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Research Article

Carbon stocks of linear category of Trees Out Side Forest (TOF) in Prakasam District, Andhra Pradesh, India

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Abstract

In the present study, carbon stocks of linear structures of Trees Outside Forest (TOF) in Prakasam district was estimated through sampling of 400 (0.1 ha) plots. A total of 10,240 tree individuals belonging to angiosperm species were enumerated in the sampled plots. The mean tree density was 240.31 per ha. The mean basal area is 29.39m^2 ha^{-1}. Mean volume of trees with ≥10 cm diameter is 24.26m^3 ha^{-1}. The mean total tree biomass is 209.88 tons ha^{-1}. The mean carbon stock is 99.69 tons ha^{-1}. Extrapolated biomass and carbon content for linear structures is calculated as 0.7634 Mt and 0.3626 Mt respectively. The carbon sequestration potential is estimated as 1.33 Mt.

INTRODUCTION

The increase of carbon dioxide concentration in the atmosphere and its potential effect on climate are the most important global environmental issues on the earth (Brown *et al.*, 1989). Due to these increased levels of CO_2 concentration, rise of atmospheric temperature by 0.5°C is recorded over the past hundred years and it is projected to rise by 0.6 to 5°C in the next 100 years according to latest report of Inter governmental Panel on Climate Change (IPCC, 2014). Carbon dioxide levels which were under 300 ppm during the last 600,000 years are now at 413 ppm, average for 2020 (Tans and Keeling, 2021). As third largest producer of coal and fourth largest greenhouse gas (GHG) emitter, India's total emissions are 7% of global emissions and is increasing at 4.5% per annum (Gupta and Paul, 2019).

The main natural carbon sinks are plants, the ocean and soil. The uptake of carbon dioxide (CO_2), during photosynthesis is the major pathway by which carbon is removed from the atmosphere and this 'capturing and securing of atmospheric carbon in the form photosynthesis and subsequently to dead organic matter is called as 'carbon sequestration'. Carbon sequestration has been recognized as an effective and low-cost method of mitigating carbon emissions. Vegetation in the form of forests and especially trees play a pivotal role in sequestration and trees are the largest component of aboveground biomass in terrestrial ecosystems. Apart from forest ecosystems, trees outside forests also have great potential in sequestration of atmospheric carbon (Dhyani *et al.*, 2009).

Trees Outside Forests (from now onwards, abbreviated as TOF) refers to trees found on neither lands that are not categorized as 'forest' nor 'other wooded land' irrespective of their patch size (FSI, 2009; FAO, 2010).TOF include agricultural land (including meadows and pastures), built-on land (including settlements and infrastructure) and barren land (including sand dunes and rocky outcroppings), orchards and plantations. In spatial terms they may be scattered on farmland and pasture, or growing continuously in line-plantings along roads, canals and water courses, around lakes,

in towns, or in small aggregates with a spatial continuum such as clumps of trees, sacred woods, urban parks (Alexandrov *et al.*, 1999). Trees growing along the roadside, either planted or grown naturally perform ecological function to reduce the pollution as well sequester carbon and help mitigate climate change.

Assessment of above ground biomass of Trees outside Forest (TOF), regardless of their location is important for carbon storage (Shreshta *et al.*, 2020). Obligations from international conventions has also made it necessary for conduct TOF assessment particularly the United Nations Framework Convention on Climate Change (UNFCCC) and United Nations Convention on Biological Diversity (UN-CBD) have urged on keeping up-to- date information on tree resources within and outside forests (Beckschafer et al., 2017). Such assessements especially at district level hold immense significance. Indian Space Research Organization (ISRO) has initiated National Carbon Project under the auspices of Indian Geosphere Biosphere Programme (IGBP) (Singh and Dadhwal, 2008). Due to the lack of reliable data on standing biomass and rates of forest degradation, the net carbon emission estimates for India are highly variable (Ravindranath *et al.*, 1997). Precise information on TOF at micro level is lacking and this has become a major hindrance in estimating TOF potential in carbon sequestration.

TOF are classified into 3 categories: linear, scattered and block. The five carbon pools of terrestrial ecosystem involving biomass are the above-ground biomass, below- ground biomass, the dead mass of litter, woody debris and soil organic matter (Tanabe, 2006). Estimating above ground biomass (agb) is the most critical step in quantifying carbon stocks and fluxes from tropical forests and trees. Biomass is closely related to and often estimated directly from the growing stock (Volume). Estimation of agb is essential aspect of carbon sequestration studies which can be converted into carbon. The present study is oriented to estimate the carbon stocks of linear category of TOF of Prakasam district, Andhra Pradesh following as a comprehensive format design of Vegetation Carbon pool Assessment (VCP) National Carbon Project (Singh and Dadhwal, 2008). Under linear structures, roads, canals, river bunds, rail tracks are included.

