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Carbon Stock of Woody Vegetation in Hot Arid Region of Rajasthan

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ABSTRACT: *Climate change is already harming people and damaging ecosystems with frequent calamities occurring in nature. The arid regions of India are also facing the consequences of changing climate in the form of droughts, excessive heat waves, floods, etc. There are many international and national agreements to minimise the effect of global warming and emphasized to plant more trees under different programmes. As woody vegetation store large amount of carbon above ground as well as below ground, present study was conducted to quantify the amount of carbon stored by woody vegetation in parts of arid western Rajasthan. In study sites tree biomass ranged between 6.89 to 20.21 t/ha. The average biomass of trees was 18.27 t/ha, 13.81 t/ha and 11.37 t/ha in study sites Jodhpur, Barmer and Jaisalmer district, respectively. On an average the carbon stored in the trees was 6.84 t/ha in the targeted sites. The shrub biomass ranged between 3.39 to 8.33 t/ha among studied sites. The carbon stored by the shrub species ranged between 1.69 t/ha to 4.16 t/ha in different sites. The present approach helped to make out the role of trees and shrubs in carbon cycling and carbon sequestration in arid region of India.*

Key words*: arid region, carbon, climate change, woody species*

INTRODUCTION

Climate change has now become a reality and arid ecosystems have to face the consequences of climate change in the form of erratic rainfall, rising temperature and increased incidences of other extreme events. Forest ecosystems play a very important role in the global carbon cycle, storing about 80% of all above-ground and 40% of all below-ground terrestrial organic carbon [5]. During the productive season, CO_2 from the atmosphere is taken up by vegetation and stored as plant biomass [6]. Various international environmental agencies, agreements like Clean Development Mechanism of the Kyoto Protocol and some voluntary carbon markets have emphasized on the tree planting projects to combat the increasing emission of the greenhouse gases. For this reason, the United Nations Framework Convention on Climate Change and its Kyoto Protocol recognized the role of woody vegetation in carbon sequestration and storage [3].

Woody vegetation in addition to its multipurpose uses in deserts, also helps in stocking carbon aboveground (stem, branches and leaves) and belowground (roots and soil). Trees are unique in their ability to lock up large amounts of carbon in their wood, and continue to add carbon as they grow. Although they do release some CO_2 from natural processes such as decay and respiration, a healthy forest typically stores carbon at a greater rate than it the rate releases. Trees and shrubs affect climate change, but are often disregarded because their ecosystem services are not well understood or quantified. Trees and shrubs including plantations, if well stocked, typically sequester carbon at a maximum rate between about age 10 to 30. As an indication, at age 30 years about 200 to 520 tonnes CO_2-e are sequestered per ha with productivity ranging from low to high [1]. Therefore, to quantify the contribution of trees and shrubs in carbon storage the present study was conducted in the eight villages of western Rajasthan.

MATERIAL AND METHODS

Experimental sites

The target sites were selected from different landforms in eight villages of three districts of arid western Rajasthan viz. Govindpura and Mansagar (Jodhpur district), Dhok and Dhirasar (Barmer district) and Didhu, Dedha, Damodara and Sakariya (Jaisalmer district) (Fig. 1). Govindpura and Mansagar

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Figure 1: Target sites in selected districts

village is located in Osian Tehsil of Jodhpur district at 329 m elevation with average annual total rainfall of 213 mm and maximum average day temperature between 25 ° C to 44° C. Physiographically, Mansagar village is sandy plains whereas Govindpura is sandy plain interspersed with rocky uplands. Dhok and Dhirasar village were located in Chohtan tehsil of Barmer district at 178 m elevation with average annual total rainfall of 360 mm and temperature varies between 10° C (minimum) to 37° C (maximum). Physiographically, Dhirasar village is sandy plains and Dhok village is duny sandy plains. Sakaria and Didhoo village is located in Nachna tehsil of Jaisalmer district located at 151m elevation with average annual total rainfall of 335 mm and temperature varies between 8 ° C (minimum) to 42° C (maximum). Landform of Sakaria village is sandy plain, but Didhu has sandy plains with duny complex. Damodara and Dedha villages located in Jaisalmer tehsil have duny landforms. Temperature varies between 7° C to 42 °C and average annual total rainfall is 209 mm.

