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Species

Assessment of plant community structure in Tal Chhapar Wildlife Sanctuary, Rajasthan, India

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ABSTRACT

The present study was undertaken in Tal Chhapar Wildlife Sanctuary (TWS), Rajasthan from June 2015 to May 2017 to assess the plant community structure of the area. Random vegetation sampling was done covering different seasons (summer, monsoon, and post-monsoon) following the quadrat method to cover the overall vegetation spectrum. The data were quantitatively analyzed for

different community characters**.** A total 78 angiosperm species belonging to 61 genera and 28 families were recorded and species richness of the family Poaceae was found to be highest followed by Asteraceae and Amaranthaceae. The grass *Dichanthium annulatum* was found to be the most dominant species followed by *Lasiurus scindicus* and *Desmostachya bipinnata*. The study revealed the area represents a saline grassland of *Dichanthium-Lasiurus* type. The dominance diversity curves approached a log normal series for trees, herbs and grasses/sedges, though shrubs followed the geometric series. The peak species diversity was observed during monsoon and least in summer and evenness was found to be almost similar across all the seasons. In absence of any prior study, this study will be very helpful to provide baseline information about the vegetation of TWS.

Key Words: Plant community, diversity, distribution, dominance, richness, Tal Chhapar

1. INTRODUCTION

Vegetation is a key feature in determining the status of an ecosystem as various ecological parameters such as microclimate, energy budget, photosynthesis, water regimes, surface runoff, soil temperature and biotic interactions within an ecosystem are influenced by its vegetation (Tappeiner and Cemusca, 1996). Different vegetation types growing in a particular area have a mutual relationship among themselves and with the environment, and together they represent plant community of that area (Mishra et al., 1997). The quantitative study of such community is called phytosociology and its principal aim is to describe and classify the vegetation in a meaningful manner, and explain or predict its structural pattern (Braun-Blanquet, 1932; Odum, 1971). In terrestrial ecosystem, understanding of plant community is crucial to assess the ecological sustainability of the area, functioning of any community within it and management of flora and fauna existing in that area (Warger and Morrel, 1978; Sharma and Pandey, 2010; Mandal and Joshi, 2014).

Various community aspects of vegetation of different parts of India have been dealt with by a number of workers like Joshi and Tiwari (1990), Atapati and Das (2012), Moktan and Das (2012), Rao et al. (2013), Mandal and Joshi (2014) and Thakur (2015). Few such studies have also been carried out in Rajasthan by Khan and Frost (2001), Sharma and Pandey (2010), Islam and Rehmani (2011), Sharma and Upadhyaya (2012); Krishna et al., (2014), Parihar and Choudhary (2017). Rajasthan represents the largest state in India and geographically located in both arid and semi-arid parts of India. However, till date little is known about phytosociological studies from the western Rajasthan that is characterized by the famous Thar Desert. Such studies are highly neglected in this region except very few viz., Sharma and Pandey (2010), Krishna et al., (2014) and Parihar and Choudhary (2017).

Tal Chhapar Wildlife Sanctuary (TWS), Churu, Rajasthan represents one of the two Protected Areas in the Thar desert of Rajasthan and popularly known as a Blackbuck Sanctuary. Though small and spreads over an area of about 7ha only, it is located on the eastern most edge of the Thar desert of Rajasthan and act as a gateway for passage of many migratory birds to the Thar desert of Rajasthan (Dookia et al., 2011). The area represents a typical savannah ecosystem characterized by Xerophilous grassland with isolated trees and home for many rare and endangered animals enlisted in the Indian Wildlife Protection Act (1972) (Dookia et al., 2011). So far, the Sanctuary lacks base line information about plant community structure except enlisting of a few plants from the area by Das et al., (2013) and Ojha, (2016). The present study aims to fill this gap by accessing the plant community structure of this area that will no doubt be helpful for management of this biodiversity rich area in future.

2. MATERIALS AND METHODS

Study area

The present study was undertaken in TWS ($27^0$48'38''N; $74^0$26'88"E), Sujangarh Tehsil, Churu district, Rajasthan (Figure 1). Located in the biogeographic zone 3A-Thar Desert (Rodgers et al., 2002), the vegetation of this area represents desert thorn forest (6B/C1) (Champion and Seth, 1968). This region is characterized by a distinct summer (March to May), monsoon (June to September), post-monsoon (October and November) and winter (from December to February) (Nawar, 2015; Poonia and Rao, 2018). The zone has a harsh climate with large variation in temperature and mean annual rainfall. The maximum temperature reaches up to 48°C in May-June and the minimum temperature falls to 10°C in December-January.

Vegetation sampling

In the present study vegetation sampling was carried out from June 2015 to May 2017 covering summer, monsoon and post-monsoon seasons. Random sampling was carried out following the quadrat method (Mishra, 1968). For each season, ten sample plots of 20×20m^2 each were laid down to study the tree diversity. For shrubs and herbs/grasses/sedges, ten sub-plots of 5×5m^2 and

1×1m^{2}respectively were laid within 20×20m^2 plots in all the selected systems. The species were identified using manuals of Bhandari (1990) and Shetty and Singh (1987,1991,1993). Selected plants were photographed in the field and herbarium was prepared following Jain and Rao (1977).

