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Estimation of Carbon sequestration potential of Vegetation under different forest types of Pushkar Valley, Aravalli Region of Rajasthan, India

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Abstract

Forest Vegetation are important sinks of atmospheric carbon and may significantly contribute to mitigation of climate change. The carbon pool in forest vegetation varies depend upon various factors such as plant species, plant age, geographical location and land use changes. To quantify the sequestered C in the forest ecosystem, C pools under various forest types should be assessed. To calculate the above ground and belowground biomass, allometric equations can be used. The objective of this study is to estimate the carbon sequestration potential of vegetation under different forest types of pushkar valley of Rajasthan. The Pushkar valley is located in the center of Rajasthan State between 26.5° North and 74.5° East covering an area of about 26.6 km According to the Intergovernmental Panel on Climate Change (IPCC), this area belongs to the tropical dry climatic region. Four land use pattern has been selected for the study. The valley area can be broadly divided into land use categories of forest types namely Dry deciduous forest (DD), Mixed deciduous forest (MD), Thorn scrub forest (TS), Open scrub forest(OS). Non destructive allometric method was employed for calculation of carbon stock in each plant species. For this different indicator parametres have been measured (e.g. tree DBH, height). During our present study carbon sequestration potential of different tree species have been observed under different forest type. In dry decidous forest, it has been observed that maximum carbon storage in Terminalia arjuna (2.2 t/species) followed by Anogeissus pendula (1.22 t/species). In mixed decidous forest Maximum carbon storage potential is found in Acacia nilotica (1.07 t/species) followed by Acacia raddiana (.59 t/species). In thorn scrub forest,it has been observed that maximum carbon storage potential in Acacia leucocephala (6.80 t/species) followed by Acacia nilotica (1.07 t/species). Maximum contribution in carbon sequestration is by vegetation of thorn scrub forest. In all forest type the maximum carbon sequestration potential is found in Acacia leucocephala followed by Terminalia arjuna.

Keywords: Carbon Sequestration, Allometric method, Aboveground biomass, Belowground biomass, Green house gases.

Introduction

The industrialization, urbanization and land use change are responsible in increasing the concentration of Carbon Dioxide (CO_2) and other greenhouse gas in the atmosphere. CO_2 is a major greenhouse gas and contribute to global warming[1]. Thus increasing CO_2 emission is one of the major environmental concerns and it has been well addressed in 'Kyoto protocol[2]. Forest vegetation and soils share almost 60% of the world's terrestrial carbon[3]. In terrestrial ecosystem, the two major carbon pools are vegetation (biotic) and soil (pedologic)[4]. Vegetative carbon is categorized into carbon in aboveground (shoot) biomass and belowground (root) biomass[4]. Forest ecosystem is one of the most important reservoirs of atmospheric carbon[5]. They store huge amount of carbon by uptaking the atmospheric carbon dioxide by the process of photosynthesis and thus play significant role in the global carbon cycle and mitigate climate change[5]. The carbon stock in forest vegetation depend upon various factors such as plant species, geographical location and most significant factor is land use, land-use changes, and deforestation[4]. Land-use change, especially the change of forest to agricultural land, results in removal of trees and reduces a large amount of sequestered carbon in the terrestrial ecosystem[4]. An ecosystem can act as sink or source of carbon depending on the species, and their age, land use change and soil erosion. Carbon sequestration is a process in which atmospheric carbon is captured and stored in the biosphere. To quantify the sequestered carbon in the forest ecosystem, C pools under various forest types should be assessed.

To estimate Total Forest carbon pool both above ground tree biomass and belowground root biomass need to be calculating. The above ground tree biomass and belowground root biomass both need to be measured to enable better calculations of total forest carbon. Non destructive allometric method can be use to estimate the total biomass. The objective of this study is to quantify the amount and distribution of C stocks in the vegetation of pushkar valley of Rajasthan.

