Research Journal of Recent Sciences ____ISSN 2277-2502
Vol. **13(1),** 15-19, January **(2024)** *Res. J. Recent Sci.*

Above-ground biomass and carbon stored by teak (*Tectona grandis)* in Gir National Park, Gujarat, India

Nidhi Goyal[1*], Jamal A. Khan[2] and Nazneen Zehra[2]
[1]Wildlife Institute of India, Chandrabani, 248001, Dehradun, Uttarakhand, India
[2]Department of Wildlife Science, Aligarh Muslim University, 202002, Aligarh, Uttar Pradesh (U.P.), India
agarwalnidhi782@gmail.com

Available online at: www.isca.in, www.isca.me
Received 17th October 2023, revised 24th November 2023, accepted 27th December 2023

Abstract

Earth's most crucial greenhouse gas is carbon dioxide (CO2), a gas responsible for absorbing and emitting heat. An accurate characterization of above-ground biomass and tree carbon in tropical forest is important to estimate their contribution to Global Carbon stocks. A non-invasive method was used to estimate the carbon stored by the dominant tree species of Gir National Park and Sanctuary (GNPS) i.e., Teak. Circular plots of 10 x 10 m were laid in GNPS with a systemic random sampling to get the Girth at Breast Height (GBH) of the trees. An allometric equation with GBH as one of the independent variables was already developed for Teak and was used to estimate the total biomass and stored Carbon in present study. The result indicates that total dry biomass in National Park is 189.07 ± 6.7 kg per tree. The Carbon sequestered per tree is 94.5(±3.3) with 16.34 (±0.02) tonnes of carbon and 59.96 tonnes of CO_2 per hectare. In case of Wildlife sanctuary, the total dry biomass was 202.42 kg (± 18.2) per tree. The carbon sequestered per tree is 101.21 kg (± 9.14) with 9.113 (± 0.02) tonnes of carbon and 33.44 tonnes of CO_2 per hectare. It is the first study to estimate dry biomass and carbon stored by the tress in GNPS and the carbon storage vary among species so there is need to estimate carbon stored by other tree species in future. Carbon sequestration plays a vital role in addressing climate change. Considering the impact of climate change, a synergistic approach involving both bioenergy and carbon sequestration emerges as the most effective strategy for long-term mitigation of CO_2 emissions.

Keywords: Greenhouse gas, Carbon sequestration, Systemic random sampling, Above ground biomass, Climate change, Bioenergy.

Introduction

The increasing Carbon Dioxide (CO_2) is main reason for increasing global warming and climate change.It constitutes about 0.04% in the atmosphere but is the main component of greenhouse gases. Its concentration has been increased from 280 ppm during pre-industrial period to 390 ppm[1]. It plays a vital role in the process of photosynthesis by which trees stored CO_2 in the form of biomass for several years. The forest biomass both above and below ground accounts for approximately 90% of all the living terrestrial biomass on earth[2]. The world's forests contain around 80% of all above ground Carbon and 40% of all belowground terrestrial Carbon[2]. Among all ecosystems, tropical forests play a crucial role in sequestering carbon dioxide, thereby helping to alleviate the impact of rising Earth temperature. Encompassing 7-10% of the Earth's total land area, these forests store nearly half of the global carbon found in terrestrial vegetation. Moreover, they engage in the annual processing of roughly six times the amount of carbon through photosynthesis and respiration compared to the carbon emissions humans generate from fossil fuel use[3,4]. The carbon sequestered by plants depend on its biomass which depends on many factors like soil type, environmental condition, land change and land use, etc. Numerous techniques have been devised to assess stocks of above-ground biomass (AGB)[5.6.7]. Nonetheless, accurate estimates of carbon stocks in tropical forests were elusive as specific equations for calculating above-ground biomass (AGB) from tree measurements were lacking[6]. Carbon sequestration can be accessed through various approaches, including direct and indirect methods. While direct methods offer greater precision than indirect ones[8], it's important to note that direct methods can be destructive and involve harvesting a sample tree[9]. This practice is not suitable, particularly in areas like Gir, which serves as the last habitat for Asiatic lions (Panthera leo). An indirect and non-invasive method was used in this study in the form of an allometric equation which has been already developed with GBH (Girth at Breast Height). The GBH is mostly used as independent variable to enumerate the biomass as it is more precise than other variables and there is a strong correlation between diameter of a tree and the biomass[10]. These allometric models are species specific and also vary along with the physiograph gradients and also can vary at different sites[11]. It also varies from species to species and at different age of the same tree species. Different parts of a tree store different amount of carbon, it is maximum in branches than tap root and fine root than bole than leaf than lateral root, seed, twig and the minimum content is present in bark[12]. The carbon content in a tree varies from 48% in leaves to 54% in wood[9]. Average carbon content is taken 50% in most of the study so we have also taken 50% carbon content in this study which has 0.05 conversion factor.

