Asian Jr. of Microbiol. Biotech. Env. Sc. Vol. 23, No. (2) : 2021 : 186-191

ISSN-0972-3005

ESTIMATION OF CARBON SEQUESTRATION POTENTIAL OF TREES UNDER TAMIL NADU BIODIVERSITY CONSERVATION AND GREENING PROJECT (TBGP) - A VIABLE OPTION FOR CLIMATE CHANGE MITIGATION IN TAMIL NADU, INDIA

K. BOOMIRAJ[1]*, R. JUDE SUDHAGAR[2], V. ARUNASALASWAMY[3], R. POORNIMA[3], K. SENTHILRAJA[4], AND R. JAGADEESWARAN[5]

[1]Directorate of Open and Distance Learning, TNAU, Coimbatore, T.N.,India
[2]Forest College and Research Institute (TNAU), Mettupalayam, T.N.,India
[3]Department of Environmental Sciences, TNAU, Coimbatore, T.N.,India
[4]Directorate of Crop Management, TNAU, Coimbatore ,T.N.,India
[5]Agricultural College and Research Institute (TNAU), Kudumiyanmalai, Pudukottai, T.N., India

(Received 21 February, 2021; Accepted 22 March, 2021)

***Key words**: Carbon sequestration, TBGP, Bamboo, Bixa orellana, Khaya senegalensis*

Abstract – Tamil Nadu Biodiversity Conservation and Greening Project (TBGP) was launched in Tamil Nadu to create awareness and increase the green cover area through establishment of plantations in farmers' lands. Carbon sequestration potential was assessed in Pollachi forest range, where TBGP was implemented from 2011to 2015, with tree crops such as Bamboo, *Bixa orellana* and *Khaya senegalensis*. Green weight, dry weight and tree carbon content were estimated and subsequently tree carbon sequestration was calculated.The study revealed that different villages recorded variation in growth rate of tree species. Potential dry weight of four year old bamboo ranged from 25 to 145 kg tree^{-1}and five year old bamboo ranged from 149 to 256 kg tree^{-1}. Five year old Bamboo, *Bixa orellana* and *Khaya senegalensis* recorded carbon sequestration potential ranging from 23.9 to 13.2 tonsacre^{-1}, 71 and 334 kgacre^{-1} respectively. Considering the huge extent of cultural waste lands, current fallow lands and other fallow lands in Tamil Nadu, which is estimated to be 2.645 million ha, bamboo cultivation in these lands under TBGP has the potential to sequester 31.7 to 121.2 million tonnes of carbon, while *Bixa orellana* could sequester 0.47 million tonnes of carbon and *Khaya senegalensis* has the potential to sequester 2.21 million tonnes of carbon in five years apart from other ecosystem benefits. Large scale establishment of tree plantations of the above mentioned tree species could provide to be a viable option for mitigation of climate change through implementation of TBGP in the state of Tamil Nadu.

INTRODUCTION

Impact of climate change across the globe is one of the hottest issues which has emerged in the 21st century. Climate is a dynamic system which tends to change with time, but the rapid rate of change which is occurring now is attributed mainly to human activities. One of the major issuesrelated to climate change is the increasing concentration of atmospheric Greenhouse Gases (GHGs) and their impact over life systems on earth in future. Continuous monitoring of atmospheric CO_2 concentration at Mauna Loa observatory, Hawaii from 1958 revealed the alarming increase of CO_2 from 316 ppm in 1958 to 390 ppm in 201O. According to IPCC (2007), the mean global CO_2 concentration was increasing at the rate of 1.7 ppm per year. Total anthropogenic GHG emissions have continued to increase over 1970 to 2010 with larger absolute decadal increases toward the end of this period. Even though there are many number of mitigation strategies implemented throughout the world, still annual GHG emissions grew on average by 1.0 gigatonne carbon dioxide equivalent (Gt CO_2 eq.) (2.2%) per year from 2000 to 2010 compared to 0.4 GtCO_2eq (1.3 %)compared to per year from 1970 to 2000 (IPCC, 2014). Total anthropogenic GHG emissions were the highest in human history from 2000 t0 2010 and reached 49 (±4.5) GtCO_2eq. yr^{-1}in 2010. Carbon sequestration which is one of the best

options refers to the removal of carbon di-oxide from the atmosphere into a long lived stable form that does not affect atmospheric chemistry (Miller *et al.*, 2002). Thus, identification of viable sinks is of high priority which act as passive pools of carbon with a long residence time. Several options of CO_2 sequestration being considered are of geologic, oceanic, chemical transformation and terrestrial significance. Among these options, carbon capture in the form of terrestrial sequestration is a natural process withancillary benefits coupled withcost-effectiveness (Lal, 2008).