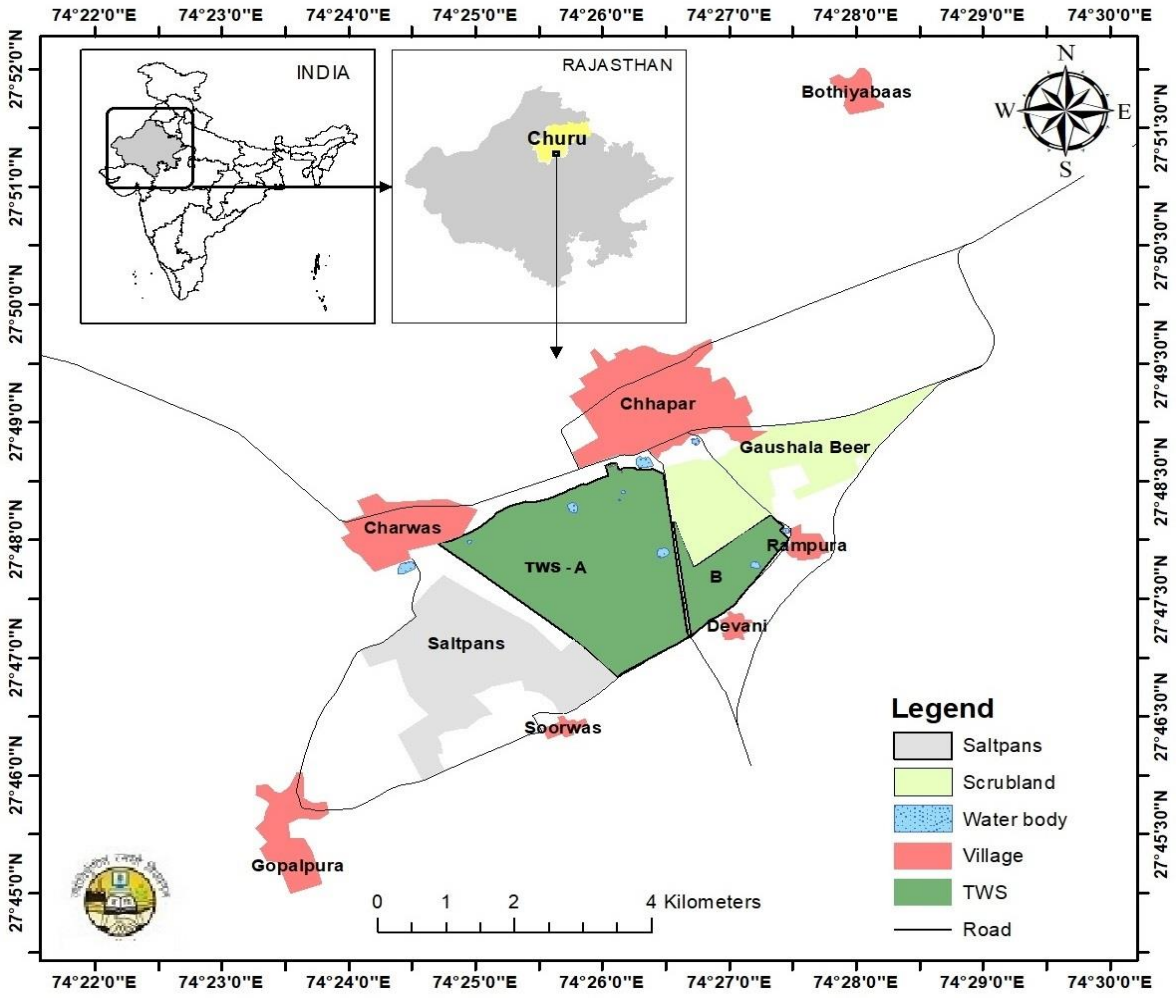

Figure 1 Tal Chhapar Wildlife Sanctuary

The vegetation data were quantitatively analyzed for community characters such as species richness, dominance, diversity and distribution pattern by using prescribed methods (Whitford, 1948; Simpson, 1949; Curtis and McIntosh, 1950; Margalef, 1958; Philips, 1959, Shannon and Weiner, 1968; Mishra, 1968).

Species richness (d) was calculated using Margalef's index (Margalef, 1958)

$d = (S - 1)/\ln N$

Where, S is the number of species and N is the total number of individuals in the sample

The dominance of the species was determined from importance value index (IVI) (Curtis and McIntosh, 1950) and Simpson's dominance index (Simpson, 1949).

IVI = Relative Frequency+Relative Density+Relative Dominance

Relative Frequency = Frequency of a species/Total frequency of all species×100

Relative Density = Density of a species/Total density of all species×100

Relative Dominance= Basal area of a species/Total basal area of all species×100

Frequency = No. of quadrats in which species has occurred/Total no. of quadrats sampled

Density = Total no. of individuals of a species/Total no. of quadrats sampled

Basal area = Density×Average basal area of individuals of a species

Simpson's Dominance index (SDI) = $\sum pi^2$

Pi=Number of individuals of species i (n)/total number of individuals (N)

The dominance-diversity curve for different habit groups were drawn on the basis of determined IVI.

