Environment Conservation Journal 15(3)101-107, 2014
ISSN 0972-3099 (Print) 2278-5124 (Online)
Abstracted and Indexed

Carbon sequestration by different tree species in tropical dry deciduous forest of Panchmahal District (Gujarat) in India

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Received:18.01.2014 **Revised: 11.07.2014** **Accepted:14.08.2014**

Abstract

Trees act as a sink for CO_2 by fixing carbon during photosynthesis and storing surplus carbon as biomass which alter through time as trees grow, die and decay. There is uncertainty about the extent of carbon stored in forests by trees. 28 species belonging to 20 families were studied to demonstrate relationship among carbon sequestration which was half the tree biomass. Total carbon sequestration was 448.044 tonnes dominated by *Tectona grandis* L.F., *Butea monosperma* (Lam) Taub and *Diospyros melanoxylon* Roxb. The deviation in carbon sequestration was observed due to girth, height, biomass, native place and economic importance of species. Statistically a positive correlation of 0.966 was found between the total number of trees and total carbon sequestration.

Keywords: Carbon emission, carbon sink, girth, height, total above ground biomass, tropical dry deciduous forest

Introduction

Climate change, an impact of greenhouse effect, has turn out to be the severe environmental trouble for ecosystems, natural resources, economics, society and politics at both national and international levels. The greenhouse effect is obviously the outcome of human activities concerning energy, agriculture, and forest which are rapidly rising these days. Industrialization has altered the global environment, fluctuating global biogeochemical cycles, transforming land and enhancing the mobility of biota. Globally, forests play a major role in the carbon cycle because they account for a greater part of the carbon exchange between the atmosphere and terrestrial biosphere than any other ecosystem type (Dixon *et.al.*, 1994). Laland Singh (2000) reported that annual carbon uptake increment by Indian forests and plantation has been able to sequester about 0.12 Giga ton of carbon dioxide from the atmosphere in the year 1995. Warran and Patwardhan (2008) reported that carbon sequestration potential of trees was 4178 Mt for the year 1986. Haripriya (2003) estimated the average biomass carbon of the forest ecosystem in India for the year 1994 was about 46 Mg C ha^{-1}, out of which 76% was due to above ground biomass and the rest was due to root system. Atmospheric carbon is estimated to be increasing by approximately 2600 million metric tons annually (Sejdo, 1989). Decline of tropical forest areas has an immense impact on the amount of carbon dioxide stored in the atmosphere (Houghton, 1985), because forest is the huge important source of the world producing oxygen and storing carbon dioxide. Importantly, the carbon dioxide is an influential gas leading to climate change. Estimating the aboveground biomass content is necessary for considering total carbon content stored in forest ecosystem. Biomass density of each area in the tropical forest widely varies according to weather, soil, topography, and forest utilization.

Majority of plants convert the carbon dioxide into sugar chemical compounds, oxygen etc. (Francesco, 2011 and Jana *et al*. 2009) and thereby remove the atmospheric carbon dioxide. The release of carbon dioxide cannot be stopped easily so the only solution for CO_2 mitigation is reforestation and conservation of the already existing species and diversity. Tropical dry deciduous type of forest of Panchmahal district located between the parallels of latitude 22.17° and 23.20° and the meridians of Longitude 73.20° and

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74.20° was selected for study. The objective of the study was to find difference in above ground biomass and carbon sequestration of twenty eight trees species comprising of twenty families at different girth classes.

Material and Methods

In this case study, measurement of the amount of carbon sequestered by trees has been carried out and this was based on the amount of standing woody biomass of trees in forest area. For this study 11 sites were taken into account. At each site different quadrats were laid. Number of quadrats varies depending upon the area of the site (Misra 1968). Quadrats of 20 m×20 m were taken at different sites and at the same time measurement of diameter at breast height (DBH) in centimeter (cm) and height (m) for different trees were taken (Yadav and Devi 2006). Based on these values biomass and carbon sequestration were calculated. Results obtained were then converted into tons as per unit conversion and comparisons were done of total carbon sequestered by different species and families.