The present study estimated the carbon stored for teak (*Tectona grandis*) as it is one of the dominant tree species of many tropical forests of India including GNPS. Teak forests in India are distributed across the states of Gujarat, Madhya Pradesh, Maharashtra, Tamil Nadu, Karnataka, Kerala, Uttar Pradesh, Orissa, and Rajasthan[13]. The ability of teak in sequestrating carbon is determined by many factors like age class or growth level. Some study[14] showed that in the oldest teak which is represented by larger trunk diameter has higher stored carbon, around $699.01 m^3 ha^{-1}$, while 21-year-old teak store around 1,037 kg of carbon. There are many factors which govern the productivity of a forest and rainfall is one of the limiting factors effecting the biomass production and accumulation in seasonally dry tropical and tropical forest and hence also for carbon storage[15]. The regulating service like carbon sequestration also effects other ecosystem services like nutrient cycling, climate change, water cycling and ultimately to the biodiversity of the forest. Therefore, carbon sequestration adds another reason in favour of conservation of tropical forest like Gir. This is the first study conducted in GNPS for estimating dry biomass and carbon sequestration.

Study area: The study was conducted in Gir National Park and Wildlife Sanctuary (hereafter Gir), Gujarat. It is situated between latitude 208400 N 218500 N and longitude 708500 E 718500 E in the Saurashtra region of Gujarat. The area of gir is 1413^2 km, with 258^2 km area as National Park and 1155^2 km as wildlife sanctuary. Gir belongs to the type 5A/Cla forest type, i.e., very dry teak forest[16]. The temperature of Gir varies from 10 to 45^0 C and rainfall from 199 to 1866 mm. It has a hot dry summer from mid of March to mid of June followed by Monsoon which arrives in mid of the June to September with a short winter period from December to January. Gir supports a rich biodiversity, 606 recorded flowering plant species, 39 mammalian species, 37 reptiles, 300 species of birds and more than 2000 species of insects[17,18]. Gir is divided into three main parts, West gir, Central gir and East gir. *Tectona grandis* is main tree species of Gir along with *Ziziphus spp*. and *Acacia spp.* Teak is the main source of carbon storage and to support diversity of gir and other ecosystem services like climate change etc. The internal region of Gir is occupied by old tribes called Maldharis and there are around 50 nesses of those maldharis inside the Gir.

Materials and methods

The GBH was one of the independent variables in the allometric equation used for calculating the biomass of teak. The biomass can also be calculated by using both the GBH as well as the height but gbh is more accurate as it is not possible to measure the accurate height of tress without falling it down. For GBH, the circular vegetation plots of 10 x 10 m were laid in a random stratified manner comprising the grid system. The size of the grid was $4km^2$. There are 13 grids in National Park having 104 plots and 53 grids in wildlife sanctuary having 424 plots so the total number of plots in Gir were 528. The diameter at breast height and height of all the trees (teak) within the plot were measured.