The distribution pattern of the species was studied by using Whitford's Index (Whitford, 1948).

Whitford's index = Abundance (A)/ Frequency (F)

Abundance**=** No. of individuals of a species/number of quadrats of occurrence of the species

If A/F ratio <0.025:Regular distribution

0.025-0.05: Random distribution

>0.05: Contagious or clumped distribution

The species diversity was determined using Shannon-Weiner's diversity (H) and evenness (J) indices (Shannon and Weiner, 1963)

H= $-\sum [(pi)\ln (pi)]$

Pi=Number of individuals of species i (n)/ total number of individuals (N)

S=Number of species

$J = H/H_{max}$

H_{max}=Maximum possible diversity which is natural logarithm of (N)

Statistically, to check the variance among diversity at seasonal levels, Shapiro-Wilk normality tests were performed followed by non-parametric Kruskal-Wallis H test using Statistical Package for the Social Sciences (SPSS) version 23.0 (Henderson, 2009).

3. RESULT

Floristic composition

A total 78 angiosperm species belonging to 61 genera and 28 families were recorded and identified during the study of which 8 were trees, 13 shrubs, 43 herbs, 13 grasses/sedges and 1 climber (Table 1; Figures 2,3). However, few plant species were not encountered in the quadrats on account of their sparse distribution in the study site. Number of species for different vegetation groups were found to be almost constant in both the study years (2015-16: Trees-8, Shrubs-11; Herbs-34; Grasses and sedges-10, Climber-1; 2016-17: Trees-8, Shrubs-10; Herbs-31; Grasses and sedges-11, Climber-1) (Table 1). Species richness of the family Poaceae was found to be highest (d=1.029) followed by Asteraceae (d=0.999) and Amaranthaceae (d=0.713) (Figure 4).

Table 1: Plant species recorded in Tal Chhapar Wildlife Sanctuary

S. No	Genus/species	Habit	Vernacular Name	IVI	SDI	A/F
	Family-Aizoaceae					
1	*Trianthema portulacastrum*L.[1,2]	Herb	Dhedosanto	0.80	0.00019	3.466
2	*Trianthema triquetra* Rottl. andWilld.[1,2]	Herb	Lunki	1.73	0.00092	0.347
3	*Zaleya govindia* (Buch.-Ham. ex G.Don) N.C.Nair[1,2]	Herb	Bawra	0.69	0.00015	1.200
	Family- Amaranthaceae					
4	*Achyranthe saspera* L.[2]	Herb	Chirchita	0.23	0.00002	0.600
5	*Aerva persica* (Burm.f.) Merr.[1,2]	Herb	Bui	4.86	0.00722	0.106
6	*Amaranthus lividus* L.[1,2]	Herb	Shandalio	1.75	0.00094	0.492
7	*Amaranthus viridis* L.[1]	Herb		0.15	0.00001	3.600
8	*Celosia argentea* L.[1,2]	Herb	Imarti	0.80	0.00020	1.650
9	*Haloxylon salicornicum* (Moq.) Bunge ex Boiss.[1,2]	Shrub	-	6.10	0.02194	0.094
	Family- Asclepiadaceae					

