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Original Article

Spatial variations in floristic diversity and carbon storage in arid zone forests of western Rajasthan, India

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Abstract
Forests play important roles in conserving biodiversity and sequestering carbon. A study was conducted to monitor changes in vegetation diversity and carbon storage in six blocks (Panchayat Samiti) one in each six desert districts of western Rajasthan during 2013-2015. Thirty forest areas, five each from Aburoad, Bap, Baitu, Bali, Sanchor and Sankara blocks situated in Sirohi, Jodhpur, Barmer, Pali, Jalor and Jaisalmer district, respectively were selected for vegetation study and estimation of carbon storage in vegetations and soils. There were 78 plant species belonging to 31 families. Number of shrub and herbaceous species, population of trees, diversity and richness of herbaceous vegetation and standing biomass carbon were highest in Aburoad. Number of tree species, their girth and shrub height were highest in Sanchor block. Population and diversity of most plant habits were lowest in Bap block. Sankara block indicated lowest standing biomass carbon. Soil bulk density was lowest and per cent soil organic carbon (SOC) was highest in Bali block. Soil carbon stock was highest in Aburoad block and lowest in Baitu block. Rainfall was positively related (P<0.01) to total standing carbon, tree population, herbaceous diversity and richness and SOC stock. Conclusively, variation in rainfall (soil water availability) and soils conditions like bulk density, gravel content and soil texture between studied blocks strongly influenced vegetation composition, diversity and growth and carbon storage in both biomass and soils. These factors needs to be managed to increase forest composition and cover and enhanced carbon sequestration.
Keywords: Species diversity, Biomass, Carbon density

Introduction

Natural vegetation in arid region of Rajasthan falls under Northern Tropical Thorn Forest (Champion and Seth 1968) occurring in small clumps scattered more or less openly and composed of tree, shrubs and herbs. About 9.54% of Rajasthan's geographical area is under forests against India's average of 20.6%. Area under forest is even low in arid districts as compared to the districts situated in semi-arid or dry sub-humid regions. Strong spatial variations in vegetation structure and composition (Singh 2015) influences carbon storage in both vegetation and soils. Though less in concentration, soil organic carbon in arid zone soils play an important role in global carbon cycle because of its greater extent distributed throughout the globe (Jobbagy and Jackson 2000). Carbon storage in forests involve numerous components including biomass carbon and soil carbon and help in maintaining a dynamic equilibrium with its environment. Despite of low coverage forest soils play an important role in carbon cycling in arid ecosystem and growing vegetation is one such method of capturing andstoring CO_2 (Lavelle 2014).

Forest soil also works as a carbon reservoir and if not managed effectively it may act as source of atmospheric CO_2, which is an important aspect of the global carbon cycle (Lal 2004). Rising temperatures as observed in recent years may not only influence the decomposition of fresh carbon fraction in soil, but also stimulate carbon releases from humified soil organic matter(Planteet al. 2011).In contrast, increased number of species along with vegetation cover accelerate building-up of new carbon pools throughout the soil profile with increasing age, whereas plant diversity positively help mitigate soil carbon losses in deeper horizons (Steinbeiss et al. 2008).Further, depending upon the types of species and their composition different land uses differ in carbon storage potential as well as their ecological functions (Hicks et al. 2014). For example, healthier and more diverse area with more dense shrub and tree cover are associated with greater aboveground carbon as well as soil carbon (Eldridge and Wilson 2002). However, vegetation diversity and covers show significant spatial variations with rainfall in arid areas and may influence carbon sequestration and climate change mitigation. This highlights close relationship between vegetation and soil organic carbon storage and requires a clear understanding for effective management of such forests and vegetation for enhanced carbon sequestration in both vegetation and soils.

Therefore, objectives of this study were: (i) to assess status and diversity of forests in western Rajasthan and corresponding carbon storage; (ii) variations in soil carbon storage in spatially distributed sites; and (ii) find out relationship in carbon stored among vegetation and soil for devising strategies in enhancing carbon storage for climate change mitigation.

Material and methods

Description of the site

The study was conducted in forest areas situated in different villages in six Panchayat Samiti (called block). These blocks were Aburoad, Bap, Baitu, Bali, Sanchor and Sankara situated in Sirohi (24º 20' to 25º 17' N and 72º 16' to 73º 10' E), Jodhpur (26º 0' to 27º 37' N and 72º 55' to 73º 52' E), Barmer (24º 58' to 26º 32'N and 70º 05' to 72º 52' E), Pali (24º 45' and 26º 29' N and 72º 47' to 74º 18' E), Jalor (24.48º 5' to 25.48º 37' N and 71º 07' to 75.5º 53' E) and Jaisalmer (26° 04’ to 28° 23' N and 69°20' to 72°42' E) district, respectively in Western Rajasthan, India (Fig 1). Block is a geographical unit in three tiers (i.e., Village Panchayat, block or Panchayat Samiti and Jila Parishad) system of Panchayat Raj Institution in Rajasthan. The climate is characterised by extreme of temperature, uncertain rainfall, high potential of evapotranspiration and strong winds. The landscape of Aburoad block is mainly comprised of pediments, hills, intervening basins and plains, whereas Sankara block has undulating dunes, sandy plains with shallow soils and saline depressions. Maximum temperature rises up to 51°C during summer, whereas minimum temperature drops down to freezing point during winter season. The annual rainfall varied from 58 mm to 800 mm during 1960 to 2012 (Poonia and Rao 2013). Rainfall in the studied areas showed high temporal and spatial variations. There was greater rainfall in August than in July in Jodhpur, Jaisalmer and Barmer, whereas it was relatively higher in July as compared to August in Jalor, Pali and Sirohi districts (Fig. 2a). Further, area under former districts received lesser rainfall as compared to the area under latter districts. The soils are sandy to sandy loam in texture, whereas soil depth varies with physiographic conditions of the area. The vegetations of the area are xerophytic in nature and most of the plant species are spiny and smaller in leaf size (Champion and Seth 1968).