STUDY AREA

Prakasam district (14^0-57′-00″ to 16^0-17′-00′ NL and 78^0-43-00′ to 80^0-25’-00″ EL) is one of the coastal districts of Andhra Pradesh State, and the third-largest district in the state with an area of 17,626 km^2 located in Peninsular Indian region. The district comprises three revenue divisions namely Ongole, Kandukur and Markapur and 56 Mandals, besides one corporation and three municipalities. As many as 1002 Inhabited Revenue villages are existing in the district constituted into 1043 Gram Panchayats. The district has 102 km of coastline. Red loamy, black cotton and sandy loams are the predominant soils in the district and the former two comprise 51% and 41% respectively over the total area of the district. The normal maximum and minimum temperatures are 33.7^0C and 24.10^0C respectively. The District average annual rainfall is about 900mm. The District is drained by the rivers, Gundlakamma, Manneru, Musi and Paleru Rivers besides small rivers like Thammileru, Sagileru and Gudisileru and streams like Ogeru vaagu, Nallavaagu and Vedimangala vaagu. The total forest area in the district accounts for 4.61 lakh hectares constituting 26.2% of the total geographical area. The important hill ranges in the district are the Nallamalais and the Veligondas which separate the district from Kurnool and Kadapa Districts. Nallamalais, part of Central Eastern Ghats are extended into Giddalur, Komarole, Racherla, Ardhaveedu, Yerragondapalem, Pullalacheruvu and Dornala Mandals. In the coastal areas, there is abundant growth of Casuarinas and cashew plantations.

MATERIALS AND METHODS

In the present study, a non-destructive approach of Above-Ground Biomass (AGB) estimation was done. A comprehensive format design of Vegetation Carbon pool Assessment (VCP) of Indian Institute of Remote Sensing (IIRS) (Singh and Dadhwal, 2008) was adopted for ground data collection. Sampling sites were identified and located with the help of Google earth software. The geographical co-ordinates for each plot were identified with the help of Global Positioning System (GPS). Plots were selected based on different density classes. All the tree taxa in the sampled plots were inventoried and identified following regional and local floras. For the purpose of the present study, field data was collected from randomly selected linear structures outside the forests in Prakasam district. A total of 400 linear plots of size 100×10 m (0.1 ha) were laid along roads and canals in different locations covering varied topographic terrain and different density classes.

Enumeration of trees was done and girth at breast height (gbh) measurements was taken with measuring tape and height was measured manually. Considering both sides of the linear structures, a total of 124 km for national highway, 733 km for state highways, 1586 km for major district roads, 995 km for approach roads; 377 km for canals and 224 km of railway track has been estimated. The area under each sub-sub category is calculated based on transect width of 10m. As the mean basal area of the sampled plots is 37.34 m2 ha-1 for approach road, the tree covered area is projected for the same at 743.06 ha. In case of others the projected figures are: major district roads, 1171.41, national highway, 64.75 ha; state highway, 664.09 ha; canals, 144.99 ha and railway track, 51.20 ha.

Biomass estimation

Basal area- of each tree was calculated by using following standard formula:

Basal Area (m^2 ha^{-1}) = πr^2 × area (ha)

Growing Stock (Volume) Estimation- Volume of each tree was estimated using the selected species specific volumetric equation developed and compiled by FSI (1996).

Specific Gravity values of different species were selected from literature (Reyes *et al.,* 1992; FRI, 1996; Mani and Parthasarathy, 2007). For stems with unknown specific gravity, the arithmetic mean of all known species was substituted and used in particular sample plot following Brown *et al.* (1989).

Estimation of above ground biomass

Bole Biomass ≥10cm diameter:

The estimated volume was converted into biomass by multiplying with specific gravity (Rajput *et al*., 1996; Limaye and Sen 1956). Biomass of all the trees was summed to obtain biomass for 1 ha.