Plantation tree crops play a key role in terrestrial carbon sequestration,which efficiently convert CO_2 into biomass, besides improving soil carbon pools. Thus, it is a win-win strategy to establish tree plantations for stabilizing the GHGs. Every country is taking measures to reduce the GHGs emission by different methods of sequestering carbon in the soil, trees and water. One such major initiative taken by the Tamil Nadu Government for carbon sequestration by trees was accomplished by implementing Tamil Nadu Biodiversity Conservation and Greening Project (TBGP) in the state of Tamil Nadu. Hence, the present research investigation was carried out to quantify the carbon sequestration potential of trees which were planted under TBGP in Pollachi range of Tamil Nadu.

MATERIALS AND METHOD

Study Area

The study area selected for the research was Pollachi range of Tamil Nadu Forest department which is located about 40 km south of Coimbatore city. Pollachi is the second largest town in the district after Coimbatore (Fig. 1). Three locations *viz* Samuraipatty, Poolavadi and Suryanallur villages in Pollachi range and three tree species *viz.* bamboo, *Bixa orellana* (Annatto) and *Khaya senegalensis* (African Mahogany) were considered for this study. Bamboo was cultivated under TBGP in all the three villages while *Bixa orellana* and *Khaya senegalensis* were cultivated in Suryanallur village alone. Bamboo (5m x 4m) was found in all the three villages in two ages*viz.* four and five years old whereas Annatto (2.5m x 4m) and African Mahogany (5m x4m) were of three years and five years age.

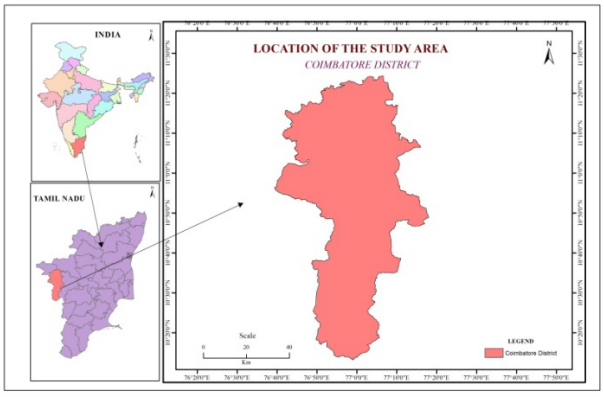

Fig. 1. Study area

Calculation of CO_2 sequestered per tree per year

The average carbon content is generally 50% of the tree's total volume. Rate of carbon sequestration depends on the growth characteristics of the tree species, locality factors, and wood density of. Generally, sequestration is highest in the younger stages of tree growth (between 20 to 50 years).

Total green weight

According to Alexander Clark III *et al.* (1986), the algorithm used to calculate the weight of a tree is as follows:

For trees with D < 11 inches $W = 0.25\ D^2H$; for trees with D >= 11inches $W = 0.15D^2H$

W = Above-ground weight of the tree in pounds; D = Diameter of the trunk in inches; H = Height of the tree in feet. Depending on the species, the coefficient (e.g. 0.25) could change, and the variables D^2 and H could be raised to exponents just above or below. However, these two equations could be considered as an "average" of all the species' equations.Tree root system weighs about 20% as much as the above-ground weight of the tree. Therefore, to determine the total green weight of the tree, multiply the above-ground weight of the tree by 120%.

Tree dry weight

This methodology is based on an extension publication from the University of Nebraska by Alexander Clark III *et al.* (1986). This publication has a table with average weights for one cord of wood for different temperate tree species. Taking all species into account, the values for an average tree is 72.5% dry matter and 27.5% moisture. Therefore, to determine the dry weight of the tree, multiply the weight of the tree by 72.5%.

Determination oftree carbon content

The average carbon content is generally 50% of the

tree's total volume. Therefore, to determine the weight of carbon in a tree, multiply the dry weight of the tree by 50% (Toochi, 2018).

Determination of CO_2sequestration

CO_2 is composed of one molecule of carbon and 2 molecules of oxygen. Atomic weight of carbon is 12.001115, atomic weight of oxygen is 15.9994, and weight of CO_2 is C+2*O=43.999915. The ratio of CO_2 to C is 43.999915/12.001115=3.6663. Therefore, to determine the weight of carbon dioxide sequestered in a tree, multiply the weight of carbon in the tree by 3.6663 (Toochi, 2018).