Study design and vegetation study

A total number of 30 forest areas one each in 30 villages was randomly from six blocks (Panchayat Samitti) of six districts in western Rajasthan. Thus there were five replicate forest areas (named after a village name) in each block (Fig. 2a). A cluster of five plots each of 100 m^2 area (10 m×10 m size) were laid out in each forest area and used for counting and measuring tree, tree saplings and shrub species (Fig. 2b). In this, four plots were laid at the corner of the central plot. The centre to centre distance between central and the side one plots was 24.2 m. Nested plots of $1m^2$ size laid out in the centre of above-mentioned five plots were used for counting and biomass recording of herbaceous species. All trees were measured for girth (circumference) at breast height (GBH) and height. Shrubs and tree saplings (GBH<30 cm) were measured for collar girth (G) at ankle height (15 cm above ground) and height (Fig. 2b). In case of multiple stem, particularly for the shrubs, individual tillers were measured and converted to a single value using equation (Chojnack 1999)

$$G = \sqrt{g1^2 + g2^2 + g3^2 \ldots\ldots\ldots. gn^2} \;\ldots\ldots\ldots\ldots\text{Eq (1)}$$

Here 'G' in single value collar girth and 'g' is collar girth of individual tiller.

Herbaceous vegetation was clipped from the ground wherever available in the nested plots of 1m x 1m size laid in the tree/shrubs plots. Herbaceous species were counted manually for their number or population. Dry biomass of each species was recorded after oven drying of the sample at 60 ºC. Summed biomass of all herbaceous species was considered herbaceous biomass. Plants were identified as per taxonomical classification using standard literature (Shetty and Singh 1993; Bhandari 1990).

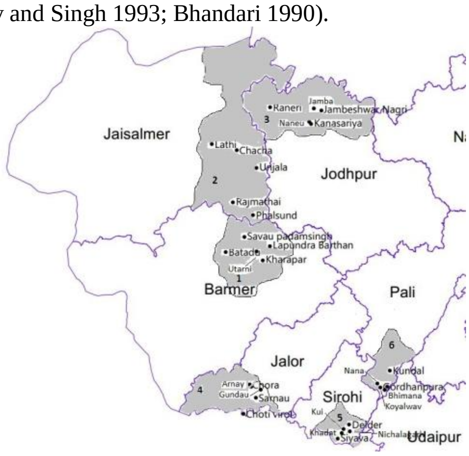
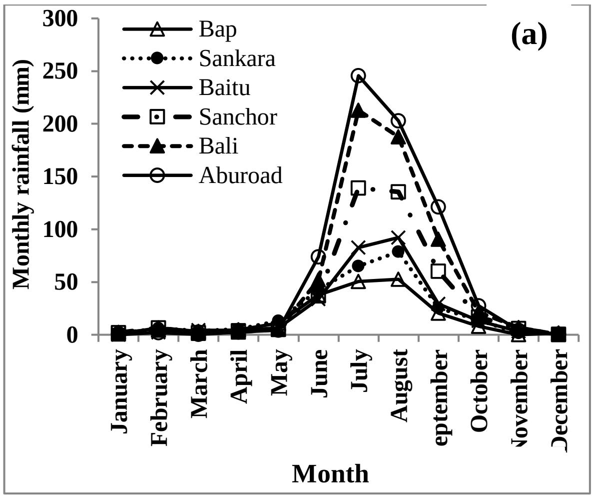


Figure 1. Distribution of forest area (name by villages) in different blocks (shaded area) delineated in different districts of western Rajasthan



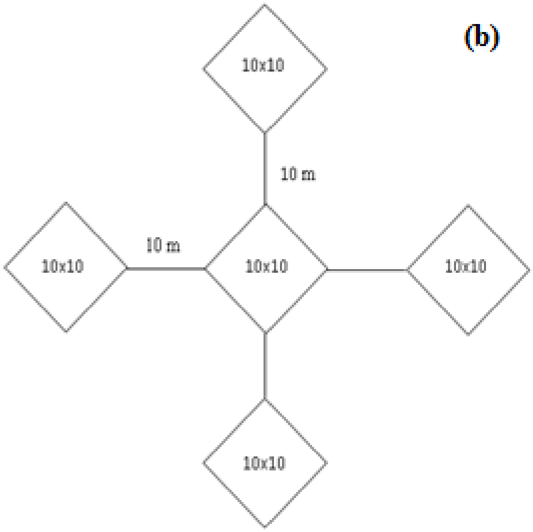


Figure 2. Distribution of average annual rainfall in different months in the studied blocks (a) and cluster design of sample plots in a forest area (b) of a village in the block.