Biomass (tons) = Volume (m^3) x Specific gravity

Bole Biomass <10 cm diameter

Volume equations for trees <10cm diameter are not available, hence a methodology for trees of this class developed in Vegetation Carbon Pool Assessment Project (Singh and Dadhwal, 2008; Dadhwal *et al*., 2009; Patil *et al*., 2011) by relating basal area and biomass has been followed. The model developed was Y=3.6808*X+0.264 and used for assessing the AGB of trees <10cm diameter. Where, Y=Biomass, X= Basal of trees (>10cm diameter and <10cm diameter), 3.6808 and 0.264 = Coefficients

Estimation of total above ground biomass, below ground biomass and total biomass

The biomass of trees having >10cm diameter and <10cm diameter in each plot were added together to get biomass of one ha plot. In the present study, 26% of the total agb was considered as root biomass following Houghton *et al*., (2001) and Ramankutty *et al*., (2007). Total biomass for each one ha plot was obtained by the addition of total agb and bgb. Further the mean was calculated and extrapolated for the whole study area.

Estimation of carbon stocks

Extrapolation of linear structures of TOF

Based on the mean biomass estimation of sampled plots, total carbon stock of linear structures of TOF of Prakasam district was estimated by extrapolating the same for the whole district area. For this, tree covered area under each sub category and sub-sub category was determined based on 2011 official statistics of Prakasam district (Anon., 2011).

Estimated area (ha) =
Length of linear category (m) × 2 (both sides) ×10 m (transect width)/ 10,000

Tree covered area (ha) = Estimated area × % of mean basal area of sampled plots

Estimation of carbon stocks and carbon sequestration potential

Estimation of carbon stocks from the biomass has been calculated by multiplying the total biomass by a conversion factor that represents the average carbon content in biomass. In the present study, the IPCC default of 0.475 carbon fraction (Mc Groddy *et al.*, 2004) has been used.

Carbon (tons) = Biomass (tons) × Carbon %

Carbon sequestration potential of trees was calculated following Eneji et al. (2014) and Chavan and Rasal (2010) through the ratio of CO_2 to C, i.e. multiplying carbon content with 3.666.

RESULTS AND DISCUSSION

In the present study, a total of 50 angiosperm species belonging to 45 genera and 22 families were recorded (**Table 1**). A total of 10240 tree individuals ranging 10 to 76 per sample plot of 0.1 ha were encountered in 400 inventory plots laid throughout the district. The mean tree density was 256 per ha. The highest values of tree density found along State Highways (314), National Highways (291) major district roads (263) (**Table-2**). *Azadirachta indica*, *Borassus flabellifer*, *Tamarindus indica, Albizia lebbeck*, *Tectona grandis*, *Senna siamea, Pongamia pinnata*, *Leucaena leucocephala*, *Peltophorum pterocarpum*, *Ficus benghalensis*, *Cocos nucifera* and *Dalbergia sissoo* are the dominant trees which contribute more than 75% of total number of individuals (TNI) (Table-1).

The mean basal area is 26.21 m^2 ha^{-1} ranges between 1.38 – 141.5 m^2 ha^{-1} across the plots. Lowest value of basal area was recorded in rail track and canals. Mean volume of trees with ≥10 cm diameter is 29.09 m^3 ha^{-1}. The correlation between basal area and biomass of trees with ≥10 cm diameter revealed the determination coefficient of R^2 is 0.824 (**Fig.1**). The mean total tree biomass is 209.88 tons ha^{-1} range 8.98 to 1316.79 tons ha^{-1} across the sampled plots. The maximum biomass content has been found along state highways, major district roads, approach roads and national highways due to relatively less disturbance and growth of huge mature old trees. The mean carbon stock for linear structures is 99.69 tons ha^{-1} ranging from 4.26 to 625.47 tons C ha^{-1} across the sampled plots. For the total estimated area under all categories of linear structures of trees outside forests in Prakasam district, the projected biomass and carbon content are calculated as 0.7634 Mt and 0.3626 Mt respectively (Table-3).