10	*Calotropi sprocera* (Ait.) R. Br[1,2]	Shrub	Akaro	0.36	0.00008	0.400
11	*Leptadenia pyrotechnica* (Forssk.) Decne.[1,2]	Shrub	Khimp	0.85	0.00044	0.220
	Family- Asteraceae					
12	*Blumea* sp.[*]	Herb	-	-	-	-
13	*Echinops echinatus* Roxb.[1,2]	Herb	Unt-kantalo	0.98	0.00029	0.187
14	*Gnaphalium* sp.[*]	Herb	-	-	-	-
15	*Grangea*sp.[*]	Herb	-	-	-	-
16	*Parthenium hysterophorus* L.[2]	Herb	Chatak Chandani	0.12	0.00001	1.200
17	*Pulicaria crispa* Sch.-Bip.[1]	Herb	-	0.48	0.00007	1.333
18	*Pulicaria wightiana* (DC.) C.B.Clarke[1,2]	Herb	Sonela	0.99	0.00030	0.206
19	*Verbesina encelioides* (Cav.) Benth. andHook. f. ex A. Gray[1,2]	Herb	-	1.74	0.00092	0.337
20	*Vernonia cinerea* (L.) Less.[1,2]	Herb	Sahadevi	0.46	0.00007	1.200
21	*Xanthium strumarium* L.[1,2]	Herb	Ghaghra	0.42	0.00005	0.800
	Family- Boraginaceae					
22	*Heliotropium marifolium* Koen. ex Retz. [1,2]	Herb	Choti-santari	3.98	0.00487	0.101
23	*Heliotropium ovalifolium* Forsk.[1]	Herb	Kunden	0.19	0.00001	6.000
24	*Heliotropium* sp.[1]	Herb		0.29	0.00003	12.000
	Family- Cactaceae					
25	*Opuntia elatior* Mill.[1]	Shrub	Hatha-thor	0.11	0.00001	1.200
	Family- Capparaceae					
26	*Capparis decidua* (Forsk.)Edgew.[1,2]	Tree	Ker	6.72	0.01924	0.133
27	*Cleome gracilis* Edgew.[1,2]	Herb	-	0.96	0.00029	0.666
28	*Cleome gynandra* L.[*]	Herb	SafedBagro	-	-	-
29	*Cleome viscose* L.[1,2]	Herb	Bagro	2.58	0.00203	0.482
	Family- Chenopodiaceae					
30	*Suaeda fruticosa* (L.) Forsk.[1,2]	Shrub	Lunaki	18.19	0.17710	0.097
31	*Suaeda nudiflora* Thw.[1,2]	Shrub		1.26	0.00096	0.296
	Family- Convolvulaceae					
32	*Cressa cretica*L.[1,2]	Herb	Rudravanti	4.75	0.00689	0.184
	Family- Cucurbitaceae					
33	*Cucumis callosus* (Rottl.) Cogn.[1,2]	Climber	Kachri	0.67	0.00000	0.480
	Family- Cyperaceae					
34	*Cyperus rotundu s*L.[1,2]	Sedge	Motho	20.09	0.01762	0.232
35	*Cyperus* sp.[1,2]	Sedge	-	11.05	0.00534	0.189
	Family- Euphorbiaceae					
36	*Croton bonplandianum* Baill.[1,2]	Herb	Ban tulsi	3.76	0.00431	0.179
37	*Euphorbia prostrata* Aiton.[1,2]	Herb	-	2.05	0.00130	0.121
38	*Euphorbia* sp.[*]	Herb	-	-	-	-
	Family- Fabaceae					
39	*Crotalaria burhia* Buch-Ham.ex Benth.[1,2]	Herb	Shinio	1.69	0.00088	0.156
40	*Crotalaria medicaginae* Lamk.[*]	Herb	Gugario	-	-	-
41	*Indigofera linnaei* Ali[1,2]	Herb	Bekario	2.04	0.00127	0.672
42	*Tephrosia purpurea* (L.) Pers.[1,2]	Herb	Biyani	1.17	0.00042	1.033
43	*Prosopis juliflora* (Sw.) DC.[1,2]	Tree	Jungalikikar	4.15	0.00736	0.078
	Family- Liliaceae					
44	*Urginea indica* (Roxb.) Kunth[*]	Herb	Jungalipyaz	-	-	-

	Family- Malvaceae					
45	*Abutilon indicum* (L.) Sweet[1,2]	Shrub	Kanghi	2.11	0.00267	0.239
	Family- Meliaceae					
46	*Azadirachta indica* A. Juss.[1,2]	Tree	Neem	0.78	0.00026	0.400
	Family- Mimosaceae					
47	*Acacia jacquemontii* Benth.[*]	Shrub	Bu-banvali	-	-	-
48	*Acacia nilotica* (L.) Del.sub sp. *indica* (Benth.) Brenan[1,2]	Tree	Banwal	15.91	0.10769	0.062
49	*Acacia Senegal* (L.) Willd.[1,2]	Tree	Kumbat	1.59	0.00108	0.600
50	*Prosopis cineraria* (L.) Druce[1,2]	Tree	Khejari	11.91	0.06038	0.054
	Family- Molluginaceae					
51	*Mollugo* sp.[1,2]	Herb	-	0.27	0.00002	1.200
	Family- Nyctaginaceae					
52	*Boerhavia diffusa* L.[1,2]	Herb	Chinawari	4.99	0.00761	0.162
53	*Boerhavia elegans* Choisy[1,2]	Shrub	-	4.72	0.01337	0.098
54	*Commicarpus verticillatus* (Poir.) Standl.[1]	Herb	-	0.25	0.00002	0.900
	Family- Papaveraceae					
55	*Argemone Mexicana* L.[1,2]	Herb	Satayanasi	1.25	0.00049	0.168
	Family- Poaceae					
56	*Cenchrus biflorus* Roxb.[1,2]	Grass	Bhurat	3.57	0.00056	0.419
57	*Cenchrus ciliaris* L.[1,2]	Grass	Dhaman	7.40	0.00240	0.446
58	*Chloris* sp. [1,2]	Grass	-	10.58	0.00489	0.606
59	*Dactyloctenium sindicum* Boiss.[*]	Grass	Tantia	-	-	-
60	*Desmostachya bipinnata* (L.) Stapf.[1,2]	Grass	Dab	25.12	0.02755	0.508
61	*Dichanthium annulatum* (Forssk.) Stapf.[1,2]	Grass	Karad	35.97	0.05651	0.128
62	*Digitaria* sp.[1,2]	Grass	-	2.25	0.00022	0.369
63	*Eragrostis* sp.[1, 2]	Grass	-	2.89	0.00037	0.716
64	*Lasiurus scindicus* Henrard[1,2]	Grass	Sevan	29.58	0.03822	0.359
65	*Sporobolus marginatus* Hochst. ex A. Rich.[2]	Grass	-	2.79	0.00034	1.451
66	*Sporobolus* sp.[*]	Grass	-	-	-	-
	Family- Portulacaceae					
67	*Portulaca pilosa* L.[1, 2]	Herb	-	0.94	0.00027	0.633
	Family- Rhamnaceae					
68	*Ziziphus nummularia* (Burm. f.) Wight. and Arn.[1,2]	Shrub	Borti	4.51	0.01064	0.060
	Family- Salvadoraceae					
69	*Salvadora persica* L.[1,2]	Tree	Pilu	6.40	0.01744	0.171
	Family- Solanaceae					
70	*Datura* sp.[1,2]	Herb	-	0.60	0.00011	0.288
71	*Lyciumbarbarum* L.[1,2]	Shrub	Morali	1.06	0.00067	0.243
72	*Solanum surattense* Burm. f.[1,2]	Herb	Bhurhingani	0.86	0.00023	0.195
	Family- Tamaricaceae					
73	*Tamarix* sp.[*]	Tree	-	-	-	-
	Family- Tiliaceae					
74	*Corchorus depressus* (Linn.) Stocks[1,2]	Herb	Cham-gash	5.49	0.00919	0.105
75	*Corchorus tridens* L[1,2]	Herb	Kagnasha	0.90	0.00025	0.566
	Family- Zygophyllaceae					
76	*Balanites roxburghii* Planch[1,2]	Tree	Ingoriyo	0.99	0.00042	0.150