Soil sampling and analysis

Soil samples were collected in 0-90 cm soil layer from the centre of the central plot of the cluster plots mentioned above for soil organic carbon (SOC) estimation and divided into 0-30, 30-60 and 60-90 cm soil layer. For soil bulk density, soil samples were collected from each plot using an iron corer of fixed volume at 15 cm, 45 cm and 75 cm soil depth after excavating a pit. These soil samples were transported to laboratory, oven dried at 110 ºC and weighed (McIntyre and Loveday 1974). Soil samples for carbon estimation were dried and passed through a 2 mm sieve for separation of gravel and fine earth fraction. Soil organic carbon was determined from fine earth fraction following standard procedures (Walkley and Black 1934) by using potassium dichromate as the oxidant and ferrous ammonium sulphate as the reducing agent (IPCC 2007). Soil organic carbon stock was calculated using the following equation (Batjes 1996):

$$\mathrm{Qi} = \mathrm{CiDiEi}(1 - \mathrm{Gi}) * 1000 \ldots\ldots\ldots\ldots\text{Eq (2)}$$

Where Qi (tons or Mg C ha^{-1}) is soil organic carbon content in a soil layer i, Ei is soil depth in meters, Ciis carbon content in g C g^{-1} soil, Di is bulk density in Mg m^{-3}, and Gi is volume fraction of coarse (gravel or stones of >2 mm size) elements.

Data calculation and Statistical analysis

Diversity indices of trees, shrubs, tree sapling and herbaceous vegetation were calculated. Species richness and Shanon-Weiner diversity index were calculated following standard literatures (Magurran 1988; Shannon and Weiner1963). Dry biomass was estimated based on diameter at breast height (DBH) for trees and collar diameter for tree saplings and shrubs using common regression equations (Table 1) developed by Singh (2014). Carbon stock was estimated by multiplying the dry biomass with a factor of 0.447 (Singh 2014). All data were analyzed statistically using SPSS version 17.0 statistical package. Soil bulk density, SOC and plant growth and species diversity and richness were analyzed using one way ANOVA. Spatially distributed blocks (one in each district) were considered main factors and five forest areas in each block were considered replications. To find out relations between rainfall, bulk density, SOC with biomasses, population, species richness, species diversity of tree, shrub, saplings, herbaceous species and carbon stock in biomass as well as in soils, Pearson correlation coefficient were also estimated. Duncan Multiple Range Tests (DMRT) was applied to observe homogeneous sub-setting of different block for different observed variables at the *P*< 0.05 levels. Regression relations were observed to relate SOC stock of different soil layers with average rainfall observed in different blocks.

Table 1. Different regression equations used in predicting standing biomass of individual trees, shrubs or tree sapling on dry biomass basis. (Source: Singh, 2014)

Equation no.	Plant habit	Equations
1	Shrubs	AGB (kg) = $1.422873 - 0.909824*D + 0.199237*D^2$
2		RDB (kg) = $1.221440 - 0.76480*D + 0.138231*D^2$
3	Trees	AGB (kg) = $0.181494261*D^{2.058650773}$
4		RDB (kg) = $0.084773863* D^{2.028825779}$
5	Tree saplings	AGB (kg) = $0.035391472* D^{3.087807162}$
6		RDB (kg) = $0.026583624* D^{2.699255524}$

AGB = above-ground dry biomass, RDB = root dry biomass, D = diameter at breast height for trees/collar diameter for shrubs and tree sapling.

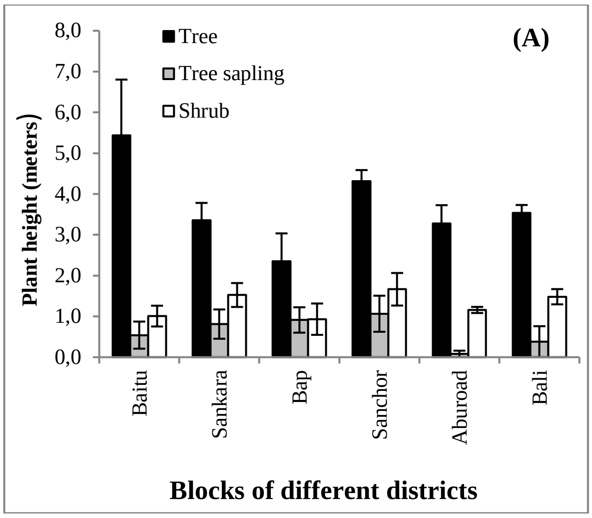
Results

Species composition and diversity

A total number of 78 plant species belonging to 31 families were recorded during field study. There were 12 grass, 38 herbs, 3 undershrubs, 10 shrubs and 15 tree species. In this, 64% species are ephemerals and annuals. Dominant family was Fabaceae with 21 plant species followed by Poaceae with 12 species. Only one species was recorded in most of the families.