Although studies on different categories of TOF were initiated throughout India data a comparative study has been made with the four neighboring districts of the study area. Ramesh *et al.* (2015) after sampling of 236 (0.1 ha) plots, registered 3922 tree individuals and found the mean carbon stock at 83.66 tons ha^{-1} and the extrapolated carbon stock at 0.251 Mt for Kurnool district. In Ananthapuramu district, 344 (0.1 ha) plots were sampled for linear structures and inventoried 4229 tree individuals with mean carbon stock at 57.385 tons ha^{-1} and extrapolated carbon content as 0.083 Mt respectively (Kavitha *et al.*, 2016). A sampling of 1 ha (10 plots) for linear plots in Prakasam and Kadapa districts, estimated the carbon stock of 7.95±9.66 Mg ha^{-1} (Srinivasa Rao, 2012a) and 59.36±121.61 Mg ha^{-1} (Srinivasa Rao, 2012b) respectively. Present study on linear structures of Trees Outside Forest in Prakasam district was estimated through sampling of 400 (0.1 ha) plots with inventory of a record of 10,240 tree individuals; mean carbon stock is 99.69 tons ha^{-1} and extrapolated carbon content at 0.3626 Mt. Thus, Prakasam district has highest carbon stocks per hectare area compared to other Rayalaseema districts studied.

CONCLUSION

Present study on TOF (linear structures) of Prakasam district highlight the importance of maintaining highest amounts of carbon stocks compared to other districts in Rayalasema region of Andhra Pradesh and their ability in sequestering carbon dioxide by the trees outside the forest area.

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Table-1: List of tree species encountered in the present study

S. No.	**Name of the Species**	**Family**	No. of tree individuals in all inventoried plots
1	*Acacia leucophloea* (Roxb.) Willd.	Fabaceae	1
2	*Acacia nilotica* (L.) Delile ssp *nilotica*	Fabaceae	73
3	*Aegle marmelos* (L.) Corrêa	Rutaceae	1
4	*Ailanthus excelsa* Roxb.	Simaroubaceae	20
5	*Albizia lebbeck* (L.) Benth.	Fabaceae	866
6	*Alstonia scholaris* (L.) R. Br.	Apocynaceae	86
7	*Anogeissus latifolia* (Roxb. ex DC.) Wall. ex Guillem. & Perr.	Combretaceae	2
8	*Azadirachta indica* A.Juss.	Meliaceae	2968
9	*Balanites aegyptiaca* (L.) Delile	Zygophyllaceae	4
10	*Bauhinia purpurea* L.	Fabaceae	1
11	*Bauhinia racemosa* Lam.	Fabaceae	1
12	*Borassus flabellifer* L.	Arecaceae	1709
13	*Cassia fistula* L.	Fabaceae	3
14	*Ceiba pentandra* (L.) Gaertn.	Malvaceae	1
15	*Cocos nucifera* L.	Arecaceae	148
16	*Cordia dichotoma* G.Forst.	Boraginaceae	2
17	*Dalbergia sissoo* DC.	Fabaceae	60
18	*Delonix regia* (Hook.) Raf.	Fabaceae	60
19	*Dendrocalamus strictus* (Roxb.) Nees	Poaceae	1
20	*Eucalyptus camaldulensis* Dehnh.	Myrtaceae	38
21	*Ficus benghalensis* L.	Moraceae	199
22	*Ficus racemosa* L.	Moraceae	6
23	*Ficus religiosa* L.	Moraceae	46
24	*Gliricidia sepium* (Jacq.) Walp.	Fabaceae	5
25	*Hardwickia binata* Roxb.	Fabaceae	4
26	*Holoptelea integrifolia* Planch.	Ulmaceae	1
27	*Lannea coromandelica* (Houtt.) Merr.	Anacardiaceae	1
28	*Leucaena leucocephala* (Lam.) de Wit	Fabaceae	313
29	*Limonia acidissima* Groff	Rutaceae	4
30	*Mangifera indica* L.	Anacardiaceae	10
31	*Millingtonia hortensis* L.f.	Bignoniaceae	5
32	*Morinda pubescens* Sm.	Rubiaceae	1
33	*Moringa oleifera* Lam.	Moringaceae	11
34	*Peltophorum pterocarpum* (DC.) K.Heyne	Fabaceae	241
35	*Phoenix sylvestris* (L.) Roxb.	Arecaceae	65
36	*Phyllanthus emblica* L.	Euphorbiaceae	1
37	*Pithecellobium dulce* (Roxb.) Benth.	Fabaceae	27
38	*Polyalthia longifolia* (Sonn.) Thwaites	Annonaceae	26
39	*Pongamia pinnata (L.) Pierre*	Fabaceae	478
40	*Prosopis cineraria (L.) Druce*	Fabaceae	24
41	*Prosopis juliflora (Sw.) DC.*	Fabaceae	3
42	*Senna siamea (Lam.) H.S.Irwin & Barneby*	Fabaceae	594
43	*Syzygium cumini (L.) Skeels*	Myrtaceae	39
44	*Tamarindus indica L.*	Fabaceae	1220
45	*Tectona grandis L.f.*	Verbenaceae	774
46	*Terminalia arjuna (Roxb. ex DC.) Wight & Arn.*	Combretaceae	11
47	*Thespesia populnea (L.) Sol. ex Corrêa*	Malvaceae	14
48	*Wrightia tinctoria R.Br.*	Apocynaceae	9
49	*Ziziphus jujuba Mill.*	Rhamnaceae	1
50	*Ziziphus xylopyrus (Retz.) Willd.*	Rhamnaceae	33