RESULTS AND DISCUSSION

Rate of carbon sequestration depends on the growth characteristics of the tree species, locality factors and wood density. It is greatest in the younger stages of tree growth generally between 20 and 50 years. However, research on this aspect in tropical tree species is scanty when compared to temperate tree species.

Total green weight of Bamboo

Total green weight of Bamboo was calculated including the root system. The average green weight of four year old bamboo in the three study villages *viz.* Samuraipatty, Poolavadi and Suryanallur were 50, 200 and 34 kg tree^{-1} (Table 1). Average green weight of five year old Bamboo in the sampled villages were 353, 784 and 205 kg tree^{-1}

Determination of dry weight of bamboo

Dry weight of the Bamboo was calculated using the total green weight. Average dry weight of four year old bamboo in the three sampled villages were 37, 145 and 25 kg tree^{-1} (Table 1). Average dry weight of five year old bamboo were 256, 568 and 149 kg tree^{-1}in Samuraipatty, Poolavadi and Suryanallur respectively.

Determination of weight of carbon in bamboo

The weight of carbon in bamboo was calculated using the dry weight of bamboo. Weight of carbon in four year old bamboo were18, 72 and 12 kg tree^{-1}in Samuraipatty, Poolavadi and Suryanallur respectively. Similarly, weight of carbon in bamboo of five years age were 128, 284 and 74 kg tree^{-1} in Samuraipatty, Poolavadi and Suryanallur respectively (Table 2).

Determination of weight of CO_2 sequestered by bamboo

The weight of CO_2 sequestered in bamboo was calculated by using the weight of carbon in bamboo. Average weights of CO_2 sequestered in four year old bamboo were 67, 266 and 45 kg tree^{-1} in Samuraipatty, Poolavadi and Suryanallur

Table 1. Total green weight of bamboo tree (W)

S. No.	Name of village	Age in years	Green weight (W) in kg	Dry weight (Kg)
1	Samuraipatty	4	50	37
		5	353	256
2	Poolavadi	4	200	145
		5	784	568
3	Suryanallur	4	34	25
		5	205	149

Table 2. Weight of carbon in bamboo

S.No.	Name of village	Age in years	Weight of Carbon (Kg)	Weight of sequestered CO_2 (kg)	Weight of CO_2 sequestered per treeyear^{-1} (Kg)	CO_2 sequestered t acre^{-1}
1	Samuraipatty	4	18	67	17	7.36
		5	128	469	94	41.26
2	Poolavadi	4	72	266	66	29.21
		5	284	1041	208	91.65
3	Suryanallur	4	12	45	11	4.97
		5	74	272	54	23.98

respectively. Similarly, the average weight of CO_2 sequestered by five year old bamoo were 469, 1041 and 272 kg per tree^{-1} in Samuraipatty, Poolavadi and Suryanallur respectively (Table 2). The five year old babmboo can able to sequester 41.26, 91.65 and 23.98 t acre^{-1} in Samuraipatty, Poolavadi and Suryanallur respectively.

Determination of weight of CO_2 sequestered by bamboo per year

The weight of CO_2 sequestered by bamboo per year was calculated using the weight of CO_2 sequestered in bamboo. The average weight of CO_2 sequestered in four year old bambooper yearwere17, 66 and 11 kgtree^{-1} year^{-1} in Samuraipatty, Poolavadi and Suryanallur respectively (Table 2). In five year old bamboo, the average weight of CO_2 sequestered per tree per year were 94, 208 and 54 kgtree^{-1}year^{-1} in the three sampled villages.

Determination of total green weight in African Mahogany and Annatto

The total green weight was calculated including the root system. In Suryanallur village, the average green weight of three year old *Khaya senegalensis* and *Bixa orellana* was 0.67 and 0.19 kg respectively while in five year old trees of the above mentioned tree species, the green weight was 6.29 and 0.67 kg respectively (Table 3).

Dry weight

Dry weight was calculated using the total green weight of the tree species concerned. In Suryanallur village, the average dry weight of three year old African Mahoganyand Annatto was 0.49 and 0.14 kg tree^{-1}respectively. In five year old plantations of the above mentioned tree species, the average dry weight was 4.56 and 0.48 kg tree^{-1} (Table 3).