Materials and Methods

Study Area: The Pushkar valley is located in the center of Rajasthan State between 26.5° North and 74.5° East covering an area of about 21.6 sq.km (Figure-1). According to the Intergovernmental Panel on Climate Change (IPCC), this area belongs to the tropical dry climatic region[6]. Climate of Pushkar is an important deciding factor of the ecology of Pushkar valley[7]. The valley experiences desert climate characterized with climatic variations. Summers are very hot with the temperature rising to high degrees during the days[7]. But the nights are cold, a typical feature of an extreme climate[7]. Rainfall is very less even during the rainy season. The winters are cool with the temperature fixed at around 10 degrees. Climatic data from 2013 to 2014 shows monthly average maximum and minimum temperatures of 31.3ºC and 8.3ºC in the months of May and January respectively. The mean annual rainfall is 400-450mm, with the highest monthly rainfall of 57mm in August and the minimum of 6 mm in May. The normal annual rainfall is about 527mm. Soil type is mainly sandy loam. Four land use pattern has been selected for the study. The valley area can be broadly divided into land use categories of forest types namely Dry deciduous forest (DD), Mixed deciduous forest (MD), Thorn scrub forest (TS), Open scrub forest(OS). Types of vegetation found in these forests are given in table1. A land use map of the study area showing area covering different forest type has been prepared using ERDAS (Figure-2).

Sampling: The random sampling method was used for sampling the above ground vegetation. Plot method is used, which is one of the most commonly used for all kind of vegetation sampling[1]. The method is versatile, cost-effective and applicable to baseline as well as project scenario[1]. “Plot method” is also among the methodologies approved by the Clean Development Mechanism for a forestation and reforestation projects under the Kyoto Protocol[1]. 20 plots of 20x20 m size were laid randomly in different forest type. Non destructive allometric method was employed for calculation of carbon stock in each plant species. For this different indicator parametres have been measured (e.g. tree DBH, height). The following parameters were measured for estimating the above-ground biomass pool.

Measurement of DBH (Diameter at breast height): DBH can be estimated by measuring tree Girth at Breast Height (GBH), approximately 1.3 meter from the ground[1]. The GBHs of trees having diameter greater than 10 cm were measured directly by measuring tape[1,10]. Tree diameter (D) was calculated by dividing 3.14 to the marked girth of tree i.e. GBH/3.14

Measurement of tree height: The tree height was measured by Theodolite at DBH[8]. The angle between the tree top and eye view at breast height angle (α) is taken into consideration for tree height measurement and height of the tree is calculated (Figure-3)[8].

Considering the angle ACB between tree top and the distance (b) at the point of observer at DBH, the tree height was calculated[8]. If α is the angle between eye view and top of the tree, as is the height of the tree in feet, c is the slope between tree and eye view, b is the distance in feet between tree and observer and h is height of horizontal plane of Theodolite instrument, then the height of tree (H) is calculated by the following formulae[8]:

$$H = h + b \tan \alpha$$

Table-1
Showing Types of vegetation in different land use pattern

Particular	Land use pattern	Vegetation
Site 1	Dry deciduous forest	Anogeissus pendula, Acacia catechu, Acacia leucophloea, Acacia senegal, Prosopis juliflora, Boswellia serrata, Terminalia arjuna Maytenus emarginata, Balanites aegyptica, Acacia raddiana
Site 2	Mixed deciduous forest	Butea monosperma, Anogeissus pendula, Prosopis juliflora, Ailanthus excelsa, Acacia nilotica, Acacia raddiana, Acacia leucophloea, Azardirachta indica, Pongomia pinnata
Site 3	Thorn scrub forest	Acacia nilotica, Acacia leucophloea, Acacia senegal, Acacia leucocephala,Prosopis juliflora,Prosopis cineraria, Capparis decidua, Zizyphus mauritiana, Zizyphus nummularia
Site 4	Open scrub land	Euphorbia caducifolia, Calotropis procera, opuntia, opuntia dilenii, *Echinops echinatus,* Jatropha gossypiifolia,