Selection of Sample Plot:

At each site selection of sample plot was done randomly and the sample plot covered 10% area of each site. After the selection of sample plot, base line and strip line was laid. Base line is the longest line which covers the largest area of forest and strip line is a line perpendicular to the base line. Starting from the baseline at a distance of every 200 m belt transect (quadrat) of 20m×20m was laid and different species falling in transect were considered for the study. Similar procedure was followed for the strip line also.

Collection of data:

Tree species with different girth classes and height were counted in each quadrat (20m×20m).Trees were grouped into three classes with some modifications (Baishya *et al*, 2009).The girth classes were divided into six classes such as 10-30 cm, 31-60 cm, 61-90 cm, 91-120 cm, 121-150 cm and 151 and above cm.

Calculation:

Estimation of amount of carbon dioxide in tree was done by the following method.

1) Total (green) weight (W_1) of the tree:

$W_1 = 0.25D^2H$ (If D<11) (Clark *et al.*, 1986)

$W_1 = 0.15D^2H$ (If D>11) (Clark *et al.*, 1986)

2) Dry Weight (W_2) of the Tree:

$W_2 = W_1 \times 72.5\%$ (Dewald *et al.*, 2005)

3) Weight of Carbon (C_1) present:

$C_1 = W_2 \times 50\%$ (Birdsey, 1992)

Results and Discussion

Forests are one of the most important sources to sequester carbon. During current study a total of 7307 trees of 28 species from 20 families were recorded. Carbon sequestered by these trees was 448.044 ton (50% of the biomass) (Table 1) which was approximately 3.19 ton per tree of this area. Statistically a positive correlation of 0.966 was found between the total number of trees and total carbon sequestration of different families (Fig. 3).

Family wise dry weight and carbon sequestration:

The dominating families were Verbenaceae and Papilionaceae from studied 20 families. Maximum number of individuals were recorded from Verbenaceae (3963) and Papilionaceae (817) while minimum number of individuals were from Myrtaceae (7), Euphorbiaceae and Anacardiaceae (9 each). The amount of carbon sequestration was found maximum in Verbenaceae, Papilionaceae and Ebenaceae (241.577 t, 73.831 and 42.921) while minimum by Araceae, Celastraceae and Caesalpiniaceae (0.064 t, 0.136 and 0.596) (Table 2).The dry weight and carbon sequestration was found maximum per plant in Anacardeaceae and Myrtaceae while least in Araceae and Rhamnaceae. Anacardeaceae consists of 9 large trees of *Lannea coromandelica* with large DBH and height. Their dry weight was 25.915 t and per plant dry weight was 2.879 t. Biomass and carbon sequestration varies with DBH which shows conformation with the findings of earlier work Baishya *et al.* 2009, who reported maximum trees at regeneration stage while high biomass of larger trees. Numbers of individuals were found more in regeneration stage but their biomass was found to be less when compared to intermediate and mature stages, this result shows conformation to the findings of Terakunpisut *et al.* 2007. Number of trees also affects the carbon sequestration of any region. A positive correlation of 0.966 was obtained between the total numbers of trees and carbon sequestration of this region.

Table 1: Carbon Sequestration (in t) by Tree species at different Girth Classes (in cm)