77	*Fagonia schweinfurthii* Hadidi[1,2]	Shrub	Dhamaso	2.89	0.00504	0.077
78	*Tribulus terrestris* L.[1,2]	Herb	Kanti	1.89	0.00107	1.050

Note: *species documented outside the quadrat, [1]species documented in 2015-16, [2]species documented in 2016-17.

Figure 2. Selected flora of TDS (Trees, shrubs and herbs): A (Tree): *Acacia nilotica* subsp *indica*; B-E (Shrubs): *Boerhavia elegans* (B), *Opuntia elatior* (C); *Suaeda fruticosa* (D), *Suaeda nudiflora* (E); F-L (Herbs): *Boerhavia diffusa* (F), *Cleome gracilis* (G), *Cleome gynandra* (H), *Cleome viscosa* (I), *Corchorus depressus* (J), *Corchorus tridens* (K), *Euphorbia prostrata* (L).

Figure 3. Selected flora of TDS (Herbs and grasses/sedges): A-G (Herbs): *Parthenium hysterophorus*(A); *Portulaca pilosa*(B), *Pulicaria wightiana* (C); *Solanum surattense* (D), *Trianthema portulacastrum*(E), *Trianthema triquetra*(F), *Tribullus terrestris*(G); H-L (Grasses/ sedges): *Cenchrus biflorus* (H), *Cyperus rotundus* (I), *Dactyloctenium sindicum* (J), *Dichanthium annulatum*(K), *Sporobolus marginatus* (L).