		Boerhavia diffusa

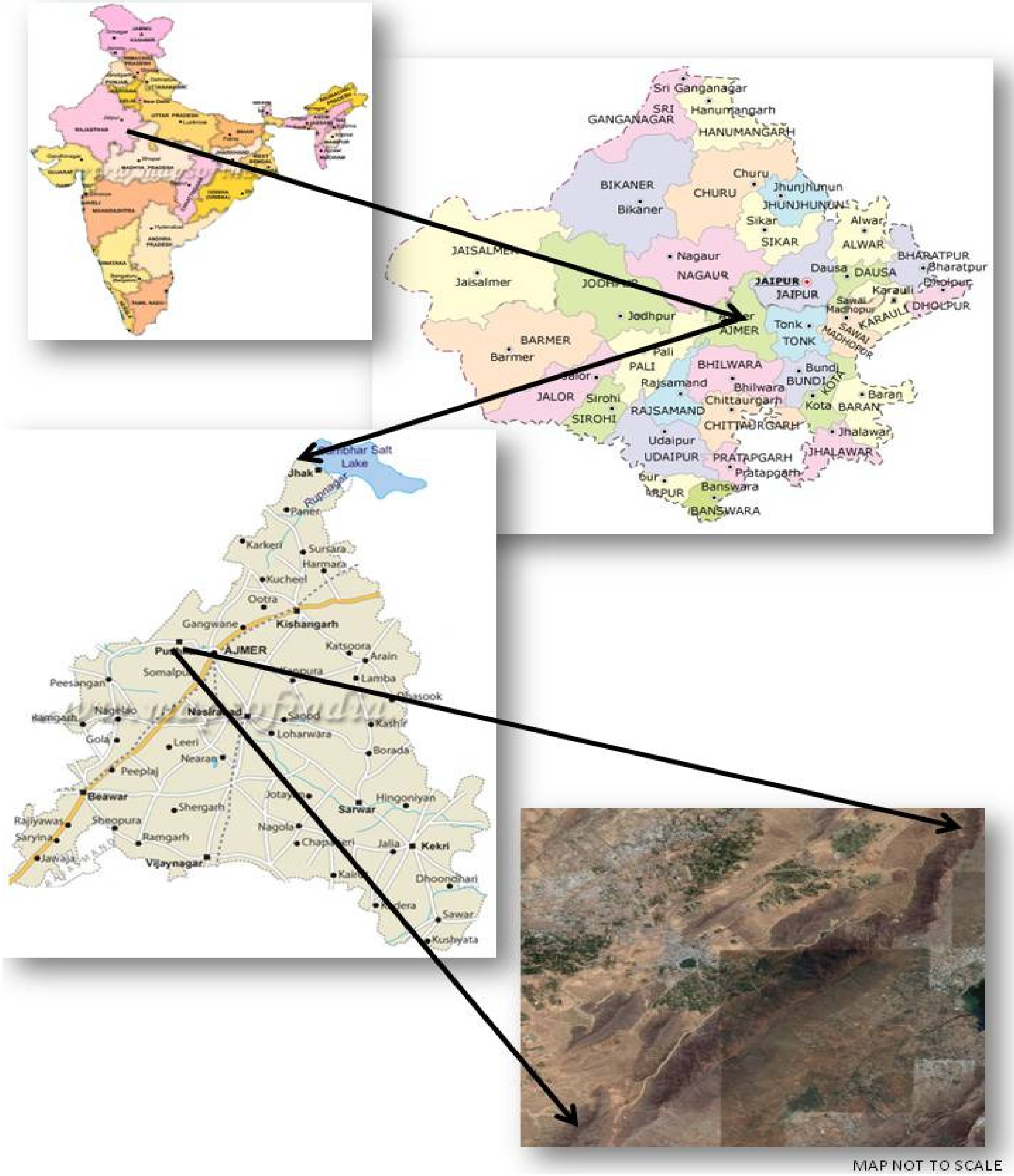

Figure-1
Map showing Study area (Pushkar valley) in Ajmer district of Rajasthan

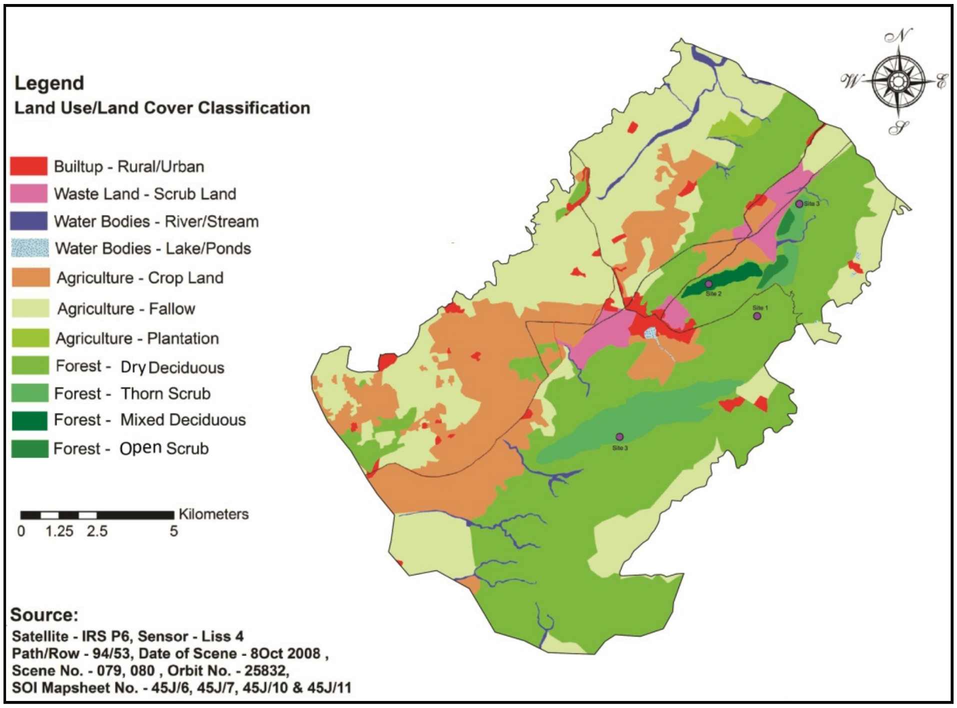

Figure-2
Showing Land use Land cover map of study area (Pushkar Valley) in Ajmer district of Rajasthan

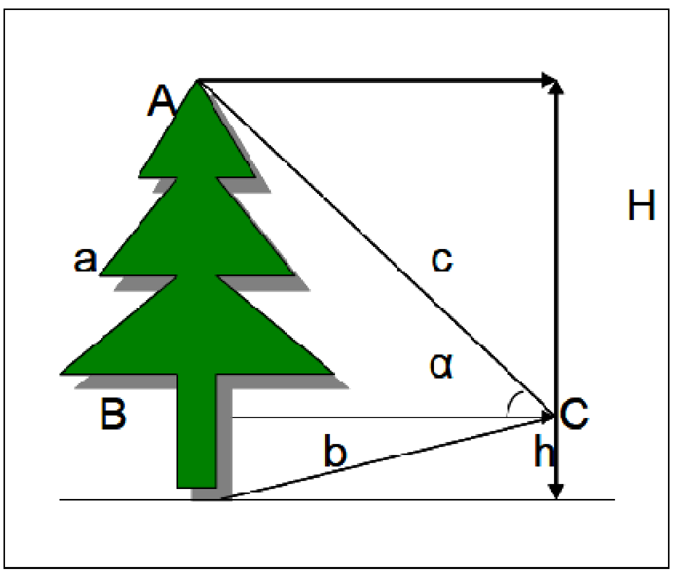

Figure-3
Showing view of tree height measurement by Theodolite at DBH

Measurement of above ground biomass: Above ground Biomass (AGB) are estimated by multiplying the bio-volume to the wood density of tree species[1,5]. Tree bio-volume (T_{BV}) value calculated by multiplying of diameter and height of tree species to factor 0.4[1,5].