The linear regression equation developed for teak[16,17] at R^2=0.898, for statically significance p=<0.01.

$$y = 3.1749x - 21.273$$

Where, x= gbh of a tree (cm), y = aboveground biomass

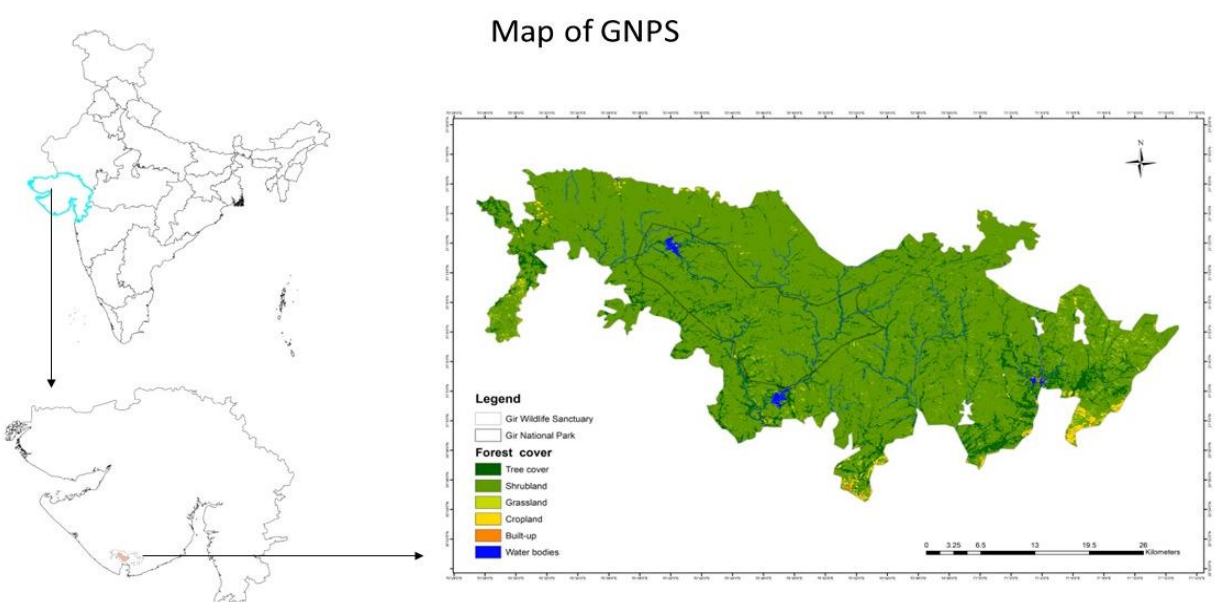

Figure-1: Map of the study area.

The formula BGB = 0.25×AGB was employed, following the guidelines of the Intergovernmental Panel on Climate Change (IPCC), to calculate the below-ground biomass (BGB) of a teak tree in an experimental setting. The carbon content was calculated as 0.5×total dry biomass (AGB+BGB) for each tree. The regression equations and correlation coefficients obtained for different variables of reference teak trees were tested for statistical significance at α =0.05
C= Total Biomass x 0.5

The carbon sequestered is multiplied by CO_2 atomic mass ratio i.e., 3.67 (15(19); 31(20)) to attain the CO_2 sequestered of any region or tree.

Results and discussion

The dominant plant species of GNPS is teak (*Tectona grandis)* therefore it plays a vital role in storing the carbon. As Gir is divided into National Park and Wildlife Sanctuary and the density of teak varies between them so the carbon storage.

The Average density of teak in National Park is 17.3/km ± 0.85, average GBH is 54.3cm ± 1.7 and average height is 8.5cm ± 0.25. The above ground biomass and below ground biomass per tree was 151.2kg ± 5.4 and 37.81 ± 1.3kg respectively. Therefore, the total dry biomass per tree was 151.2kg ± 5.4. Carbon sequestered per tree was found to be 94.5kg ± 3.3 with 16.34 ± 0.02 tonnes/hectare of carbon and 59.96 tonnes of Carbon dioxide per hectare.

The average density of teak in Wildlife Sanctuary is 9.0/km ± 0.26, average GBH teak of the wildlife sanctuary is 57.6cm ± 4.6 and average height is 8.01cm ± 0.11. The above ground biomass and below ground biomass were estimated around 161.9 ± 14.6kg/tree and 40.48 ± 3.6kg/tree respectively. Therefore, the total dry biomass per tree in wildlife sanctuary was 202.42 ± 18.2kg. Carbon sequestered per tree was 101.21 ± 9.14kg with 9.113 ± 0.02 tonnes of carbon per hectare and 33.44 tonnes of carbon dioxide per hectare.

