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Phytosociological Analysis and Species Diversity of Herbaceous Layer in Rashad and Alabassia Localities, South Kordofan State, Sudan

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Abstract

The objective of the present study is to analyze the phytosociological characteristics and the diversity patterns of herbaceous plants in Rashad and Alabassia localities. The study was conducted in selected 14 vegetation sites. Important Value Index (IVI) was used to estimate the phytosociological characteristics, the Shannon index to measure the plant diversity and the Pielou index for species evenness. During the study period, a total of 48 species, representing 42 genera from 20 families, were recorded. The phytosociological characteristics revealed that *Tetrapogon cenchriformis* dominated herbaceous species in sites 1, 7, 10, 11 with IVI values 139.3, 113, 70.3 and 95.8, respectively, followed by *Spermacoce pusilla* dominating sites 3, 4, 5 and 6 with IVI values 65.1, 50.4, 104.2 and 133.5, respectively. The distribution pattern revealed that 87.5% species showed aggregated distribution, while 12.5% were randomly distributed. The highest density was 110 plants/m^2 recorded in site 4. Species richness varied through different sites; the highest number of species was 19, recorded in site 2. The highest values of Shannon diversity index and evenness index were in site 12. The highest similarity was recorded between site 9 and site 10 (73.39%) and the lowest (41.83%) between site 1 and site 3. The herbaceous flora of the area indicated its importance as one of the productive range region.

Keywords: Importance Value Index, Aggregation, Species Richness, Species Evenness.

1. Introduction

Phytosociology deals with plant communities, their composition and development, and the relationship between the species within them. A phytosociological system is a system for classifying these communities. The aim of phytosociology is to achieve a coefficient empirical model of vegetation using plant taxa combination that characterizes vegetation units. Phytosociology is useful to describe the population dynamics of each plant species occurring in a particular community and to understand how they relate to the other species in the same community (Mishra *et al.*, 2012). The herbaceous layer composition is changing continuously in space and time due to a multitude of factors, such as grazing, fire, and rainfall which differs in intensity and duration (Shameem, *et al.*, 2010). Maintaining or increasing the plant species diversity is an important goal of habitat managers in semi-arid environments (West, 1993; Fulbright, 1996).

Species diversity is an important property of communities because it is often related to their functioning and potential for change (Stachowicz *et al.*, 2007; Gamfeldt and Hillebrand, 2008). Diversity is a measure of how likely two randomly selected individuals in a community belong to different species. Thus, diversity is affected by two other properties of communities: richness, and evenness (Magurran, 1988; Krebs, 1999). Species richness is a biologically appropriate measure of alpha (α) diversity and is usually expressed as the number of species per sample unit (Whittaker, 1972). Evenness is the degree of similarity in abundance among the species (Krebs, 1999).

The study is carried out in Rashad and Alabassia localities, South Kordofan State, Sudan, which is part of the regions involved in the civil war in the country (The Nuba Mountains).The study area is characterized by a high diversification in vegetation cover components. According to Harrison and Jackson (1958), the vegetation of the area was classified as a low rainfall woodland savanna on clay and as special areas of the low rainfall wood land savanna under Hill catena's are divided into five zones, namely the rocky summit, the rocky steep slopes, the hard surfaced soils at the food of the steep slopes, a dark cracking clay plain surrounding the hill and the seasonal watercourses. Topography plays an important role in the formation of the soils of the study area. Soils

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suitable for cultivation of the basic food staples of the area are limited. They are divided broadly by local people into the HADABA which are fertile cracking clay soils of the plains (vertsol), GARDUD the sandy/clay pediment or transitional soils found at the foot of the mountains, KARKAR the rocky soils found in the mountains (Entisol or nonsol) which are shallow and confined to the mountainous areas, and Loamy alluvial soil deposits which are limited to seasonal streams and valleys (Harragin, 2003).

The Nuba Mountains are inhabited by more than 50 tribes composed of Nuba as well as a minority of cattle-raising Arabs (WFP, 2001). Agriculture is the main activity and is practiced by all the population. Nevertheless, its contribution to household food needs is declining (UNDP, 2003). The main crops cultivated are sorghum, maize, sesame, groundnuts, cowpeas and fruit trees (WFP, 2001). Nomadic pastoralism, ranking as the second major activity after agriculture in the area, is practiced by two nomad groups: the Baggara (cattle raisers) and the Abbala (camel raisers) (Bashir and El Tahir, 2006).