AGB (kg) =Tree bio volume T_{BV} (m^3) x wood density (kg/m3)

Tree Bio-volume (T_{BV}) = 0.4 x $(D)^2$ xH

Where: D=GBH/3.14, Diameter (meter) calculated from GBH, H = Height (meter)[1,9]. Wood density is used from Global wood density database[9,11]. The standard average density of 0.6 gm/ cm is applied wherever the density value is not available for tree species[9].

Measurement of below ground biomass: The belowground biomass (BGB) includes all biomass of roots. The belowground biomass has been calculated by multiplying the above ground biomass (AGB) by 0.26 factor as the root: shoot ratio[1,5,9].
BGB=AGB x 0.26

Belowground biomass (BGB) kg/tree or ton/tree = aboveground biomass (AGB) kg/tree or ton/tree x 0.26

Total biomass: Total biomass is the sum of the above and belowground biomass[1,5,9,12]. Total Biomass (TB) = Above Ground Biomass + Below Ground Biomass

Carbon Estimation: Generally, for any plant species 50% of its biomass is considered as carbon i.e. Carbon Storage = Biomass x 50% or Biomass/2 [4,13]

Results and Discussion

Results of the study are given in Table-2,3,4 and Figure-4,5,6.

Table-2
Carbon storage in vegetation of Dry deciduous forest

Tree species	No. of Individual species	Average GBH (cm)	Average height (m)	Average biomass (t/individual)			Carbon storage = Biomass/2 (t)	Carbon storage (t/species)
				Above ground biomass	Below ground biomass	Total biomass		
Anogeissus pendula	53	44.79	4.96	.037	.009	.046	.023	1.22
Acacia catechu	25	66.1	5.38	.057	.014	.071	.035	0.87
Acacia leucophloea	6	52.57	4.64	.023	.006	.029	.0145	0.08
Acacia senegal	9	47.44	4.2	.023	.005	.028	.014	0.13
Prosopis juliflora	18	32.75	3.5	.011	.00286	.0138	.00693	0.12
Boswellia serrata	2	140	8	.318	.0826	.400	.2	0.40
Terminalia arjuna	7	135.42	**7**	.489	.127	.616	.308	2.2
Maytenus emarginata	20	39	4.63	.0194	.005	.0244	.0122	0.47
Balanites aegyptica	5	82	4.9	.0908	.0236	.114	.0572	0.28
Acacia raddiana	**5**	87	4	.0736	.01916	.09276	.04638	.231
Total								6.00 tonne