Growth variables

Average height did not vary (*P*>0.05) between the blocks for all plant habit viz. Tree, tree sapling and shrub. Trees were tallest in Baitu block, whereas shrubs and trees saplings were tallest in Sanchor block (Fig. 3). Trees, shrubs and tree saplings were shortest in Bap block. Average girth of tree varied (*P*<0.01) among forest lands of studied six blocks. Girth of tree was greater in Sanchor and lesser in Bap block than in other blocks. Tree sapling and shrubs did not vary (*P*>0.05) in girth between blocks. However, the highest and lowest values of average girth of shrub were in Sankara and Baitu block respectively.



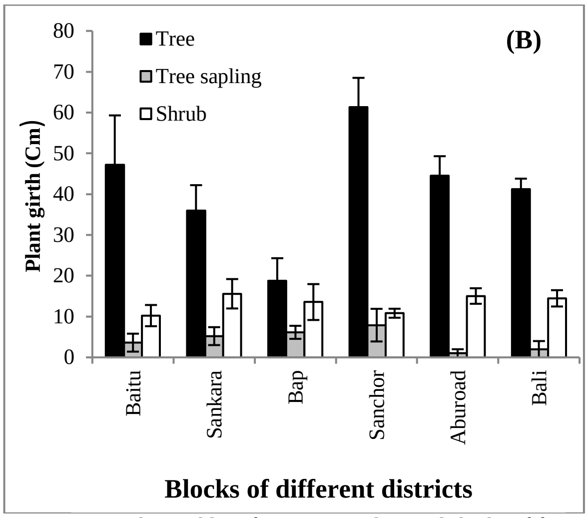


Figure 3. Growth variables of tree, tree sapling and shrubs of forest land in Western Rajasthan. Error bars are ±1 SE of five replications

Species diversity

Tree population was highest in Aburoad block, whereas species diversity and richness were highest (*P*<0.01) in Sanchor block (Fig. 4). For tree diversity block were in order: Sanchor>Sankara> Bali>Aburoad>Bap>Baitu. Population, Shanon-Weiner diversity and species richness for both tree saplings and shrubs did not vary (*P*>0.05) (*P*>0.05) between the blocks. Sapling population showed 16.5- fold variations between Bap and Bali blocks, whereas its richness and diversity were highest in Baitu block. For shrubs, population was highest in Aburoad, diversity was highest in Baitu and species richness was highest in Bap block (Fig. 4). Herbaceous population indicated 2.8-fold variations between Aburoad and Bap blocks. Herbaceous diversity and richness were highest in Aburoad block, but lowest values of these variables were in Baitu and Bap block, respectively.

Standing biomass and carbon stock

Tree (above ground and below ground) and herbaceous dry biomass varied (*P*<0.01) between the blocks. Tree biomass was highest in Sanchor (51.34 Mg ha^{-1}) and lowest in Bap block (3.24 Mg ha^{-1}). Dry biomass of shrubs was highest in Aburoad (1.38 Mg ha^{-1}) and lowest in Bali block (0.74 Mg ha^{-1}). Biomass of herbaceous species varied between 0.47 Mg ha^{-1} in Aburoad and 0.25 Mg ha^{-1} in Bap block. Dry biomass due to sapling was insignificant in Aburaod and Bali blocks. Other blocks it was in the order of

Baitu>Bap>Sanchor>Sankara. Total biomass (tree + tree sapling + shrub + herbaceous biomass) ranged between 52.43 Mg ha^{-1} in Sanchor and 5.33 Mg ha^{-1} in forest of Bap block.