Tree Biomass and Carbon Estimation

In each village five quadrates of 32m × 32m were randomly placed for determination tree species composition on farmer fields, sand dunes, khadins, orans, open scrubs and fallow lands. The trees species in each quadrate were identified, counted and measured. Height of the trees was measured using the scale of 10 m. Girth at breast height (GBH) was measured with the help of measuring tape and later GBH was converted to diameter at breast height (DBH) using formula:

$$DBH = GBH/\pi$$

Tree diameter (D) was measured by dividing π (3.14) to the actual marked girth of species [2] i.e. GBH/ 3.14.

The biomass of trees was estimated by applying simple statistical equations used by Pandya *et al*. [7]

Above Ground Biomass (AGB)

Above ground Biomass (AGB) was estimated by multiplying the bio-volume to the green wood density of tree species. Tree bio-volume (TBV) value established by multiplying diameter and height of tree species to factor 0.4.

$$\text{Bio-volume } (T_{BV}) = 0.4 \times (D)^2 \times H \quad \text{........Eq. 1}$$

$$ABG = \text{Wood density} \times T_{BV} \quad \text{........Eq. 2}$$

Where; D = (GBH/π), diameter (meter) calculated from GBH, assuming the trunk to be cylindrical, H = Height (meter). Wood density is used from Global wood density database [13].The standard average density of 0.6 gm/ cm^3 is applied wherever the density value was not available for tree species.

Above ground biomass (AGB) =Wood density x $T_{Biovolume}$

Below Ground Biomass (BGB)

The belowground biomass has been calculated by multiplying the above ground biomass (AGB) by 0.26 factors as the root: shoot ratio [4].

Below ground biomass (BGB) =AGB x 0.26

Carbon estimation

Generally, for any plant species 50% of its biomass is considered as carbon [8] i.e. Carbon Storage = Biomass x 50% or Biomass/2

Shrub Biomass and Carbon estimation

Shrubs were harvested for estimation of woody biomass. In each village ten quadrates of 5m × 5 m were placed randomly on farmer fields, sand dunes, khadin, oran, open scrub and fallow lands. The different shrubs species in each selected quadrates were identified, counted and measured. Then the shrubs were harvested and fresh weight was taken. Samples were taken to laboratory and were oven dried at 65 ±5°C to a constant weight. Using fresh/ dry weight ratio, the dry weight of plant (biomass) was estimated.

Carbon Estimation

Same procedure like that in case of tree species was applied for estimation of carbon in shrub species.

RESULTS AND DISCUSSION

Tree biomass ranged between 6.89 to 20.21 t/ha (Table 1). The average biomass of trees was 18.27 t/ha, 13.81 t/ha and 11.37 t/ha in Jodhpur, Barmer and Jaisalmer district, respectively. On an average across the villages the carbon stored in the trees was 6.84 t/ha. Tree carbon storage was maximum in Mansagar village (10.10 t/ha). The shrub biomass ranged between 3.39 to 8.33 t/ha across the villages. The carbon stored by the shrub species ranged between 1.69 t/ha to 4.16 t/ha. It was observed that Mansagar and Govindpura villages in Jodhpur district had good density of tree species moreover, the villages had good sources of irrigation like tube wells due to which the trees were well maintained on the fields, whereas the villages of Jaisalmer and Barmer had low tree densities as well as total vegetation density because of climatic limitations which do not allow much required growth and regeneration as in general tract in rain fed. Singh *et al.*, [10] observed variations in climatic and edaphic conditions influenced the population of tree and shrubs as well as their growth, and carbon and nitrogen concentration in *Leptadenia pyrotechnica* plants. Singh and Chand [11] in their study reported that above-ground tree phytomass of tree outside forest (TOF) varied from 1.26 t/ha in the scattered trees in the rural/urban area to 91.5 t/ha in the dense linear TOF along the canal. The total above-ground TOF phytomass and carbon content was calculated as 367.04 and 174.34 t/ha, respectively in the study area of semi-arid region of Haryana.

The dominant tree species which was found in all the villages were *Prosopis cineraria*, *Tecomella undulata* and *Zizyphus rotundifolia*. However, in Damodara and Dedha villages of Jaisalmer district *Aacia nilotica* and *Tamarix aphylla* were the dominant species on Khadins and ground other water bodies. In sand dunes of Didhu and Sakaria *Acacia tortilis* was the dominant species. Singh *et al.*, [10] also reported that *Leptadenia pyrotechnica* (Forsk.) Decne, *Prosopis cineraria* (L.) Druce. and *Zizyphus* species (Burm.f) Wt are commonly found in all agroclimatic zones of arid regions of country.