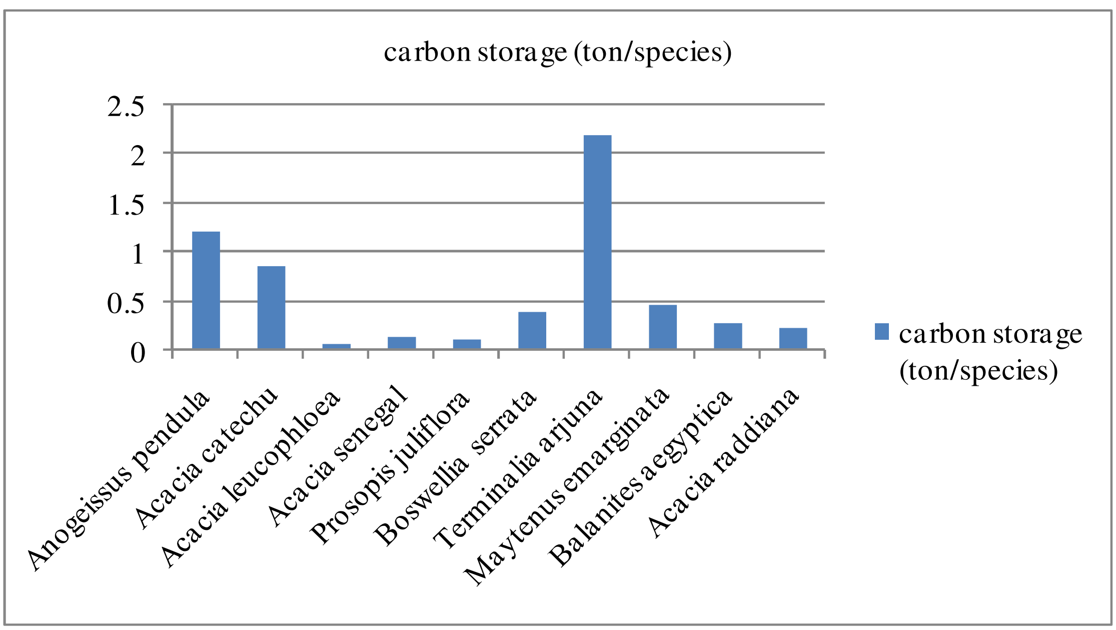

Figure-4
Graph Showing Carbon storage in vegetation of Dry deciduous forest

Table-3
Carbon storage in Vegetation of Mixed deciduous forest

Tree species	No. of Individual species	Average GBH (cm)	Average height (m)	Average biomass (t/individual)			Carbon storage = Biomass/2 (t)	Carbon storage (t/species)
				Above ground biomass	Below ground biomass	Total biomass		
Butea monosperma	2	38.6	4.2	.0142.	.003692	.017892	.008946	0.02
Anogeissus pendula	5	42	4	.025	.006	.031	.0155	0.07
Prosopis juliflora	6	32	3.2	.012	.0031	.0151	.00756	0.04
Ailanthus excelsa	1	69	6	.046	.01196	.05796	.02829	0.03
Acacia nilotica	3	46	4.4	.025	.0066	.0316	.0382	1.07
Acacia raddiana	12	85	4.5	.0791	.0205	.0996	.0498	0.59
Acacia leucophloea	5	52	4	.0197	.0051	.0248	.0124	0.06
Azardirachta indica	34	33.87	4.2	.014	.0037	.0177	.00885	0.30
Pongomia pinnata	14	41.5	4.1	.018	.00475	.0227	.0113	0.16
Holoptelea integrifolia	8	29	3.5	.0059	.0015	.0074	.0089	0.02
Total								2.35 tonne