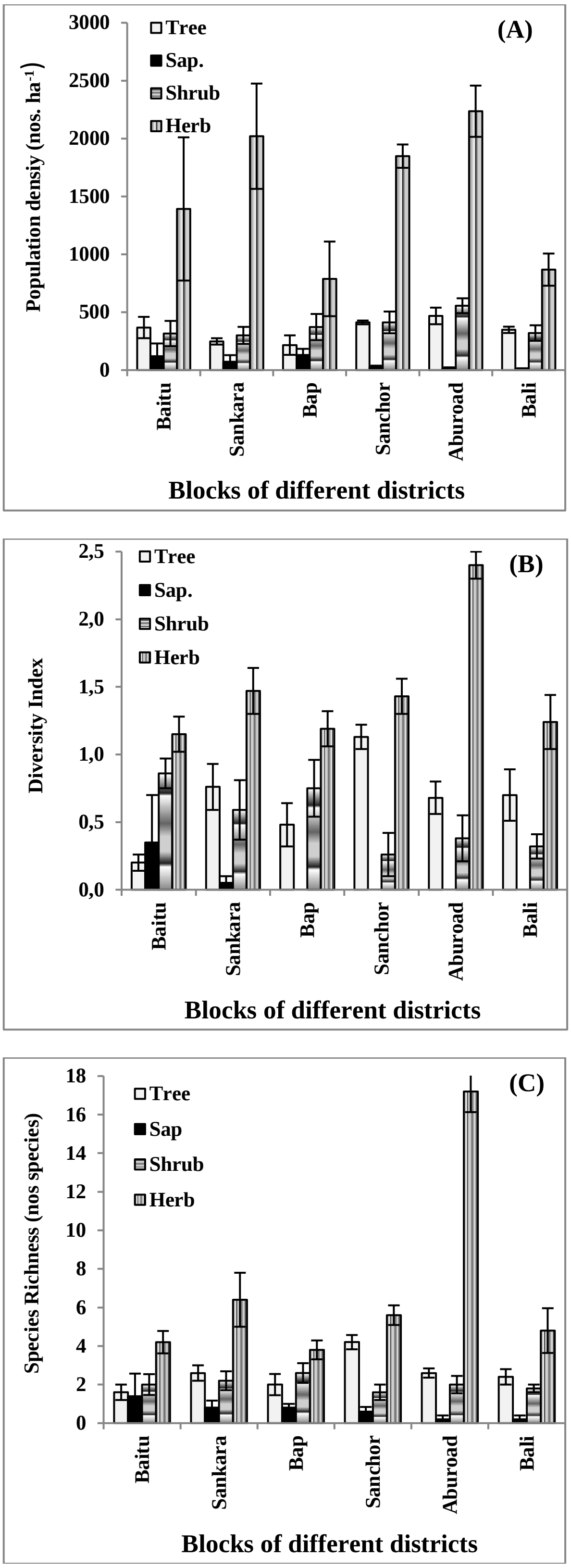
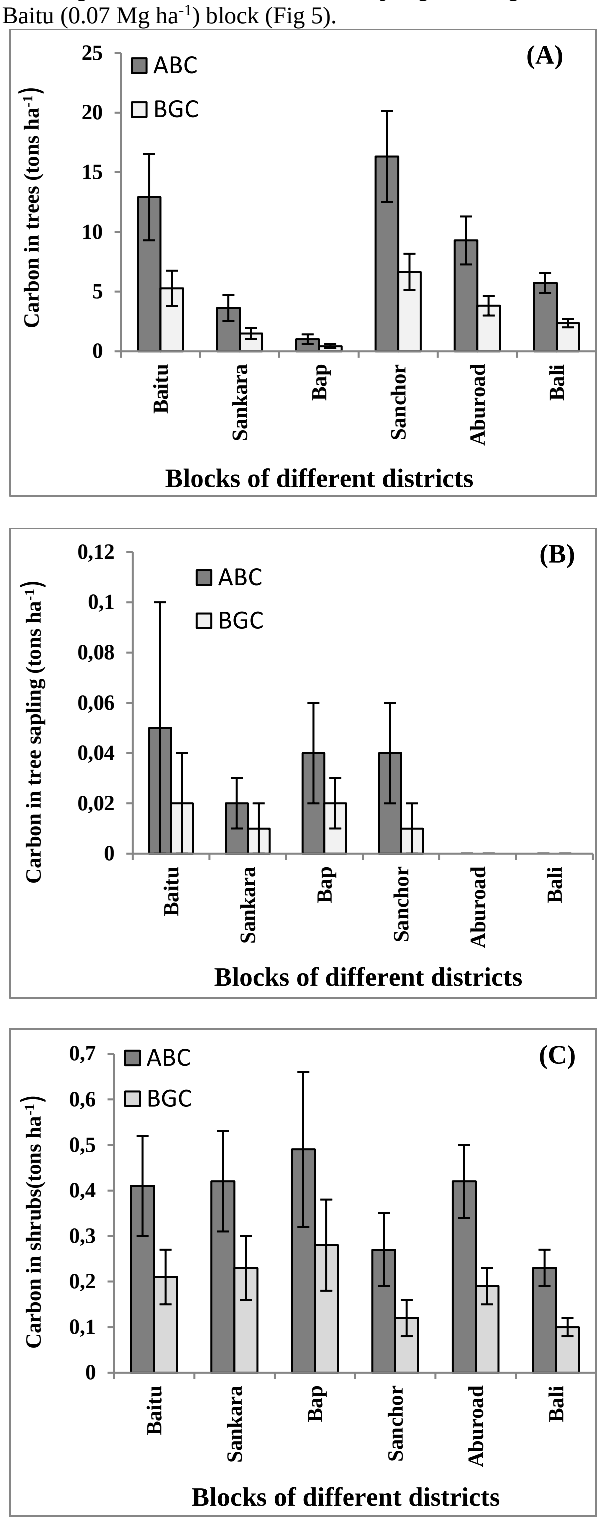


Figure 4. Population density (A), species diversity (B) and species richness (C) different plant habits in forest land of western Rajasthan. Error bars are ± 1SE of 5 replications

Carbon stock due to tree and herbaceous biomasses showed significant (P<0.01) variations among the blocks (Fig. 5). However, variations of carbon stock for tree saplings and shrubs was not significant (P>0.05). Carbon stock for trees was highest in Sanchor (23.00 Mg ha^{-1}), shrub (0.77 Mg ha^{-1}) in Bap and herbaceous vegetation (0.21 Mg ha^{-1}) in Aburoad block. There were 15.9-, 2.3- and 1.9-fold variations in carbon stock due to trees, shrubs and herbaceous species, respectively among different blocks. Standing carbon stock due to tree sapling was highest in Baitu (0.07 Mg ha^{-1}) block (Fig 5).