On an average the carbon stock of *Prosopis cineraria*, *Tecomella undulata* and *Zizyphus rotundifolia* was 0.70, 0.47 and 0.40 t/ha, respectively. *Prosopis cineraria* contributed 42.55% and 72.49% more than *Zizyphus rotundifolia* and *Tecomella undulata* to the carbon stock of trees (Table 2). Khejri (*Prosopis cineraria*) is the precious tree of Indian deserts, plays a vital role in environmental conservation of arid and semi-arid areas. It is in fact, the symbol of socio-economic development of the arid regions. Since all the parts of the tree are useful, it is called kalp taru of desert. Khejri is a tree which is worshipped by a large number of people such as Bishnoi a great environmentalist community of Rajasthan and that's why the species covers about two-thirds of the total geographical area of the state and hence contributing maximum to the carbon stock in the villages under study.

The shrubs *Aerva persica*, *Calotropis procera* and *Leptadenia pyrotechnica* on average had 0.37, 0.43 and 0.35 t/ha carbon stock, respectively across the villages. The maximum amount of carbon stock was stored by *Calotropis procera* i.e. 38.28% followed by *Leptadenia pyrotechnica* (31.53%) and *Aerva persica* (30.18%) (Table 3). The *Calotropis procera* is widely distributed in western Rajasthan and the plant has high level of regeneration potential. It could be harvested up to 4 times in a year. Studies of Wohlfahrt *et al.*, [12] indicated that carbon uptake by desert vegetation is much higher than that of the previous understanding and as such it may contribute significantly to the terrestrial carbon sink. But due to considerable uncertainties in these calculations,

Table 1
Biomass and carbon stock of woody components in different villages

District	*Village*	*Tree biomass (t/ha)*	*Carbon stock (t/ha)*	*Shrub biomass (t/ha)*	*Carbon stock (t/ha)*
Jodhpur	Govindpura	16.33±1.09	8.16	6.85±0.60	3.42
	Mansagar	20.21±1.55	10.10	8.33±0.54	4.16
Barmer	Dirassar	12.73±1.23	6.36	5.90±0.67	2.95
	Dhok	14.88±1.01	7.44	6.42±0.91	3.21
Jaisalmer	Damodara	10.60±0.44	5.3	4.71±0.26	2.35
	Dedha	6.89±0.59	3.44	3.39±0.36	1.69
	Didhu	12.35±0.84	6.17	5.73±0.32	2.86
	Sakaria	15.62±1.26	7.81	5.86±0.68	2.93

Table 2
Carbon stock of different dominant tree species from targeted villages (t/ha)

Species Village	*Zizyphus rotundifolia*	*Prosopis cineraria*	*Tecomella undulata*	*Mean*	*Std. error*
Damodara	0.34	0.48	0.01	0.28	0.14
Dhirasar	0.17	0.69	0.48	0.45	0.15
Dhok	0.44	0.67	0.42	0.51	0.08
Dedha	0.25	0.45	--	0.35	0.13
Sakariya	0.44	0.81	--	0.63	0.23
Didhu	0.72	0.38	--	0.55	0.21
Mansagar	0.46	1.12	0.79	0.79	0.19
Govindpura	0.42	1.04	0.66	0.71	0.18

Table 3
Carbon stock of different dominant shrubs from targeted villages (t/ha)

Species Village	*Aerva persica*	*Calotropis procera*	*Leptadenia pyrotechnica*	*Mean*	*Std. error*
Damodara	0.25	0.43	0.16	0.28	0.08
Dhirasar	0.19	0.21	0.37	0.26	0.06
Dhok	0.35	0.50	0.54	0.46	0.06
Dedha	0.40	0.43	0.25	0.36	0.06
Sakariya	0.57	0.38	0.41	0.45	0.06
Didhu	0.27	0.46	0.22	0.32	0.07
Mansagar	0.53	0.58	0.43	0.51	0.04
Govindpura	0.37	0.41	0.42	0.40	0.02

verification by quantifying above and below ground carbon pools over time has been suggested [9].

CONCLUSION

Trees and shrubs are unique in their ability to lock up large amounts of carbon in their wood, and continue to add carbon as they grow. On an average across the villages in present study carbon stored in the trees was 6.84 t/ha. The shrub biomass ranged between 3.39 to 8.33 t/ha across all the villages which on an average stored carbon to the tune of 2.94 t/ha. These preliminary findings indicated the potential of trees and shrubs to lock up carbon above ground and as well as below ground and their role in mitigating the global warming effects in the hot arid regions of India.

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