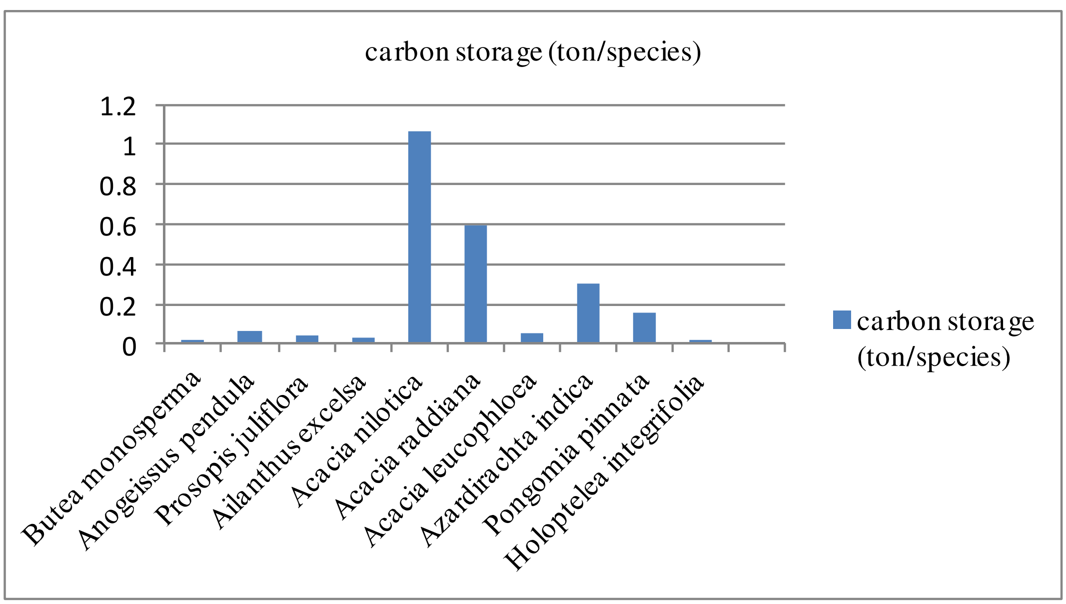

Figure-5
Graph Showing carbon storage in vegetation of mixed deciduous forest

Table-4
Cabon storage in Vegetation of Thorn scrub forest

Tree species	No. of Individual species	Average GBH (cm)	Average height (m)	Average biomass (t/individual)			Carbon storage = Biomass/2 (t)	Carbon storage (t/species)
				Above ground biomass	Below ground biomass	Total biomass		
Acacia leucophloea	12	51.5	4.64	.023	.006	.029	.0145	0.17
Prosopis juliflora	33	31.4	3.3	.012	.00312	.0151	.00755	.249
Acacia senegal	8	47	5.2	.0279	.0072	.0351	.01755	0.140
Prosopis cineraria	22	34.25	4.37	.013	.0035	.0165	.012	0.26
Zizyphus nummularia	35	35.33	4.28	.013	.003	.016	.008	0.28
Butea monosperma	2	38.6	4.2	.0142.	.003692	.017892	.008946	0.02
Maytenus emarginata	20	52.72	4	.027	.007	.034	.017	0.34
Acacia raddiana	4	87	4	.0736	.01916	.09276	.04638	.018
Acacia nilotica	28	45	4	.025	.0066	.0316	.0382	1.07
Acacia leucocephala	20	142	11	.54	.14	.68	.34	6.80
Zizyphus mauritiana	23	46.75	5	.026	.06	.086	.043	0.99
Total								10.3 tonne