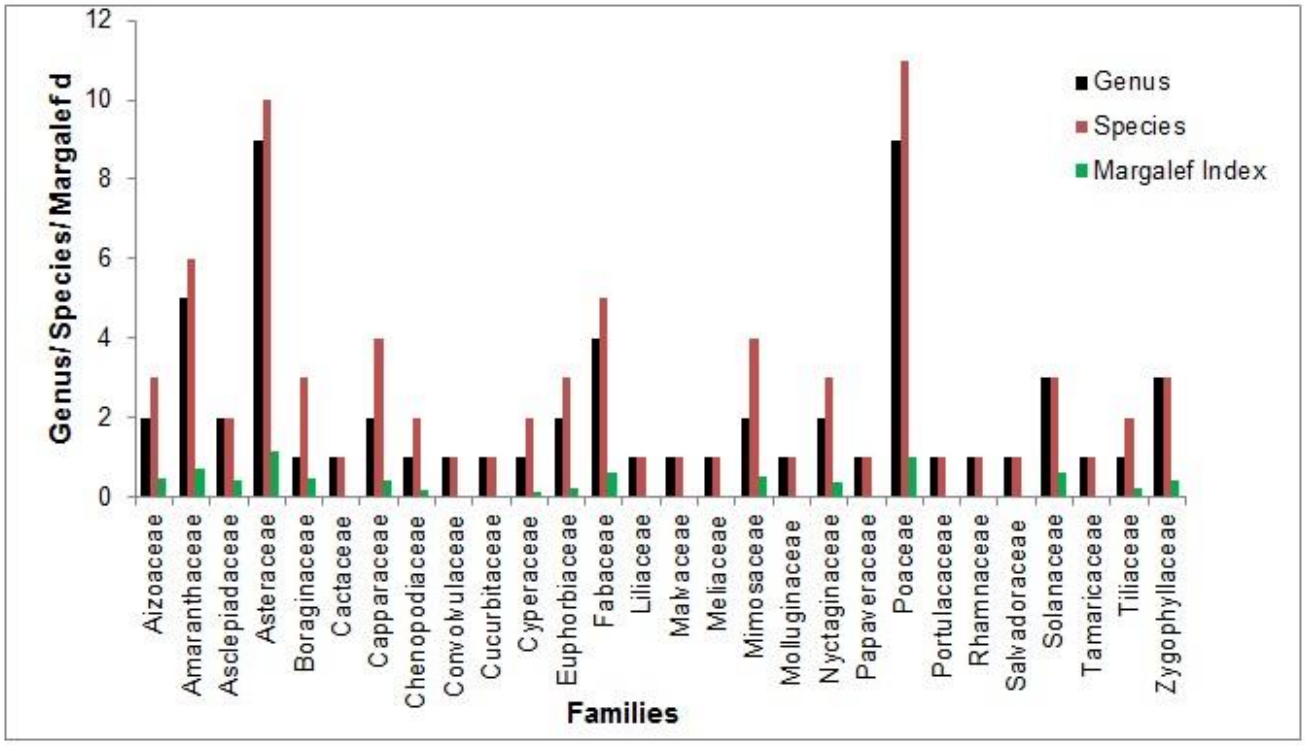

Figure 4. Floristic composition in TWS

Dominance pattern

Among trees *Acacia nilotica* subsp. *Indica* (IVI -15.91; SDI-0.10769) was found to be the most dominant species followed by *Prosopis cineraria* (IVI-11.91; SDI-0.06038) and *Capparis decidua* (IVI-6.72;SDI-0.01924), whereas *Azadirachta indica* (IVI-0.78; SDI-0.00026) was the least dominant species followed by *Balanites roxburghii* (IVI-0.99; SDI-0.00042). Among shrubs, *Suaeda fruticosa* (IVI-17.10; SDI-0.17710) was the most dominant species followed by *Haloxylon salicornicum* (IVI-6.01; SDI-0.02194) and *Boerhavia elegans* (IVI-4.69; SDI-0.01337), whereas *Opuntia elatior* (IVI-0.11; SDI-0.00001) was the least dominant species followed by *Calotropis procera* (IVI-0.35; SDI-0.00008). Among herbs, *Corchorus depressus* (IVI-5.45; SDI-0.00919) was the most dominant species followed by *Boerhavia diffusa* (IVI-4.96; SDI-0.00761) and *Aerva persica* (IVI-4.83; SDI-0.00722), whereas *Parthenium hysterophorus* (IVI-0.12; SDI-0.00001) was the least dominant species followed by *Amaranthus*

viridis (IVI-0.15; SDI-0.00001). Among grasses and sedges, *Dichanthium annulatum* (IVI-35.97; SDI-0.05651) was the most dominant species followed by *Lasiurus scindicus* (IVI-29.58; SDI-0.03822) and *Desmostachya bipinnata* (IVI-25.12; SDI-0.02755), whereas *Digitaria* sp. (IVI-2.25; SDI-0.00022) was the least dominant species followed by *Sporobolus marginatus* (IVI-2.79; SDI-0.00034) (Table 1).

The dominance diversity curves showed a log normal series distribution for trees, herbs and grasses/sedges whereas shrubs followed a geometric series during the study period (Figure 5).

Species diversity

Maximum species diversity (H) was recorded during monsoon followed by post-monsoon and summer, though evenness (J) was found to be almost similar across all the seasons (Figure 6). Also to validate whether seasonality effects the plant species composition, the data was checked for its normal distribution using Shapiro-Wilk test. The result showed the data was not normally distributed as the p-value <0.05. Therefore difference in plant composition or abundance between different seasons was tested using Kruskal-Wallis non-parametric H test, whereby seasons were treated as an independent variable and plant species abundance as a dependent variable. The test showed that there was a statistically significant difference in plant species abundance between different seasons (χ^2 =10.36, df=2, p=0.006, α=0.05 level of significance).