The comparison of different parameters of how carbon storage varies with height and gbh is described in Table-1.

Discussion: The anthropogenic activities like deforestation, burning of fossil fuels, mining etc enhances the amount of greenhouse gases (GHGs, especially CO_2) in the atmosphere and 12 to 20 per cent of GHG emission has resulted from deforestation activity alone[21]. Among the GHGs, CO_2 accounts for a major share of 60 per cent[22]. According to Global Change the amount of carbon dioxide has been increased more than 42% in the atmosphere from the last 42 years owing mainly to anthropogenic activities. The reduction of carbon emission is called carbon credits, permanent credits are referred to reduce the carbon emission at source whereas the carbon reduction by reforestation and afforestation are called non-permanent credits[23]. One-gram dry organic matter fixes 1.63g of CO_2[21] which if left unmonitored leads to global temperature rise. Studies of Indian forests as a part of the National Forest carbon balance[24-27] have examined strata and state/regional forest area changes. Their results range from the finding that the forests are a major sink for atmospheric carbon[28]. In case of non-permanent carbon credit, globally, the annual planting rate is 4.5 million ha, with Asia and South America accounting for 89%[29].

Table-1: Comparison of different parameters of National Park and Wildlife Sanctuary.

Parameters	National Park	Wildlife Sanctuary
Teak density (per km)	17.3 ± 0.85	9.0 ± 0.26
Average GBH (cm)	54.3 ± 1.7	57.6 ± 4.6
Average height (cm)	8.5 ± 0.25	8.01 ± 0.11
AGB per tree (kg)	151.2 ± 5.4	161.9 ± 14.6
BGB per tree (kg)	37.81 ± 1.3	40.48 ± 3.6
Total Biomass per tree (kg)	189.07 ± 6.7	202.42 ± 18.2
Carbon per tree	94.5 ± 3.3	101.21 ± 9.14
Carbon (ton/hec)	16.34 ± 0.02	9.113 ± 0.02
Carbon dioxide (ton/hec)	59.96	33.44

Studies have revealed that the forest in India has a potential to sequester 92 t/hectare of CO_2[30] with a carbon uptake of 11.8 metric ton and a projected carbon uptake of 55.48 Mt and 73.48 Mt and a sequestration potential of 4.1 and 9.8 Gt for the year 2020 and 2045[31,32]. According to the Forest Survey of India, 2017, India has a total carbon stock of 7082 million tons sequestered in the trees and soil. According to India state of forest report (2017), the total carbon stock of Gujarat state was 110.697 million tonnes which was classified as AGB is 32.668 million tonnes, BGB was 11,719 million tonnes, dead wood contains 322 million tonnes, litter has 993 million tones and the SOG has 64,995 million tonnes.

Regulating services like carbon sequestration varies from forest types and age of forest as well as with the tree species. Every species contributes in storing the carbon but the amount of storage varies. The genus Tectona belongs to the family *lamiaceae* which is important for human kind for its aromatic and medicinal values. Teak is native to south and south east Asia and is dominant species in arid region of India and this is the first study to evaluate the carbon storage by teak of this region. Approximately 40% of annual carbon is absorbed by volume growth of a tree in the form of above ground biomass. The forest biomass both above and below ground accounts for approximately 90% of all the living terrestrial biomass on earth[2]. The world's forest absorbs and sequesters 296 GT of carbon in its above and below ground biomass[33]. The calculation involves multiplying wood density by volume, assuming uniform wood density across individuals of a timber tree species. This means that above-ground biomass (AGB) is directly influenced by volume, which in turn is dependent on the girth at breast height (GBH) and height. This correlation between AGB and GBH has been utilized in the present study. Nonetheless, there is a need to acquire more precise and accurate biomass estimates for tropical forests to enhance our comprehension of the pivotal role tropical forests play in the global carbon cycle[34-36].

Conclusion

Stored carbon in the forests is important to study climatic change in terms of total carbon emission and global carbon storage capacity which is important for climatic regulation in future. Carbon sequestration plays a vital role in addressing climate change. Considering the impact of climate change, a synergistic approach involving both bioenergy and carbon sequestration emerges as the most effective strategy for long-term mitigation of CO_2 emissions.