Sr. No.	Botanical Name	No. of plants	Carbon Sequestration (in t) at different girth classes (cm)					
			10-30	**31-60**	**61-90**	**91-120**	**121-150**	**151 & above**
1	*Acacia catechu*	109	0.486	1.368		1.568	1.888	
2	*Acacia leucophloea*	39	0.110	0.552	0.316	0.638		1.455
3	*Acacia nilotica*	25	0.034	0.145	1.289	0.146	0.546	0.403
4	*Acacia tortiles*	79	0.218	0.938	2.585	4.412	3.389	
5	*Aeglemarmelos*	146	0.625	0.470	0.398		1.383	
6	*Alangiumsalvifolium*	97	0.317	0.408	0.335	0.232	0.401	4.151
7	*Anogeissuslatifolia*	100	0.304	0.755		1.471	1.012	1.455
8	*Azadirachtaindica*	58	0.148	0.486	1.098	0.155	2.308	0.979
9	*Bombaxceiba*	25	0.066	0.514	0.552	1.613	2.117	1.455
10	*Boswelliaserrata*	9		0.091	0.850	0.597		
11	*Buteamonosperma*	703	1.393	3.676	7.663	10.652	13.511	32.582
12	*Cassia fistula*	58	0.234	0.255	0.107			
13	*Dalbergiasissoo*	8	0.081	0.212				
14	*Diospyrosmelanoxylon*	782	2.968	5.644	3.426	17.975	3.930	8.980
15	*Emblicaofficinalis*	9	0.018				0.662	
16	*Eucalyptus globulus*	7			0.159	4.567		
17	*Garugapinnata*	15	0.055	0.089				
18	*Holopteliaintegrifolia*	602	1.305	1.709	1.167	0.413	1.529	2.000
19	*Lanneacoromandelica*	9		0.067	0.710			12.180
20	*Maytenusemarginata*	16	0.092		0.044			
21	*Miliusatomentosa*	29	0.031	0.474	0.616			
22	*Phoenix sylvestris*	14	0.052	0.011				
23	*Pongamiapinnata*	106	0.298	1.327	0.936	0.590	0.910	
24	*Tectonagrandis*	3963	23.859	48.862	65.172	49.491	34.722	19.471
25	*Terminaliabellirica*	5	0.004		0.174			4.710
26	*Terminaliacrenulata*	17	0.037	0.075	1.100	1.020	3.317	
27	*Wrightiatinctoria*	102	0.301	0.080	0.309			
28	*Zyziphusnummularia*	175	0.668	0.141				
Total		**7307**	**33.703**	**68.349**	**89.006**	**95.541**	**71.625**	**89.820**

Species wise dry weight and carbon sequestration:

Total 7307 individuals from 28 species were taken into consideration belonging to 20 families for study. Their DBH and height were noted and on the basis of DBH and height carbon sequestration was calculated. At different DBH, individuals of all species were not found. Out of 28 species 20 species were absent at one or other girth class while 8 species were found to be present at all the girth classes. Presence or absence of species depends upon their ability to regenerate and their economical use. Numbers of individuals were found more in regeneration stage but their biomass was found to be less when compared to intermediate and mature stages, this result shows conformation to the findings of Terakunpisut *et al.* 2007. Total sequestration of carbon by 7307 individuals was 448.044 t. Trees greater then girth class of 90 cm (mature stage) sequester 57.35% carbon and trees which belong to girth class of 30 to 90 cm (intermediate stage) sequester 35.12% carbon. This result shows conformation with the findings of earlier work (Baishya *et al.* 2009; Brown & Lugo 1992; Brown *et al.*1995; Brown 1996 & Clark & Clark 1996) who reported up to

Table 2: Total Dry Weight and Carbon Sequestration (in t) of Trees comprising of different Families

Sr. No.	Family	No. of Genus	No. Of Species	Total Trees	Dry Weight per Tree	Total Dry Weight of Trees	Total Carbon Seq. by Trees
1	Alangiaceae	1	1	97	0.120	11.686	5.843
2	Anacardiaceae	1	1	9	2.879	25.915	12.958
3	Annonaceae	1	1	29	0.077	2.241	1.121
4	Apocynaceae	1	1	102	0.014	1.380	0.690
5	Araceae	1	1	14	0.009	0.127	0.064
6	Bombacaceae	1	1	25	0.505	12.633	6.316
7	Burseraceae	2	2	24	0.140	3.365	1.683
8	Caesalpiniaceae	1	1	58	0.021	1.191	0.596
9	Celastraceae	1	1	16	0.017	0.272	0.136
10	Combretaceae	2	3	122	0.253	30.871	15.436
11	Ebenaceae	1	1	782	0.110	85.842	42.921
12	Euphorbiaceae	1	1	9	0.151	1.359	0.680
13	Meliaceae	1	1	58	0.178	10.347	5.174
14	Mimosaceae	1	4	252	0.178	44.973	22.486
15	Myrtaceae	1	1	7	1.350	9.453	4.727
16	Papilionaceae	3	3	817	0.181	147.661	73.831
17	Rhamnaceae	1	1	175	0.009	1.617	0.809
18	Rutaceae	1	1	146	0.039	5.752	2.876
19	Ulmaceae	1	1	602	0.027	16.247	8.124
20	Verbenaceae	1	1	3963	0.122	483.153	241.577
Total		**24**	**28**	**7307**	**6.382**	**896.088**	**448.044**