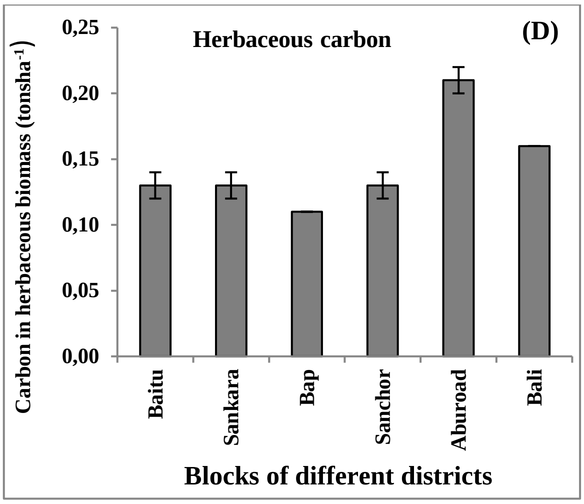
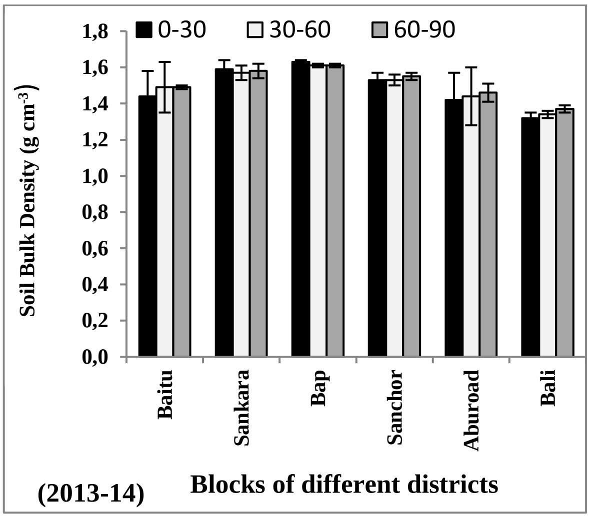


Figure 5. Carbon stock (Mg ha-1) of tree (A), tree sapling (B), shrubs (C) and herbaceous biomass (D) of forest land in western Rajasthan. Error bars are ± 1SE of five replications

Soil characteristics and carbon stock

Soil bulk density (BD) and per cent SOC varied (P<0.01) between the blocks in both 2013-14 and 2014-15. Lowest and highest (P<0.01) value of BD were in Bali and Bap block, respectively. Among soil layers, BD was lesser in top soil layer and increased downward in both the years (Fig. 6). SOC was highest (P<0.01) in Aburoad (0.62%) followed by Bali (0.44%) block across the soil layers and years. Lowest SOC in Baitu block (0.039%) did not differ with the soils of Sanchor (0.11%), Sankara (0.10%) and Bap (0.09%) blocks. SOC was greater (P>0.05) in 0-30 cm soil layer (0.291%) as compared to 30-60 cm (0.226%) and 60-90 cm (0.161%) soil layers. Block × soil layer interactions was not significant (P>0.05) for both BD and SOC.



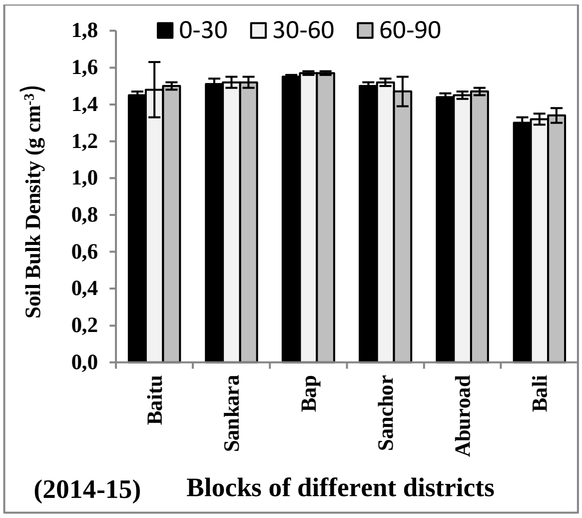
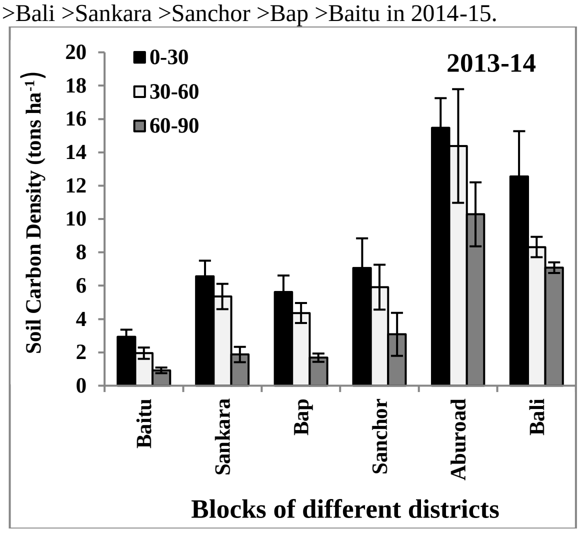


Figure 6. Soil bulk density (gm cm-3) in different soil layers of forest land in Western Rajasthan. Values are mean ± SE of five replications