Acknowledgement

We sincerely thank to the Department of Science and Technology for the funding support and the Gujarat Forest Department for allowing us to work. We also thank to all the authors and the reviewer for their contribution to this work. We thank Dr. Rohit Chaudhary and Dr. Pooja Thathola for their support during the study. We would like to thank all the seniors and colleagues of Aligarh Muslim University.

References

1. Vashum, K. T., & Jayakumar, S. (2012). Methods to estimate above-ground biomass and carbon stock in natural forests-a review. *Journal of Ecosystem & Ecography*, 2(4), 1-7.
2. Mohammadi, Z., Mohammadi Limaei, S., Lohmander, P., & Olsson, L. (2017). Estimating the aboveground carbon sequestration and its economic value: case study: Iranian Caspian Forests. *Journal of Forest Research*, 63(11), 511-518.
3. Lewis, S. L. (2006). Tropical forests and the changing earth system. Philosophical Transactions of the Royal Society B: Biological Sciences, 361(1465), 195-210.
4. Malhi, Y., & Grace, J. (2000). Tropical forests and atmospheric carbon dioxide. *Trends in Ecology & Evolution*, 15(8), 332-337.
5. Brown, S. (1997). Estimating biomass and biomass change of tropical forests: a primer (Vol. 134). *Food & Agriculture Org.*.
6. Chave, J., Andalo, C., Brown, S., Cairns, M. A., Chambers, J. Q., Eamus, D., ... & Yamakura, T. (2005). Tree allometry and improved estimation of carbon stocks and balance in tropical forests. *Oecologia*, 145, 87-99.
7. Clark, D. A., Brown, S., Kicklighter, D. W., Chambers, J. Q., Thomlinson, J. R., Ni, J., & Holland, E. A. (2001). Net primary production in tropical forests: an evaluation and synthesis of existing field data. *Ecological applications*, 11(2), 371-384.
8. Mbow, C., Verstraete, M. M., Sambou, B., Diaw, A. T., & Neufeldt, H. (2014). Allometric models for aboveground biomass in dry savanna trees of the Sudan and Sudan-Guinean ecosystems of Southern Senegal. *Journal of Forest Research*, 19(3), 340-347.
9. Bayen, P., Bognounou, F., Lykke, A. M., Ouédraogo, M., & Thiombiano, A. (2016). The use of biomass production and allometric models to estimate carbon sequestration of Jatropha curcas L. plantations in western Burkina Faso. *Environment, Development and Sustainability*, 18, 143-156.
10. Clark, D. A., Brown, S., Kicklighter, D. W., Chambers, J. Q., Thomlinson, J. R., Ni, J., & Holland, E. A. (2001). Net primary production in tropical forests: an evaluation and synthesis of existing field data. *Ecological applications*, 11(2), 371-384.
11. Tinker, D., Stakes, G. K., & Arcano, R. M. (2010). Allometric equation development, biomass, and aboveground productivity in Ponderosa pine forests, Black Hills, Wyoming. *Western Journal of Applied Forestry*, 25(3), 112-119.
12. Jha, K. K. (2015). Carbon storage and sequestration rate assessment and allometric model development in young teak plantations of tropical moist deciduous forest. *India. J. For. Res*. DOI 10.1007/s11676-015-0053-9
13. Jain, A. and Ansari, S. A. (2013). Quantification by allometric equations of carbon sequestered by Tectona grandis in different agroforestory systems. *Journal of Forestry Research*, 24(4), 699−702. DOI 10.1007/s11676-013-0406-1
14. Khanduri, V.P.; Lalnundanga; Vanlalremkimi, J. (2008). Growing stock variation in different teak (Tectona grandis) forest stands of Mizoram, India. *Environmental Science-Journal of Forestry Research*. DOI:10.1007/s11676-008-0043-2
15. Becknell, J.M., Kucek, L.K. and Powers, J.S. (2012). Aboveground biomass in mature and secondary seasonally dry tropical forests: A literature review and global synthesis. Forest *Ecology and Management* 276 (2012) 88–95
16. Alam, M. S. (2010). First record of Lesser False Vampire Bat (Magaderma spasma) in Gir National Park and Sanctuary. *Journal of the Bombay Natural History Society*, 107(2), 155-156.