The aim of the present investigation is to analyze the phytosociological characteristics and the diversity pattern of the herbaceous plants of the area. The present study sheds light on the importance of the study area as one of the main pastoral resource in Sudan.

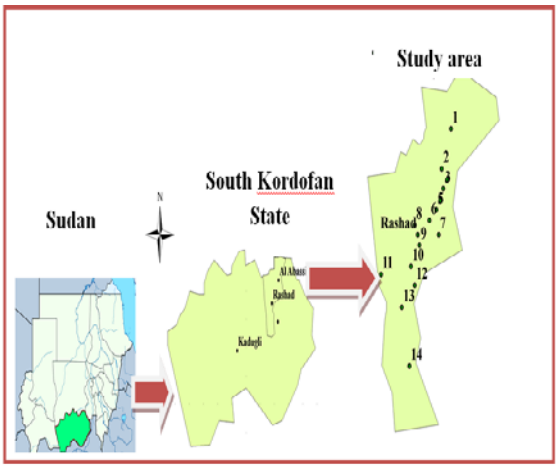
2. Materials and Methods

A field study was conducted in Rashad and Alabassia localities in the northern part of eastern Nuba Mountains of South Kordofan State extending from latitude 11° 33` to 12° 33` N and from longitude 31°08` to 31° 18` E (Map 1). The rainy season extends from mid-May to mid-October, with an annual rainfall ranging from 400 to 800 mm, allowing grazing and seasonal rain-fed agriculture (Starbase, 2003).

The study was conducted during the period from Oct. 2010 – Nov. 2011, covering both dry and wet seasons. 14 vegetation sites were selected (Map 1) on the basis of physiognomy, exposure and altitude representing vegetation variation (Table 1). The enumeration was carried out in 280 quadrate 50×50cm dimensions

In order to assess the dominance of species in the vegetation communities, density, frequency and abundance were converted to relative values and summed to obtain importance value index (IVI) following Dangoli and Shivakoti (2001) and Chaudhry *et al.* (2006). The species distribution profile was measured using Bio-Diversity Pro software (McAleece *et al.*, 1997). Species richness was determined as the total number of species present in the studied site; species diversity was measured using Shannon diversity index (H) after Shannon and Weaver (1963). Pielou index was used for the estimation of species evenness (E) after Pielou (1966).

Bray-Curtis (CN, quantitative version of Sorensen index) index was used to determine the degree of similarity in the species composition between the different sites (Magurran, 2004). The similarity dendrograms obtained from the results of cluster analysis were plotted. Data were analyzed using the program BioDiversity Pro (Version 2) (McAleece *et al*., 1997).



Map (1). study area

Table 1. Characteristic feature of the studied sites

Site	Location	Latitude N	Longitude E	Altitude M	Soil Type
1	Um Fakareen	12° 33` N	31° 18` E	500 m	Cracking clay
2	J. Damra	12° 10` N	31° 15` E	739 m	Rocky soil
3	Elmigreh	12° 02` N	31° 14` E	826 m	Rocky soil
4	J. Elmigreh	12° 00` N	31° 13` E	885 m	Rocky soil
5	Sug-Eljabal	11° 57` N	31° 12` E	914 m	Rocky soil
6	Elawai North Rashad	11° 52` N	31° 08` E	849 m	Rocky soil
7	Tabaldia	11° 50` N	31° 09` E	860 m	Rocky soil
8	Rashad Dam	11° 52` N	31° 02` E	894 m	Rocky soil
9	J. Rashad	11° 49` N	31° 03` E	852 m	Rocky soil
10	South Rashad	11° 45` N	31° 02` E	781 m	Rocky soil
11	Um Abdalla	11° 45` N	30° 52` E	664 m	*GARDUD* soil
12	Awai South Rashad	11° 43` N	31°03` E	723 m	Rocky soil
13	Tandek	11° 42` N	31°02` E	695 m	Cracking clay
14	Dibekkir	11° 33` N	31°08` E	618 m	Cracking clay

3. Results

A total of 48 species, representing 42 genera from 19 families, were recorded from the studied quadrates. Poaceae was the dominant family with 13 species, followed by Leguminosae (6), Malvaceae (4), Convolvulaceae and Euphorbiaceae (3 species each), Acanthaceae, Amaranthaceae, Lamiaceae, Solanaceae and Cyperaceae (2 species each), while the other 9 families were represented by only one species (Table 2). The herbaceous plants in the study area included 45 annuals and 3 perennials; most of them are economically important: 28 are fodder plants, 19 species are known to be used for medicinal purposes, 5 species are edible as

human food, while *Striga hermonthica* (Del.) Benth. parasitised the cultivated *Sorghum* spp.

