toward wood production and environmental amelioration by *Eucalyptus* in the Punjab state was studied by Dogra (2011) which sequester carbon at the rate of 236.8 kg per tree at DBH and height of 30 cm and 24 m, respectively. Further, biomass production and carbon sequestration potential of fast growing multipurpose tree species, viz., *Albizia procera, Casuarina equisetifolia, E. tereticornis* and *Gmelina arborea* at 20 years stand age was reported by Madhusudanan et al. (2011). Among the four species, *E. tereticornis* fixes carbon of 114.36 Mg ha^{-1}. Likewise, Chauhan et al. (2009) explained that tree stem C storage (4.20 t ha^{-1}) and total C storage (9.36 t ha^{-1}) were recorded in *E. tereticornis* plantation. The estimated rate of C flux in selected planted forests in India, further planted forests of short rotation tree species with regular leaf shedding patterns have more capacity for C sequestering in litter which decomposes more rapidly than species with annual or bimodal leaf shedding patterns, mixed planted forests of exotic and native species could be more efficient in sequestering C than

monocultures and fast growing hardy species like *Eucalyptus* could be ideal choice for wastelands afforestation or reforestation. *Eucalyptus* with the highest capacity of total C flux in the planted area of 27.5 Mt C per yr (Raizada et al., 2003). According to Joshi et al. (2013) studied that the rate of carbon sequestration by *Eucalyptus* hybrid of 8 years plantation was 7.88 t C ha^{-1}per yr of the Terai region of central Himalaya. Due to fast growth rate and adaptability to a range of environments, short rotation plantations, in addition to carbon storage rapidly produce biomass for energy and contribute to reduced greenhouse gas emissions. The net annual carbon sequestration rates were achieved for fast growing short rotation poplar (8 Mg C ha^{-1} per year) and *Eucalyptus* (6 Mg C ha^{-1} per year) plantations followed by moderate growing teak forests (2 Mg C ha^{-1} per year) and slow growing long rotation sal forests (1 Mg C ha^{-1} per year) revealed by Kaul et al. (2010). The carbon content of *E. tereticornis* plantations was found to be 38.10 t ha^{-1} (one year plantation) and 115.88 t ha^{-1} (four year plantation) when estimated by biomass and carbon content per cent formula method by Ulman and Avudainayagam (2014). Chavan and Rasal (2011) worked on carbon sequestration potential of *Eucalyptus* spp. in the Aurangabad city, found sequestered carbon stocks in above ground biomass is of 254.50 t ha^{-1}. Study also revealed clonal plantation of *Eucalyptus*, have got more potentiality to sequester carbon. Ram et al. (2011) found *E. tereticornis* clones planted in strip manner in water logging site of Haryana sequestered carbon total of 15.5 t ha^{-1} after the age of 5 years 4 months.

CARBON SEQUESTRATION POTENTIAL OF EUCALYPTUS IN DIFFERENT AGRO-FORESTRY SYSTEMS

Eucalyptus is adopted as a multipurpose tree species (MPTs) in different agroforestry systems particularly in the agrisilvicultural and silvipastoral system. *Eucalyptus* is raised for pulpwood, plywood and as an api-silviculture purpose in agroforestry. Furthermore, various authors carried out for the CS potential of *Eucalyptus* in agroforestry condition to estimate the environmental service. Carbon sequestration potential of *Eucalyptus* based agroforestry systems sequester C to the tune of 34 Mg C ha^{-1}. Carbon sequestration estimates of all the systems were made in line with their biomass production potential. CO_2 mitigation by plant is directly related to biomass production of the different plant components. Higher carbon stock value of system can be attributed to more biomass in any system (Prasad et al., 2012). Further, the carbon sequestration (t ha^{-1}) by different agroforestry systems was studied in Navsari, Gujarat. Among seven agroforestry systems maximum above ground (34.05 t ha^{-1} per year), below ground (8.85 t ha^{-1} per year) and total (42.90 t ha^{-1} per year) C was sequestered in spider lily + *Eucalyptus* system (Panchal, 2013). Similarly, the total carbon sequestered by agroforestry systems was highest (47.87 t ha^{-1} per year) in the *Eucalyptus* + Spider lily system. Average sequestration potential in agroforestry systems has been estimated to be 25 t C ha^{-1} (Sathaye and Ravindernath, 1998). Total carbon sequestration occurred in *Eucalyptus hybrid* + wheat boundary plantation based agroforestry system of 8.53 t C ha^{-1} and carbon sequestration rate of 0.88 53 t C ha^{-1} per year was reported by Yadava (2010). *Eucalyptus* clones in the tree plantation land use system has the maximum carbon sequestration potential of 106.27 t ha^{-1} per yr as compared to tree species like *Manilkara zapota, Mangifera indica, Tectona grandis, Albizia procera, Casuarina equisetifolia, Dalbergia latifolia, Jatropha curcas, Terminalia arjuna* and minimum of 7.55 t ha^{-1} per yr in *Manilkara zapota* in tree plantation land use system. Likewise, Singh and Pandey (2011) estimated net annual carbon sequestration in agroforestry crops indicate that components with the highest rates in India are poplar, *Eucalyptus* and bamboo (species in the Bambusae tribe). They also established that tropical home gardens have a particularly high carbon sequestration potential of 16-36 Mg t ha^{-1} per yr.

CONCLUSION

Under the present scenario of climate change, short rotation, fast growing tree species are mostly recommended in the different land use systems. *Eucalyptus* meets these requirements and

a cost effective measures to mitigate the problem of climate change by environmental services along with other primary produces. It covers an area of 2.5 lakh hectare at national level with an average carbon sequestration of 9.62 - 11.4 t ha^{-1}. Along with that *Eucalyptus* serves wide range of environmental services.

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