Weight of carbon per tree

Weight of carbon was calculated taking into consideration of the dry weight of the tree species concerned. Average weight of carbon in three year old plantations of African Mahogany and Annatto were 0.24 and 0.07 kg tree^{-1} (Table 4). In five year old African Mahogany and Annatto plantations, the average weight of carbon per tree was 2.28 and 0.24 kg respectively.

Weight of CO_2 sequestered

The weight of CO_2 sequestered in African Mahogany and Annatto was calculated using the weight of carbon in the tree species respectively. In three year old plantations of the above mentioned tree species, the average weight of CO_2 sequestered was 0.89 and 0.26 kg tree^{-1} whereas in five year old plantations, the values were 8.36 and 0.88 kg tree^{-1} respectively (Table 4).

Weight of CO_2 sequestered per year

Weight of CO_2 sequestered in African Mahogany and Annatto per year was calculated using the weight of CO_2 sequestered in the tree species concerned. The average weight of CO_2 sequestered in the tree species under consideration per year (3 year old plantation) was 0.30 and 0.09 kg tree^{-1} year^{-}

Table 3. Total green weight of *Khaya senegalensis* and *Bixa orellana*

S. No.	Name of the tree species	Name of village	Age in years	Total Green weight (kg)	Dry weight (kg)
1	*Khaya senegalensis*	Suryanallur	3	0.67	0.49
			5	6.29	4.56
2	*Bixa orellana*	Suryanallur	3	0.19	0.14
			5	0.67	0.48

Table 4. Carbon and CO_2 sequestration potential of African Mahogany and Annatto

S. No.	Name of the tree species	Name of village	Age in years	Total carbon (kg)/ tree	Weight of sequestered CO_2 (kg) tree^{-1}	Weight of CO_2 sequestered tree year^{-1} (kg)	Weight CO_2 sequestered kgacre^{-1}
1	*Khaya senegalensis*	Suryanallur	3	0.24	0.89	0.30	59.46
			5	2.28	8.36	1.67	334.40
2	*Bixa orellana*	Suryanallur	3	0.07	0.26	0.09	34.44
			5	0.24	0.88	0.18	70.74

[1]. In five year old plantations of the two tree species under investigation, the average weight of CO_2 sequestered was 1.67 and 0.18 kg tree^{-1}year^{-1} (Table 4). The five year old *Khaya senegalensis* and *Bixa orellana* could able to sequester 334.4 and 70.74 kgacre^{-1}.

Discussion and Conclusion

CO_2 Sequestration potential of Bamboo plantations

In the three villages taken up for the present investigation, the average weight of CO_2 sequestered per tree per year ranged from 11 to 66 kg while the values for five year old bamboo plantation ranged from 54 to 208 kgtree^{-1}year^{-1}. Potential CO_2 sequestration by bamboo in the fourth year works out to be in the range of 2.2 – 13.2 tonsacre^{-1}year^{-1}. In five year old plantations of bamboo, the potential carbon sequestration increases and is expected to be in the range of 10.8 to 41.6 tonsacre^{-1} year^{-1}. Similar results were reported by Singh *et al.* (2006) in *Dendrocalamus strictus* where in the total carbon storage was recorded to be 96.35 t ha^{-1} . Of this, the above ground storage contributed to 74 per cent while below ground storage accounted for 26 per cent. Dhruw *et al.* (2009) revealed that fast growing trees have more potential to capture and store atmospheric carbon di oxide at a faster rate in comparison to slow growing species and they reported that the carbon concentration ranged from 40.83 to 45.20 per cent.

CO_2 Sequestration potential of *Bixa orellana* plantations

Weight of CO_2 sequestered by Annatto per tree per year is estimated to be 0.09kg tree^{-1}year^{-1} when the plantations are three years old. In five year old Annatto plantations, the weight of CO_2 sequestered was estimated to be 0.18 kgtree^{-1}year^{-1}. Miehle *et al.* (2006) examined the carbon sequestration capacity of six year old *Eucalyptus globulus* plantation and recorded 1.62 t C ha^{-1}. Maikhuri *et al.* (2000) observed higher carbon sequestration potential in *Alnusnepalensis* (0.256 t C ha^{-1} year^{-1}) and *Dalbergiasissoo* (0.141 t C ha^{-1} year^{-1}).