Natural vegetation in a certain area reflects the interaction among plants, animals, soil types and the different climatic factors. The dominance of species was assigned based on the calculated IVI values. *Tetrapogon cenchriformis* was the dominant species in the studied sites with IVI 139.3 in site 1. It also dominated sites 7, 10 and 11 in different soil types with IVI values 113, 70.3 and 95.8, respectively. Its dominance at the specific sites indicated the availability of optimum conditions for its growth and ecological success. *Spermacoce pusilla* dominated sites 3, 4, 5 and 6 in rocky soil with IVI values 65.1, 50.4, 104.2 and 133.5, respectively. *Brachiaria xantholeuca* dominated sites 8 and 13 with IVI values 57.15 and 58.5, respectively. *Pennisetum pedicellatum* dominated site 2 and site 12 with IVI values 49.1 and 38.5, respectively, while *Setaria pumila* dominated site 14 with IVI 65.3 and *Zornia glochidiata* dominated site 9 with IVI 84.9. The aggregation (the distribution pattern) of plant species, in different habitats, was assessed; results revealed that 12.5% were randomly distributed and 85.5% were aggregated. (Table 2).

Figure 1 shows the different phytosociological parameters. The highest density of herbaceous plants was recorded in site 4 at 885 m a.s.l. (110 plants /m^2), followed by site 5, while site 13 at 695 m a.s.l. showed the lowest density (36 plant /m^2). The composition among the different sites in terms of species richness showed that the highest species diversity was observed in sites 1, 2, 4 and 12, sharing the same number of species (18); site 8 contained 16 species; sites 3, 6, and 11 contained 13 species; sites 7, 10 and 14 contained 12 species; sites 5 and 13 each contained 11 species, while the lowest species richness was 9 species recorded in site 9. The highest Shannon diversity index was 2.45 in site 12, followed by 2.19 in site 8, whereas the least Shannon diversity index was 1.21 in site 6. The highest species evenness index was recorded in site 12 (1.94), whereas the least evenness index was 1.09 in site 6.

The highest similarity (73.39%) was recorded between Jebel Rashad (site 9) at 852 m a.s.l and South Rashad (site 10) at 781 m a.s.l. On the other hand, Um Fakareen (site 1) at 500m. a.s.l. in clay plain m a.s.l and Elmigreh (site 3) 826 m. a.s.l. in rocky soil showed the least similarity (41.83%) (Figure 2).

Table 2. Importance value index (IVI) and distribution pattern of plant species

plant species			Values of Importance value index (IVI)														Aggregation
	Life cycle	Economic importance	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12	Site 13	Site 14	(distribution pattern)
Poaceae																	
Aristida hordeacea Kunth.	Ann.	Fd	85.1	-	-	-	41.1	20.74	-	-	-	-	-	-	6.22	-	Aggregated
Aristida mutabilis Trin. & Rupr.	Ann.	Fd	-	-	-	22.8	13.6	20.74	-	13.92	6.05	7.39	12.49	-	-	-	Aggregated
Brachiaria xantholeuca (Schinz) Stapf.	Ann.	Fd	59.01	42.0	-	42.9	10.7	20.67	-	57.15	10.5	6.36	24.09	-	58.5	-	Aggregated
Chloris pilosa Schumach. & Thonn.	Ann.	Fd	-	-	-	8.39	6.61	-	-	-	-	-	-	-	33.5	-	Aggregated
Cymbopogon nervatus (Hochst.) Chiov.	Ann.	Fd	-	-	-	-	16.7	-	-	-	-	-	-	-	-	-	Aggregated
Dactyloctenium aegyptium (L.) Willd.	Ann.	Fd	22.08	13.7	-	11.42	7.74	-	15.4	19.48	38.8	45.1	22	32.7	19.02	-	Aggregated
Echinochloa rotundiflora Clayton.	Ann.	Fd	-	-	-	4.66	-	-	-	-	-	-	-	-	-	9.18	Aggregated
Hyparrhenia confinis var. *nudiglumis* (Hack.) Clayton	Ann.	Fd	-	-	-	20.4	-	-	-	30.1	-	-	-	-	-	-	Random
Microchloa indica (L.f.) P.Beauv.,	Ann.	Fd	-	-	-	27.6	-	22.37	33.1	38.8	39.1	-	-	16.6	-	-	Aggregated
Pennisetum pedicellatum Trin.	Ann.	Fd	43.5	49.1	19.2	20.1	6.87	-	-	36.96	15.97	17	5.73	38.5	-	8.69	Aggregated
Setaria pumila (Poir.) Roem. & Schult.	Ann.	Fd	24.2	-	-	4.27	-	-	-	8.5	-	-	5.84	6.8	9.09	65.3	Aggregated
Tetrapogon cenchriformis (A. Rich.)W. D. Clyton.	Ann.	Fd	139.3	30.02	24.5	42.7	57.7	19.22	113	19.5	60.1	70.3	95.8	28.9	55.2	34.3	Aggregated
Tetrapogon tenellus (Roxb.) Chiov.	Ann.	Fd	8.87	-	-	-	-	-	-	-	-	-	-	-	-	-	Aggregated