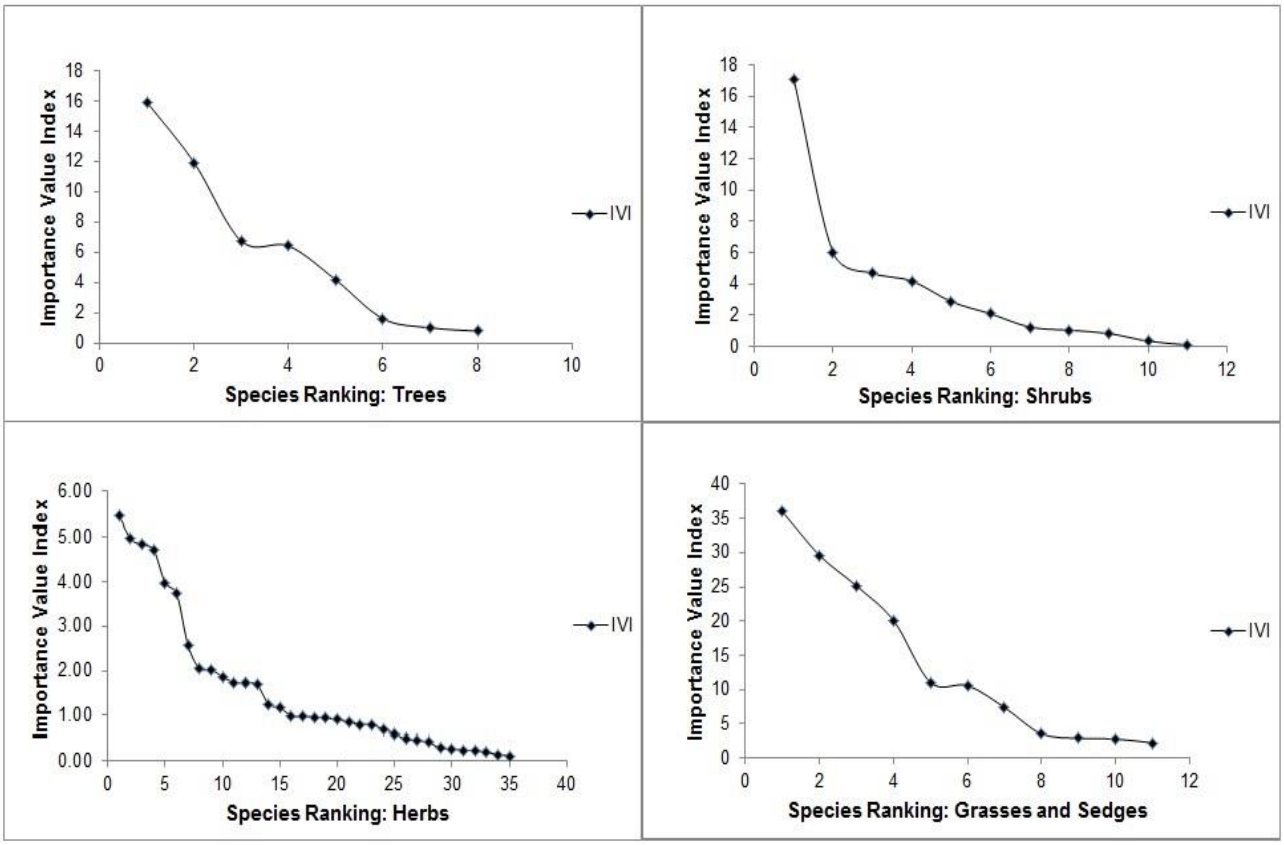

Figure 5. Dominance diversity (DD) curves of plant species

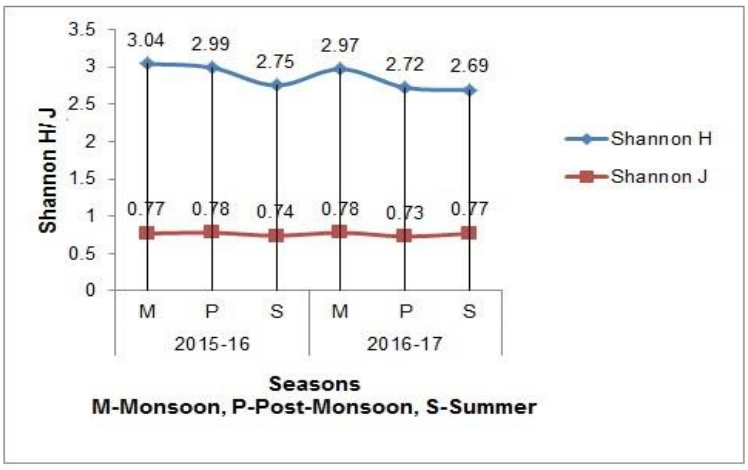

Figure 6. Seasons vs. Shannon-Weiner species diversity (H) and evenness (J) indices

Distribution pattern

The ratio of abundance to frequency (A/F) revealed that in the study area regular distribution of plants was totally absent and most of the species were contagiously distributed in the area. Shrubs, herbs and grasses/sedges showed 100% contagious distribution, whereas 12.5% tree species showed random distribution and the rest tree species (87.5%) showed contagious distribution (Table 2, Figure 7).

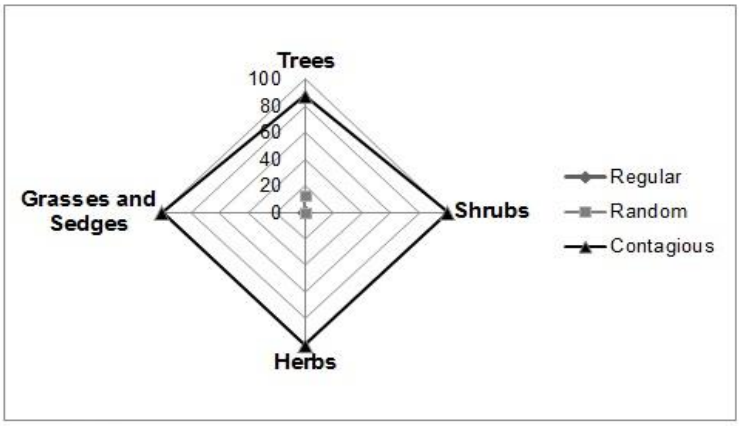

Figure 7. Distribution pattern of vegetation

Table 2. Distribution pattern of vegetation

Distribution Type	% Vegetation
Trees	
Regular	0
Random	12.5
Contagious	87.5
Shrubs	
Regular	0
Random	0
Contagious	100
Herbs	
Regular	0
Random	0
Contagious	100
Grasses and Sedges	
Regular	0
Random	0
Contagious	100

4. DISCUSSION

According to Timilsina et al. (2007), an ecosystem is defined by three main attributes i.e. structure, composition and function and the most important component of any ecosystem is the species it contains. In the past, Das et al. (2013) and Ojha (2016) have been enlisted 15 plant species from the study site. In the present study 78 plant species were documented from the area and the vegetation was found to be well represented by diverse groups of plants (Table 1, Figures 2-4). Though the findings are quite encouraging, two species viz. *Portulaca quadrifida* and *Portulaca oleracea* documented by Das et al. (2013) and Ojha (2016) from the area were not recorded in the present study and subjected to further investigation.