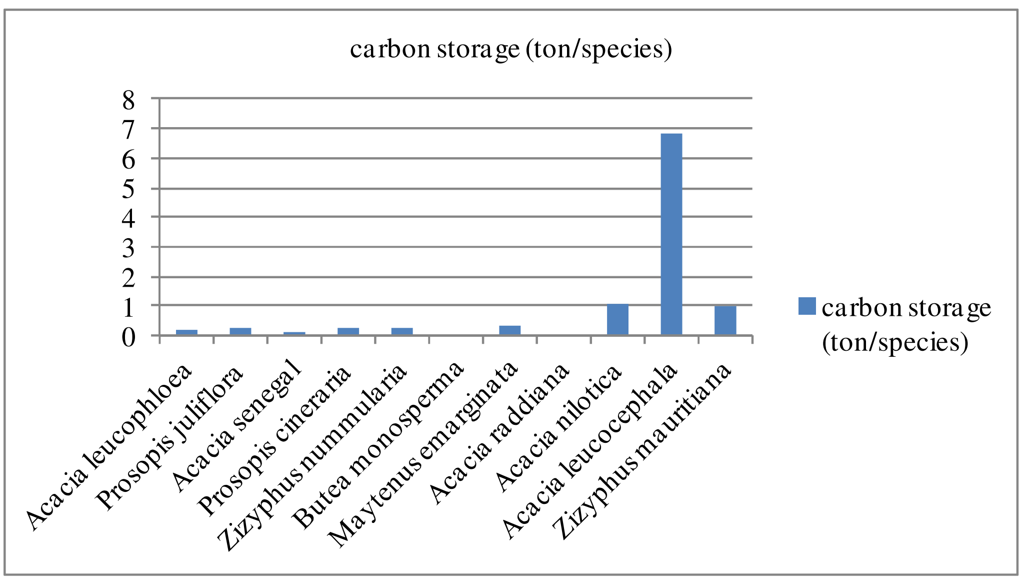

Figure-6
Graph Showing carbon storage in vegetation of Thorn scrub forest

Discussion: During our present study carbon sequestration potential of different tree species have been observed under different forest type. In dry decidous forest 11 species including 150 individuals have been recorded. It has been observed that maximum carbon storage in *Terminalia arjuna* (2.2 t/species) followed by *Anogeissus pendula* (1.22 t/species). Both the above species has similar wood density i.e. .94 g/cm^3 which is more than the other species. Since the *Terminalia arjuna* has higher GBH and height than the *Anogeissus pendula*, it has more carbon storage potential. *Anogeissus pendula* is the dominant species in the dry decidous forest and this is also one of the reason for higher carbon storage potential.

In mixed decidous forest 10 species including 90 individuals have been recorded. Maximum carbon storage potential is found in *Acacia nilotica* (1.07 t/species) followed by *Acacia raddiana* (.59 t/species). The reason for maximum carbon storage potential in Acacia nilotica is its higher wood density i.e. .65 g/cm^3 and Acacia raddiana have highest GBH among the species found in mixed decidous forest therefore having second highest carbon storage capacity.

In thorn scrub forest 11 species including 207 individuals have been found. It has been observed that maximum carbon storage potential in *Acacia leucocephala* (6.80 t/species) followed by *Acacia nilotica* (1.07 t/species) . *Acacia leucocephala* is having maximum GBH and height, therefore, having maximum carbon storage capacity. The reason for higher carbon storage in Acacia nilotica is its higher wood density and also its number is higher. It was found that dominant species in the thorn scrub forest are *Zizyphus nummularia* and *Prosopis juliflora*. Since these both species are having less average GBH and height, therefore having low carbon storage potential. Hangarge L. M. et al. (2012) reported that in Bhor region of Pune District which is a humid region, Terminalia bellirica species having 180 trees and sequestrated 327.78 tons of carbon in its standing biomass, followed by Ficus amplissima (221.0 tons). The other major carbon sequestrating species were Mangifera indica (95.2 tons), Dalbergia lanceolaria (73.082 tons), Ficus racemosa (57.96 tons), Pongamia pinnata (60.48 tons), Lagerstoemia microcarpa (43.0 tons) . This shows carbon sequestration potential depends on tree species and also climatic condition of that area.

Conclusion

It is a time limiting study and evaluation of the carbon sink is based on purely non-destructive method. In the present study, it is concluded that total carbon storage in vegetation of dry deciduous forest, mixed deciduous and thorn scrub forest are 6 tonnes, 2.35 tonnes and 10.3 tonnes respectively. Maximum contribution in carbon sequestration is by vegetation of thorn scrub forest. There are 24 species including 447 individuals recorded in the pushkar valley region. In all forest type the maximum carbon sequestration potential is found in *Acacia leucocephala* followed by *Terminalia arjuna*. Carbon sequestration potential is depend on various factors i.e. wood density, GBH, height and number of individual. Also climatic factor plays an important role. Pushkar valley is a semi arid region having low annual rainfall and high temperature, therfore trees here do not gain much height and GBH and thus having low carbon sequestration potential. The study shows that trees act as major CO_2 sink which captures carbon from the atmosphere and acts as sink, stores the same in the form of fixed biomass during the growth process. Pushkar valley is a religious place and having thick vegetation possesses high carbon sequestration potential, contributing in reducing concentration of CO_2 in the atmosphere. As they are gradually shrinking due to human activities like agricultural, Urbanization, grazing activities. Thus it is the need to preserve the forest area to maximize the carbon sequestration.

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