CO_2 Sequestration potential of African Mahogany

In three year old *Khaya senegalensis* plantations, average weight of CO_2 sequestered was recorded to be 0.30 kg tree^{-1} year^{-1} whereas in five year old plantations, the potential was recorded to be 1.67 kg of CO_2 tree^{-1} year^{-1}. Houghton (1995) opined that conceptually trees are considered to a viable terrestrial carbon sink. Carbon sequestration potential of various tree plantations was estimated and reported by various authors like Miehle *et al.* (2006) and Forrester *et al.* (2006) in *Eucalyptus globulus,* Shivanna *et al.* (2006) in *Pongamiapinnata*, Swamy *et al.* (2003) in *Gmelinaarborea,* Heryanto *et al.* (2002) in *Acacia mangium*which are in support of the results of the present investigation.

Based on the observations recorded in the present investigation, it could be observed that out of the three tree species taken up for the study, bamboo has the greatest carbon sequestration potential owing to its fast growth and ability to grow in a wide range of climatic and edaphic conditions. India is endowed with 137 species of bamboos and its natural distribution is found across the country. Among the various bamboo species, *Bambusabambos, Dendrocalamus strictus, Bambus abalcooa* and *Bambusa vulgaris* are cultivated on a commercial scale. Bamboos have more than 1500 documented uses and hence are termed as Poor man's timber or green gold. Hence, it could be concluded that Bamboos could be considered for establishment of large scale plantations in mass tree planting programmes in Tamil Nadu given its high carbon sequestration potential when compared with other tree species.

REFERENCES

Alexander Clark III, Joseph R. Saucier and Henry McNab, W. 1986. Total-Tree Weight, Stem Weight, and Volume Tables for Hardwood Species in the Southeast. Research Division, Georgia Forestry.

Dhruw, S., Lalji, S. and Singh, A. 2009. Storage and sequestration of carbon by leguminous and non-leguminous trees on red lateritic soil of Chhattisgarh. *Indian Forester.* 135(4) : 531-538.

Forrester, D.I., Bauhus, J. and Cowie, A.L. 2006. Carbon allocation in a mixed-species plantation of *Eucalyptus globulus* and *Acacia mearnsii. Forest Ecology and Management.* 233(2-3) : 275-284.

Heryanto, N., Heriansyah, I., Sirear, C. and Kiyoshi, M. 2002. Measurement of biomass in forests. *JICA & FORDA,* Bogor

Houghton, R.A. 1995. Changes in storage of terrestrial carbon since 1850. Paper presented in the Conference on *Soils and Global Change*.

Inter Governmental Panel on Climate Change. 2007. Technical Summary. In: *Climate Change.* Ed: l.T.Houghton *et al.* Cambridge University Press, Cambridge, UK, pp. 9-49.

IPCC, 2014. Summary for Policymakers, In: Climate Change 2014, Mitigation of Climate Change. Contribution of Working Group III to the Fifth

Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Lal, R. 2008. *Carbon sequestration.* Phil. Trans. R. Soc. B (2008) 363, 815–830.

Maikhuri, R., Semwal, R., Rao, K., Singh, K. and Saxena, K. 2000. Growth and ecological impacts of traditional agroforestry tree species in Central Himalaya, India. *Agroforestry Systems.* 48 (3) : 257-271.

Miehle, P., Livesley, S., Feikema, P., Li, C. and Arndt, S. 2006. Assessing productivity and carbon sequestration capacity of *Eucalyptus globulus* plantations using the process model Forest DNDC: Calibration and validation. *Ecological Modelling.* 192 (1-2):83–94pp

Miller, R. and Shennan, C. 2002. Transition from conventional to low-input agriculture changes soil fertility and biology. *Calif. Agric*. 48 : 20-26.

Shivanna, H., Janagiri, P., Balachandra, H.C. and Kyatappanvar, S. 2006. Potential of *Pongamiapinnata*in carbon sequestration – An important bio-diesel plant. *My Forest*. 42(1) : 5-11.

Singh, P., Dubey, P. and Jha, K. 2006. Biomass production and carbon storage at harvest age in superior *Dendrocalamus strictus* (Roxb) nees. Plantation in dry deciduous forest regions of India.

Swamy, S., Puri, S. and Singh, A. 2003. Growth, biomass, carbon storage and nutrient distribution in *Gmelinaarborea* Roxb. Stands on red lateritic soils in central India. *Bioresource Technology.* 90(2) : 109-126.

Toochi, E.C. 2018. Carbon sequestration: how much can forestry sequester CO_2. *Forest Res EngInt J.* 2(3): 148-150.