SOC stock differed (P<0.05) between the blocks as well as soil layers in both 2013-14 and 2014-15. It was highest (P<0.01) in Aburoad (43.56 Mg ha^{-1} and 37.64 Mg ha^{-1}) followed by Bali (Fig. 7). SOC stock was lowest in Baitu block (6.11 Mg ha^{-1}and 4.4 Mg ha^{-1} in 2013-14 and 2014-15, respectively). SOC stock in the soils of Sanchor, Sankara and Bap blocks did not differ (P>0.05, DMRT). Among the soil layers, soil carbon stock was highest (P<0.01) in 0-30 soil layer (40% of 0 to 100 cm soil layer) and lowest (4.74 and 3.41 Mg ha^{-1} in respective year) in 60-90 soil layer in both the years. Block × soil layer interaction was not significant (P>0.05) in both the years. In top 0-100 cm soil layer, SOC stock ranged between 6.11 Mg ha^{-1} in Baitu block and 43.56 Mg ha^{-1} in Aburoad block with 7.1-fold variation in 2013-14, and from 4.40 Mg ha^{-1} in Baitu to 37.64 Mg ha^{-1} in Aburoad block with 8.6-fold variation in 2014-15. For SOC stock in 0-100 soil layer, spatially distributed blocks decreased in the order of Aburoad >Bali >Sanchor >Sankara >Bap >Baitu in 2013-14 and Aburoad >Bali >Sankara >Sanchor >Bap >Baitu in 2014-15.



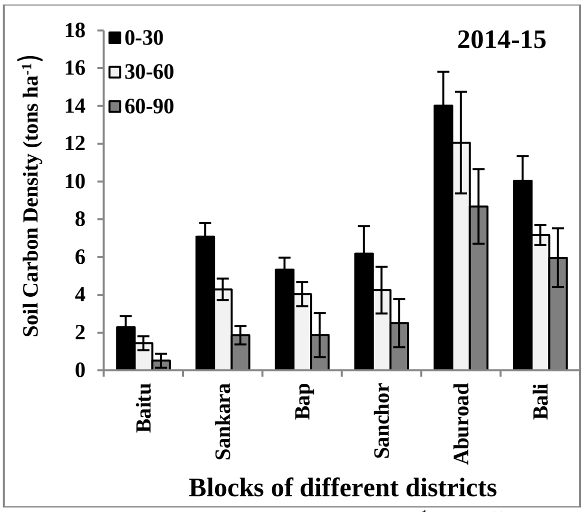


Figure 7. Soil organic carbon density (Mg ha^{-1}) in different soil layers of forest land in Western Rajasthan. Values are mean ± SE of five replications

Correlation among different variables

Rainfall observed positively correlated to per cent SOC, and negatively correlated to soil bulk density. Tree and shrub population showed positive correlation to their above ground and total biomass as well as carbon stock (Table 2).

Table 2. Correlations coefficient between different diversity indices, carbon stock of vegetation, soil bulk density, gravel content, organic carbon stock and average rainfall.

Habit	Diversity variable	Live carbon (Mg ha^{-1})			Gravel content up to 1 meter			Average annual rainfall
		AGB	BGB	TB	0-30	31-60	61-90	
Tree	Population	0.602**	0.603**	0.602**	0.377*	0.388*	NS	0.452*
	Diversity	NS	NS	NS	NS	NS	NS	NS
	Richness	0.435**	0.433*	0.434*	NS	NS	NS	NS
Sapling	Population	-0.393*	-0.394*	-0.393*	NS	NS	NS	-0.363*
	Diversity	NS	NS	NS	NS	NS	NS	NS
	Richness	NS	NS	NS	NS	NS	-0.444*	NS
Shrub	Population	NS	NS	NS	NS	NS	NS	NS
	Diversity	NS	NS	NS	NS	-0.371*	-0.424*	-0.413*
	Richness	NS	NS	NS	NS	NS	NS	NS
Herb	Population	NS	NS	NS	NS	NS	NS	NS
	Diversity	NS	NS	NS	0.575**	0.528**	0.671**	0.573**
	Richness	NS	NS	NS	0.666**	0.608**	0.740**	0.661**
SOC	0-30	NS	NS	NS	0.910**	0.895**	0.898**	0.848**
	31-60	NS	NS	NS	0.885**	0.845**	0.846**	0.834**
	61-90	NS	NS	NS	0.918**	0.869**	0.858**	0.877**
Bulk density	0-30	NS	NS	NS	-0.650**	-0.662**	-0.529**	-0.642**
	31-60	NS	NS	NS	-0.675**	-0.687**	-0.578**	-0.678**
	61-90	NS	NS	NS	-0.496**	-0.526**	-0.454*	-0.512**

NS: no significant at $P<0.05$, * significant at $P<0.05$, ** significant at $P<0.01$.

Soil bulk density and SOC stock were negatively correlated to each other in 0-30 cm soil layer. SOC and bulk density in 0-90 cm layer were positively and negatively correlated to gravel content. SOC stock in top 1 m soil layer was positively correlated to average rainfall and soil gravel content up to 90 cm soil layer (Table 2). Regression analysis indicated a linear relationship between SOC stock in 1 m soil layer and average rainfall ($F_{1/28}$= 33.03, R^2 = 0.541, $P<0.001$).