50% contribution to TAGB by large trees. Hence with girth, the carbon sequestration also increases. Minimum carbon sequestration (7.52%) was done by trees which belong to girth class of 10 to 30 cm (regeneration stage). Smaller trees belonging to regeneration are not the highest carbon sequestration potential but they are relevant in terms of their future potential to grow up.

Among all species *Tectona grandis* sequester maximum 241.577 t of carbon (Fig. 1). *Tectona grandis* sequesters was 114.03 t and 103.864 at intermediate and mature stage. There are many factors responsible for the low TAGB of different plants, which includes different stages of forests growth cycle, habitat, species variability and varying density (Terakunpisut *et al.* 2007). The avoidance of deforestation and encouragement of afforestation, has often been cited as strategies to slow down global warming (Bala *et al.* 2007).Some species like *Boswellia serrata* and *Eucalyptus globules* are exploited for their timber and medicinal values. Many species are used as fuel, fodder and for timber such as *Cassia fistula*, *Dalbergia sissoo* due to which they contribute less to carbon sequestration (Fig. 2).

As per study out of 28 species 18 species were native to Indian origin and rests were from others (Table 3). Trees native to Indian origin sequester 399.94 t of carbon which is approximately 89.26% of total carbon sequestered by all tree species. So it is essential to focus on the indigenous species and health of tree species to save our environment. There are different natural reasons for the absence of trees at higher girth class but mostly human interventions are the reason for such conditions.

Table 3: Economic importance and place of origin of tree species of Panchmahal district of Gujarat in Western India