Table-2: Category-wise Tree density, basal area, volume, biomass and carbon stock

Sub category	Sub-sub category (No. of 0.1 ha Plots)	TNI	Tree density (trees/ha)	Basal area (m^2 ha^{-1})	Volume (m^3 ha^{-1})	Biomass (tons ha^{-1})	Carbon stock (tons ha^{-1})
Road	National High way (13)	379	291.5	26.11	21.88	185.48	88.10
	State High way (73)	2293	314.1	45.30	39.88	341.60	162.26
	Major District Road (160)	4207	262.9	36.93	30.58	263.54	125.18
	Approach road (100)	2481	248.1	37.34	29.09	258.92	122.99
Canal (30)		497	165.7	19.23	15.28	135.52	64.37
Rail track (24)		383	159.6	11.43	8.87	74.23	35.26
Mean		25.6	240.31	29.39	24.26	209.88	99.69

Table-3: Biomass and carbon stock of TOF (Linear category) in Prakasam district

Sub category	Sub-sub category	Tree covered area (ha)	Mean biomass (t ha^{-1})	Extrapolated Biomass (tons)	Carbon stock (tons)
Road	National High way	64.75	185.48	12010.34	5704.91
	State High way	664.09	341.6	226855.87	107756.54
	Major District road	1171.41	263.54	308713.39	146640.06
	Approach road	743.06	258.92	192394.64	91387.45
Canal	_	144.99	135.52	19649.61	9333.56
Rail track	_	51.20	74.23	3801.05	1805.49
			Total	**763427.46 (0.7634 Mt)**	**362628.04 (0.3626 Mt)**

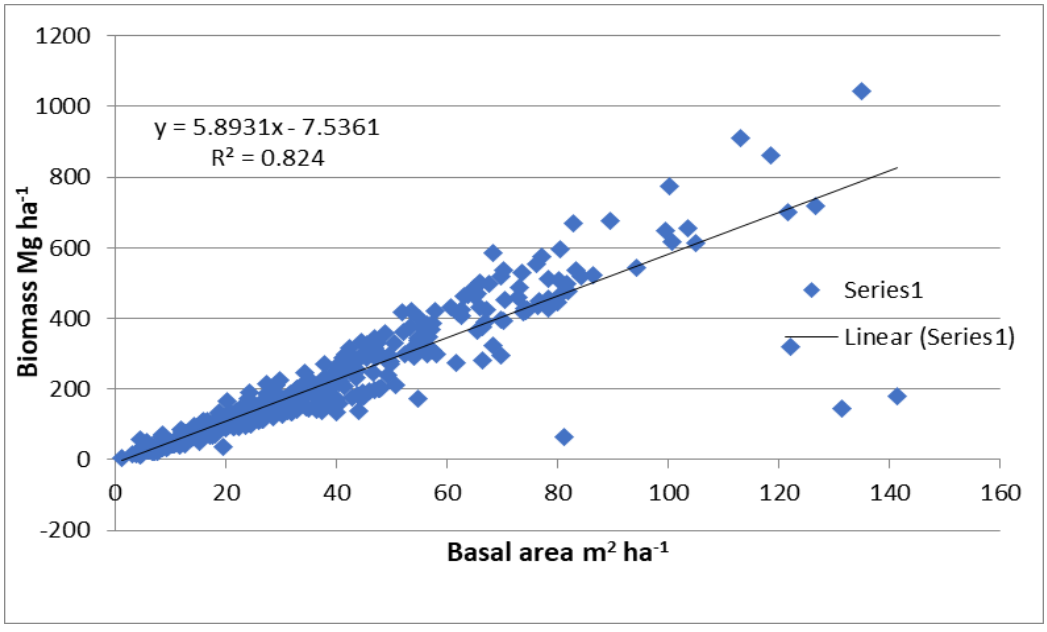

Fig. 1: Correlation between basal area and biomass of trees >10 cm diameter

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