Leguminosae																	
Alysicarpus glumaceus (Vahl) DC.	Ann.	Fd	-	-	-	-	-	-	-	19.14	25.1	28	18.24	-	-	-	Random
Indigofera hochstetteri Baker	Ann.	Fd	-	26.3	12.1	4.66	13.6	10.62	15.4	8.9	-	8.25	53.27	15.5	-	7.2	Aggregated
Indigofera nummulariifolia (L.) Livera	Ann.	Fd	-	-	-	-	-	13.14	-	-	-	-	-	-	-	-	Aggregated
Indigofera spicata Forssk.	Per.	Fd	-	3.52	-	-	-	-	-	5.91	-	-	27.64	-	-	-	Random
Senna obtusifolia (L.) H.S.Irwin & Barneby	Ann.	E	14.3	8.69	57.03	-	-	-	4.84	3.14	-	4.47	3.77	13.4	6.22	5.16	Aggregated
Zornia glochidiata DC.	Ann.	Fd	-	16.7	25.5	7.08	16.1	45.99	28.3	14.5	84.9	53.4	21.57	12.4	-	-	Aggregated
Malvaceae																	
Corchorus tridens L.	Ann.	E	25.6	-	-	-	-	20.74	4.84	-	-	-	-	-	-	-	Aggregated
Triumfetta pentandra J.M. Garg	Ann.	Fd ,E, M	-	6.96	-	-	-	-	-	-	-	-	-	30.3	-	44.8	Aggregated
Hibiscus diversifolius Jacq.		Fb, M	-	3.52	-	-	-	-	-	-	-	-	-	-	-	-	Random
Sida alba L.	Per.	M	7.67	-	7.61	4.66	-	-	-	3.14	-	-	-	31.9	6.22	39.96	Aggregated
Convolvulaceae																	
Astripomoea lachnosperma (Choisy) A. Meeuse	Ann.	M	-	22.18	-	-	-	-	-	-	-	-	-	-	-	-	Aggregated
Ipomoea cordofana Choisy.	Ann.	Fd	-	-	-	-	-	-	-	-	-	-	-	-	-	11.2	Aggregated
Ipomoea sinensis (Desr.) Choisy.	Ann.	Fd	-	-	-	-	-	-	-	-	-	-	5.84	-	-	-	Aggregated
Euphorbiaceae																	
Acalypha indica L.	Ann.	M	22.6	-	-	-	-	-	-	-	-	-	-	-	-	-	Aggregated
Dalechampia scandens L. var. *cordofana* (Webb) Müll	Ann.	Fd	-	5.24	-	-	-	-	-	-	-	-	-	-	-	-	Random
Euphorbia hirta L.	Ann.	M	8.87	-	10.6	2.9	-	-	8.01	8.99	-	-	-	5.44	-	-	Aggregated
Acanthaceae																	
Blepharis linariifolia Pers.	Ann.	Fd	7.67	-	-	-	-	-	-	-	-	-	-	-	-	-	Aggregated
Peristrophe paniculata (Forssk.) Brum.	Ann.	M, Fd	-	-	8.65	-	-	20.74	-	-	-	-	-	-	-	-	Aggregated
Amaranthaceae																	
Amaranthus hybridus L.	Ann.	Fd	33.7	-	49.8	-	-	-	-	-	-	-	-	-	-	8.69	Random
Achyranthes aspera L.	Ann.	M	-	3.52	-	-	-	-	-	-	-	-	-	-	-	-	Aggregated
Lamiaceae																	
Leucas martinicensis R. Br.	Ann.	M	-	-	5.53	5.65	-	-	-	-	-	-	-	5.4	-	-	Aggregated
Ocimum americanum L.	Ann.	M	12.7	-	-	-	-	-	-	-	-		-	8.3	-	-	Aggregated
Solanaceae																	
Physalis peruviana L.	Ann.	M	-	-	9.01	-	-	-	-	-	-	-	-	-	-	-	Aggregated
Solanum incanum L.	Per.	M	25.6	-	5.43	8.29	-	-	-	-	-	-	-	5.99	-	-	Aggregated
Cyperaceae																	
Cyperus amabilis L.	Ann.	M	-	-	-	-	-	-	-	11.91	-	-	-	-	-	-	Aggregated
Cyperus rotundus L.	Ann.	M	-	-	-	-	-	-	2.97	-	-	-	-	-	-	-	Aggregated
Rubiaceae																	
Spermacoce pusilla Wall.	Ann.	M	21.7	11.5	65.1	50.4	104.2	133.5	76.9	-	19.16	44.0	-	14.9	43.7	60.4	Aggregated
Asteraceae																	
Acanthospermum hispidum DC.	Ann.	M		47.6	-	-	-	20.74	12.9	-	-	-	3.77	23.3	-	-	Aggregated
Nyctaginaceae																	
Boerhavia erecta L.	Ann.	Fd	-	-	-	-	-	12.53	-	-	-	11.3	-	-	-	-	Aggregated
Cleomaceae																	
Cleome gynandra L.	Ann.	E	-	5.68	-	-	-	-	-	-	-	-	-	5.99	-	-	Aggregated