17. Meena, R. L., & Kumar, S. (2012). Management plan for Gir protected areas. Gujarat Forest Department, Gujarat, India.

18. Hernandez, S.G. and Sheehan, S.W. (2020). Comparison of carbon sequestration efficacy between artificial photosynthetic carbon dioxide conversion and timberland reforestation. *MRS Energy and Sustainability*. doi:10.1557/mre.2020.32

19. Othman, R., & Kasim, S. Z. A. (2016). Assessment of plant materials carbon sequestration rate for horizontal and vertical landscape design. *International Journal of Environmental Science and Development*, 7(6), 410.

20. Ninan, K. N., & Inoue, M. (2014). Valuing forest ecosystem services: Case study of a forest reserve in Japan. In Valuing Ecosystem Services (pp. 245-268). Edward Elgar Publishing.

21. Melkania, N.P. (2009). Carbon Sequestration in Indian Natural and Planted Forests. *Indian Forester*, 135(3), 380-387.

22. Derwisch, S., Schwendenmann, L., Olschewski, R., Ho¨lscher, D. (2009). Estimation and economic evaluation of aboveground carbon storage of Tectona grandis plantations in Western Panama. *New Forests* 37, 227–240. DOI 10.1007/s11056-008-9119-2

23. Ravindranath, N.H. (1997). Somasekhar BS, Gadgil M. Carbon ows in Indian forest. *Climatic Change*; 35(3), 297–320.

24. Haripriya, G. S. (2000). Estimates of biomass in Indian forests. *Biomass and bioenergy*, 19(4), 245-258.

25. Chhabra, A., & Dadhwal, V. K. (2004). Assessment of major pools and fluxes of carbon in Indian forests. *Climatic Change*, 64(3), 341-360.

26. Manhas, R. K., Negi, J. D. S., Kumar, R., & Chauhan, P. S., (2006). Temporal Assessment of Growing Stock, Biomass and Carbon Stock Of Indian Forests. *Climatic Change*, 74: 191–221 DOI: 10.1007/s10584-005-9011-4

27. Kaul, M., Mohren, G. M. J., & Dadhwal, V. K. (2010). Carbon storage and sequestration potential of selected tree species in India. *Mitigation and Adaptation Strategies for Global Change*, 15:489–510 DOI 10.1007/s11027-010-9230-5

28. Fang, S., Xue, J., & Tang, L. (2007). Biomass production and carbon sequestration potential in poplar plantations with different management patterns. *Journal of environmental management*, 85(3), 672-679.

29. Haripriya, G. S. (2002). Biomass carbon of truncated diameter classes in Indian forests. *Forest Ecology and Management*, 168(1-3), 1-13.

30. Lal, M., & Singh, R. (2000). Carbon sequestration potential of Indian forests. *Environmental monitoring and assessment*, 60, 315-327.

31. Atkinson, G., & Gundimeda, H. (2006). Accounting for India's forest wealth. *Ecological Economics*, 59(4), 462–476. https://doi.org/10.1016/J.ECOLECON.2005.10.022

32. FAO (2015). The State of Food and Agriculture - Social protection and agriculture: breaking the cycle of rural poverty. http://www.fao.org/3/a-i4910e.pdf

33. Brown, S., Gillespie, A. J., & Lugo, A. E. (1989). Biomass estimation methods for tropical forests with applications to forest inventory data. *Forest science*, 35(4), 881-902.

34. Kale, M., Singh, S., Roy, P. S., Deosthali, V., & Ghole, V. S. (2004). Biomass equations of dominant species of dry deciduous forest in Shivpuri district, Madhya Pradesh. *Current Science*, 683-687.

35. Keller, M., Palace, M., & Hurtt, G. (2001). Biomass estimation in the Tapajos National Forest, Brazil: examination of sampling and allometric uncertainties. *Forest Ecology and Management*, 154(3), 371-382.