In the area maximum species richness was observed for grass family Poaceae followed by herbs Asteraceae and Amaranthaceae (Figure 4). The dominance of grasses can be explained by the fact that the area consists of largely of perennial grasses, as similar pattern of dominance was recorded by Astapati and Das (2012) and Shilla and Tiwari (2015) in grasslands of northeast India.

Importance value index and Simpson dominance index are commonly used in vegetation studies as they indicate ecological importance of a species in a given ecosystem. Higher these values, greater is the ecological success and power of regeneration of a species (Shameem et al., 2017). In this study, the grass *Dichanthium annulatum* was found to be the most dominant species followed by *Lasiurus scindicus* and *Desmostachya bipinnata* and they were associated with trees, shrubs and herbs (Table 1). Hence, the area represents a saline grassland of *Dichanthium-Lasiurus* type that comes under one of the five grassland types of India found in arid and semi-arid parts of India (Dhadabgao and Sankarnarayan, 1973). However, the finding is not in accordance with vegetation mapping of Rajasthan by Reddy et al. (2011) who have identified seven grassland communities in Rajasthan using multi-season

satellite data, but the species composition of the study area doesn't match with any of them. Hence, vegetation classification given by Reddy et al. (2011) is subjected to further research.

Dominance of different species in relation to the availability of suitable niche and resource apportionment in a community has often been interpreted from dominance diversity (D-D) curves (Whittaker, 1972; Nautiyal et al., 2000). In this study, the D-D curves approached a log normal series distribution for trees, herbs and grasses/sedges (Figure 5). Log normal distribution gives the best distribution of species-abundant pattern (Preston, 1948) as this pattern may be expected with large or heterogeneous assemblage of species in which there is more or less an even allocation of resources among the members of the important species (May, 1975).The shrub layer followed the geometric series (Figure 5) that shows uneven allocation of resources among the members of the species (Heip et al., 1998).

In community structure, species diversity is always considered to be an important attribute as it is often related to population dynamics and competition (Palit and Banerjee, 2013). In this study, peak diversity was observed during monsoon and least in summer (Figure 6). This is because after first few monsoon showers, new species goes on sprouting depending upon the root/seed stock in the soil and thereby adding species that results in more diversity. In the late post-monsoon and pre-monsoon/summer, the rate of sprouting of root/seed stock lowers that declines the species number due to adverse climatic conditions. Statistical analysis also revealed seasonality plays a significant role for variation in species abundance. The result is in accordance with similar findings by Joshi et al. (1994), Kumar et al. (2004), Tripathi and Shukla (2007), Ratan et al. (2011), Astapati and Das (2012) and Shilla and Tiwari (2015). However, almost similar evenness across all seasons revealed that the plant community in the study area is close in number of individuals for each species across the seasons which may be due to small size of the overall study area.

The distribution of species in a community is measured by the ratio of abundance to frequency (A/F). The patterns of plant distribution entirely depend on the physicochemical natures of the environment as well as on the reproductive biology the organisms themselves (Mandal and Joshi, 2014). In this study, A/F ratio showed the absence of regular distribution of species as most of the species were contagiously distributed (Table 2, Figure 7). Shrubs, herbs and grasses/sedges showed 100% contagious distribution, also most tree species showed contagious distribution (87.5%) and only few showed random distribution (12.5%). The result is in accordance with findings by other workers like Singh and Yadava, (1974), Joshi and Tiwari (1990), Pande et al. (1996) and Kukshal et al. (2009) in grasslands and other grazing ecosystems. According to Singh and Yadava (1974) grasslands displaying the dominance of aggregation are due to tussock forms of grasses. The study area being part of desert ecosystem characterized by harsh environmental conditions, the findings are in according with Odum (1971) who revealed contagious distribution is common in nature and formed as a result of small but significant variations in the ambient environmental conditions and random distributions prevails in very uniform environments where severe competition exists between individuals.

Study on grasslands is highly neglected in India and in recent years with the introduction of India Gandhi Nahar (Canal) Project (IGNP) in the Thar desert of Rajasthan, the floral diversity in this region is facing high anthropogenic pressure (Khan and Frost, 2001; Islam and Rahmani, 2011). The overall findings of the present study are highly encouraging as it deals with grassland ecosystem within one Protected Area of this region and hence, of conservation importance.

5. CONCLUSION

The present study brings into knowledge a detailed about plant community structure and dynamics of TWS. In absence of any prior study to properly document or record the plant species of the area, this study will be very helpful to provide baseline information about the plants in this Protected Area. The study also reveals much about phytosociology of desert grassland ecosystem that will be no doubt helpful in further research on grasslands.

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Authors' contributions

The first author (MK) along with third (KS) and fourth authors (SKD) have designed the study. MK has carried out the field data collection; also analyzed the data and prepared the manuscript along with SKD. MK has identified the plants with the help from second author (PK).

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Conflict of Interest

The authors declare that there are no conflicts of interests.

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