Sr. No.	Botanical Name	Local Name	Family	Uses	Place of Origin
1	*Acacia catechu* Willd	Kher	Mimosaceae	An ingredient to paan, Medicinal	Asia , China, India
2	*Acacia leucophloea* (Roxb) Willd	Aniyar/ Rhinjado	Mimosaceae	Timber, Fodder	India, Indonesia, Myanmar, Nepal, Pakistan, Sri Lanka, Thailand, Vietnam, Bangladesh
3	*Acacia nilotica* (L) Dell	DeshiBawal	Mimosaceae	Timber, Gum, Medicine	Africa, Middle East, Indian Sub Continent
4	*Acacia tortiles*(Forsk) hyne ex Roth	Isrilebawal	Mimosaceae	Fuelwood, Shelter for cattles	Africa, Middle East.
5	*Aeglemarmelos* (L) Corr	Bili	Rutaceae	Religious, Medicinal, Fruit, Cash	India
6	*Alangiumsalvifolium* (L f) Wang	Ankal	Alangiaceae	Medicinal	India
7	*Anogeissuslatifolia*(Roxb) Wall ex Bedd	Dhavdo	Combretaceae	Fodder, Medicinal, Cash	India, Nepal, Myanmar, Sri Lanka.
8	*Azadirachta indica* A Juss	Neem	Meliaceae	Medicinal, Religious, Timber	India, Pakistan, Bangladesh
9	*Bombaxceiba* L	Simado	Bombacaceae	Timber, Fibre, Cash	Southeast Asia, northern Australia.
10	*Boswelliaserrata*Roxb	Salaigugal	Burseraceae	Medicinal	Africa, Asia
11	*Buteamonosperma* (Lam) Taub	Khakhar	Papilionaceae	Plates, Dye, Pesticide, Medicine, Food, Fibre, Fodder	Indian subcontinent, Southeast Asia
12	*Cassia fistula* L	Garmado	Caesalpiniaceae	Ayurvedic medicine	Southern Asia, India, Pakistan, Myanmar
13	*Dalbergia sissoo*Roxb	Sissoo	Papilionaceae	Charcoal, Timber, Fodder	India, Nepal, Pakistan.
14	*Diospyrosmelanoxylon* Roxb	Timru	Ebenaceae	Cash, Bidi, Food, Fuel,	India, Sri Lanka
15	*Emblica officinalis* Gaertn.	Amla	Euphorbiaceae	Fruit, Medicinal, Small timber	India
16	*Eucalyptus globulus* Labill	Nilgiri	Myrtaceae	Timber, Essential oil	Australia
17	*Garugapinnata*Roxb	Kakad	Burseraceae	Medicinal	India, E. Pakistan, Malaya, Philippines
18	*Holopteliaintegrifolia*(Roxb) Planch	Kanji	Ulmaceae	Fodder, Medicinal	India, Nepal, Sri Lanka, Indo-China
19	*Lanneacoromandelica* (Houtt) Herrill	Moyno	Anacardiaceae	Medicinal	Southeast Asia.
20	*Maytenusemarginata* (Willd) D Hou	Vikado	Celastraceae	Medicinal	Not Known
21	*Miliusatomentosa* (Roxb) Sinclair	Umbh	Annonaceae	Fodder, Medicinal	Indo-Malesia
22	*Phoenix sylvestris*(L) Roxb	Khajuri	Araceae	Tady, Bevarages, Oil	India
23	*Pongamiapinnata*(L.) Pierre.	Karanj	Papilionaceae	Fuel, Medicinal	Asian subcontinent
24	*Tectonagrandis* L. f.	Saag	Verbenaceae	Timber, Medicinal, Charcoal	Asia(mainly India), Indonesia, Malaysia, Thailand, Burma,
25	*Terminaliabellirica*(Gaerth.) Roxb.	Bahedo	Combretaceae	Medicinal	Southern Asia to south western China
26	*Terminaliacrenulata* Roth	Sadad	Combretaceae	Religious, Medicinal	India, Ceylon, Srilanka
27	*Wrightiatinctoria* R Br	DudhiKada	Apocynaceae	Fodder	Indigenous (India)
28	*Zyziphusnummularia* (Burm f) W & A	Bor	Rhamnaceae	Fruit, Fuelwood	Western India, South eastern Pakistan, South Iran

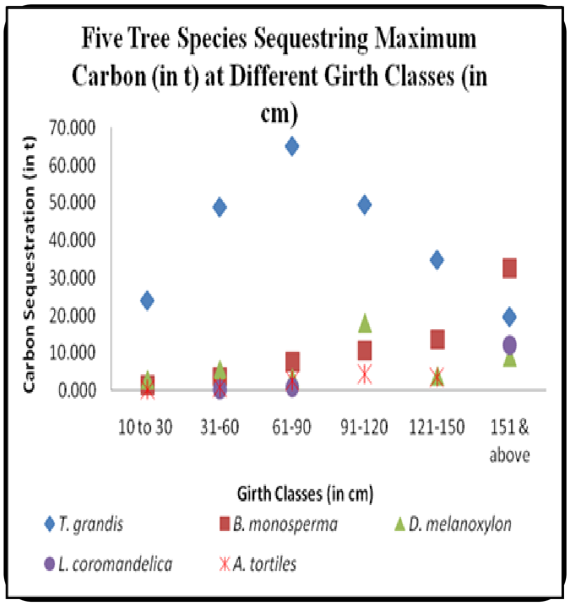

Fig. 1: Maximum Carbon seq. by five species at different girth classes species at different girth classes