Discussion

Growth variables and diversity

Relatively low height and girth of trees and shrubs in Bap block was due to harsh climatic condition, low rainfall and compact soils affecting normal physiology and growth (Kujawski 2011). This was also indicated by taller shrubs in Sanchor block with higher amount of annual rainfall. Thus soil water availability obtained mostly through rainfall affected the growth and productivity of different categories of plants (Roux et al. 1995). Low species richness and species diversity in the studied region was certainly due to poor soil and environmental conditions as recorded in other studies in similar environment (Saiz et al. 2014; Singh and Singh 2015). The prevailing climatic and edaphic conditions resulted in high shrub diversity than tree diversity in Baitu, Bap and Sankara blocks. This indicates that arid region is much conducive for shrub population as compared to tree which require relatively higher amount of water for their survival. Other studies (Nawal et al. 2006; Kumar 2009) also showed dominance of *Crotolaria burhia* Buch.-Ham., *Leptadenia pyrotechnica* (Forsk.) Decne, *Calligonum polygonoides* L., *Calotropis procera* (Aiton) W.T. Aiton., *Acacia jacquemontii* Benth., *Sericostoma pauciflorum* Stocks ex Wight and *Zizyphus nummularia* (Burm. f.) Wight et Arn. shrubs in arid region. Greater number of ephemeral herbaceous species as compared to trees and shrubs species appeared to be indicative of low rainfall confined to a limited period of time in a year (Singh and Singh 2015). Better rainfall, soil water availability and soil condition in Aburoad, Bali and Sanchor than in other blocks resulted in high population, species richness and diversity of species of different plant habits favoring tree regeneration and distribution of plant species (Fonge et al. 2011, Zhang et al. 2013). Lowest population of tree coupled with highest shrub diversity in Bap block appeared to be related with poor edaphic condition and low rainfall influencing plant habits and their establishment (Singh and Singh 2015).

Standing biomass and carbon stock

Highest value of biomass and carbon storage in vegetation (trees, shrubs and herbs) in Aburoad, Bali and Sanchor block compared to the other blocks indicated significant spatial variation under climatic conditions, soil structure and precipitation. Absence of old stocked forests and consequently new plantation in Bap and Sankara blocks was the main cause of low standing carbon stock in biomass in these blocks as indicated by positive correlation (r=0.444, $P<0.05$) with lowest average rainfall for last 20 years in these blocks. However, soil type, plant growth, species diversity and climatic conditions are the controlling factors influencing carbon sequestration and thus biomass accumulation in dry areas (Singh and Singh 2015). Greater tree carbon stock in Sanchor block was due to greater number of trees with wider girth class similar to the study of Pragasana (2015) in Shervarayan hill in India. However, highest amount of biomass carbon in shrubs and herbaceous species in Aburoad block as compared to the other blocks was due to greater soil water availability and favourable environmental conditions (Roux et al. 1995). This indicates direct effect of rainfall upon carbon storage both in vegetation as well as in soils.

Soil characteristics and carbon stock

Significant variations in SOC stock in different blocks was due to variations in soil conditions and rainfall, which is indicated by positive correlations between soil carbon stock and average annual rainfall (P<0.01). Study of Satrio et al. (2009) on effect of precipitation fluctuation on soil carbon storage of a tropical peat swamp forest indicated decomposition of SOC and releases of CO_2 by oxidation under low rainfall. Significant spatial variations in soil carbon concentration and soil carbon stock were related to annual average rainfall and soil conditions. Despite of higher soil bulk density but better soil conditions in Sankara than in Sanchor block favoured SOC stock in former block, though organic matter content and compaction influenced soil bulk density (Chaudhary et al. 2013). Lowest amount of SOC stock in Bap, Sankara, Baitu and to some extent Sanchor block was due to water limitations affecting plant production and their contribution to SOC accumulation (Jobbagy and Jackson 2000). Increasing temperature in arid regions also results in a considerable decline in water use efficiency by increasing evapotranspiration leading to low biomass production and consequently low SOC stock (Lal 2004). Differences in soil organic carbon stock in different soil layers between the blocks appeared to be due to variations in soil texture and rainfall pattern. Venkanna et al. (2014) also observed variations in SOC with soil texture and annual rainfall. Depth-wise distribution of carbon stock appeared very much related to litter accumulation, its decomposition and fine root turnover and least partly affected by water content as deeper soil layers showed more soil water but least SOC (Singh et al. 2007; Lv and Liang 2012).

Conclusions

Combined effects of rainfall, soils and climatic conditions played significant role in plant diversity and carbon stock. About 64% species recorded were ephemerals and annuals growing mostly during rainfall season and thus very much influenced by rainfall pattern. Major role played in carbon accumulation in biomass as well as soils was by tree in Sanchor and by shrub in Bap block. However, environmental and edaphic conditions appeared dominant factors favoring vegetation growth and carbon accumulation in Aburoad, Bali and Sanchor blocks, but adversity of climatic and edaphic conditions affected carbon storage both in biomass and soils in Bap, Baitu and Sankara blocks negatively. Thus suitable trees and shrub species can be taken into consideration for increased vegetation cover, diversity and carbon sequestration based on climatic and edaphic conditions.

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