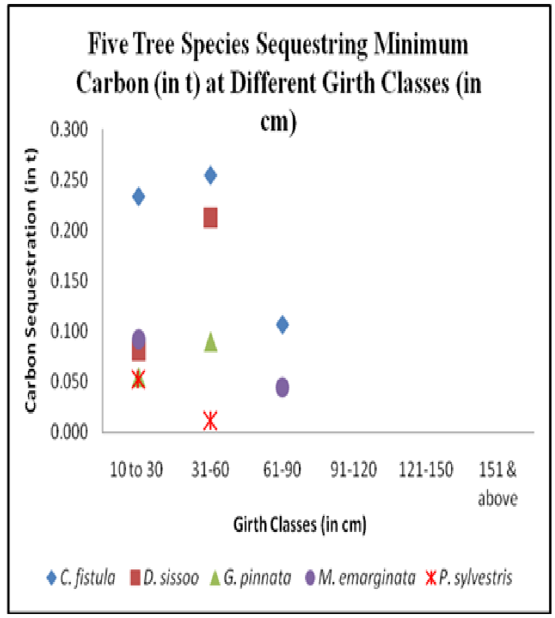

Fig. 2: Minimum Carbon seq. by five species at different girth classes species at different girth classes

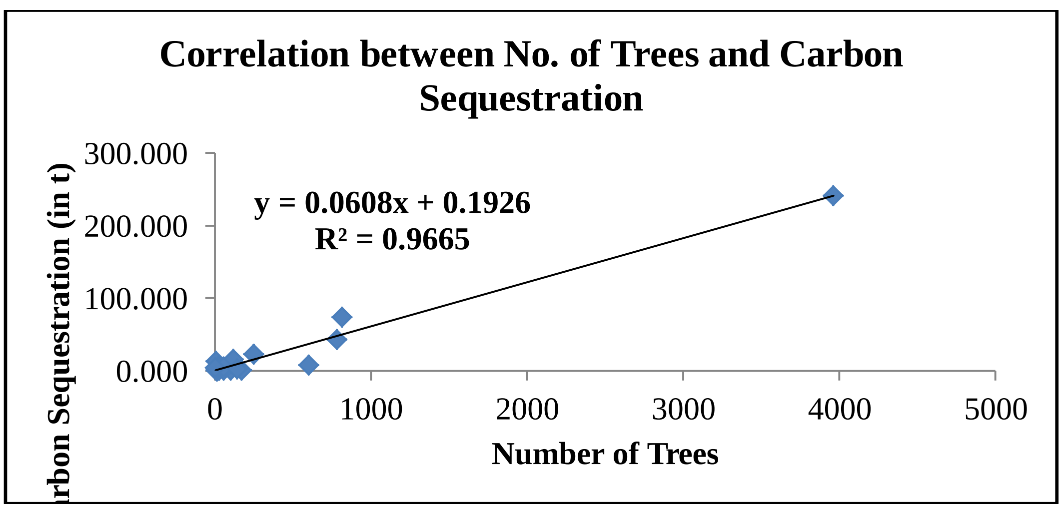

Fig. 3: Correlation between No. of Trees and Carbon Sequestration

There is a reason of degradation of forests due to illicit cutting of larger and valuable trees which has also been found in forests of tropical Asia (Brown *et al.*1991). Firewood is the dominant fuel for found at each girth class. Absence of these species will affect the environment in future such as rise in temperature due to global warming. Tropical cooking in rural areas (as 95% of households depends on firewood and dung) and for about 35% of urban households (NCAER, 1985). Due to illicit cutting and grazing practices many species are not deforestation has been responsible one major reason for the increasing concentration of carbon dioxide in the atmosphere (Houghton 1990).

Enhancing Carbon sequestration by monitoring forested land area (e.g. plantation forests) has been recommended as an valuable measure to diminish elevated atmospheric CO_2 concentrations and hence contributes to the prevention of global warming (Watson 2000). To avoid rise in temperature and for the benefit of human society including others creatures of life, action must be taken to conserve the forests and to avoid illicit cutting.

Acknowledgement

The authors are thankful to Gujarat Forest Department for their financial support.

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