Aristolochiaceae																		
Aristolochia bracteolata Lam.	Ann.	M	7.76	-	-	-	-	-	-	-	-	-	-	-	-	-	Aggregated
Commelinaceae																		
Commelina imberbis Ehrenb. ex Hassk.	Ann.	Fd	-	12.1	-	-	-	-	-	-	-	-	-	3.68	-	-	Aggregated
Cucurbitaceae																		
Cucumis prophetarum L.	Ann.	M	-	3.52		-	-	-	-	-	-	-	-	-	-	5.16	Aggregated
Araceae																		
Stylochaeton hypogaeus Lepr	Ann.	M,E	-	-	-	11.1	-	-	14.3	-	-	4.5	-	-	6.22	-	Aggregated
Scrophulariaceae																		
Striga hermonthica (Del.) Benth.	Ann.	(Parasitic)	-	-	-	-	-	-	-	-	-	-	-	-	10.1	-	Aggregated

Ann.= annual, per.=perennial, M= medicinal, Fd= fodder, E= edible

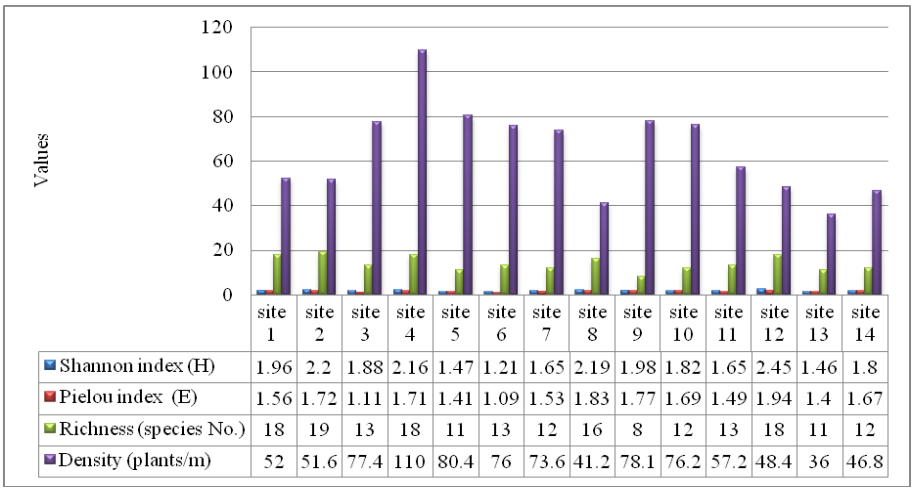


Figure 1. Species richness, diversity indices and density of herbaceous layer.

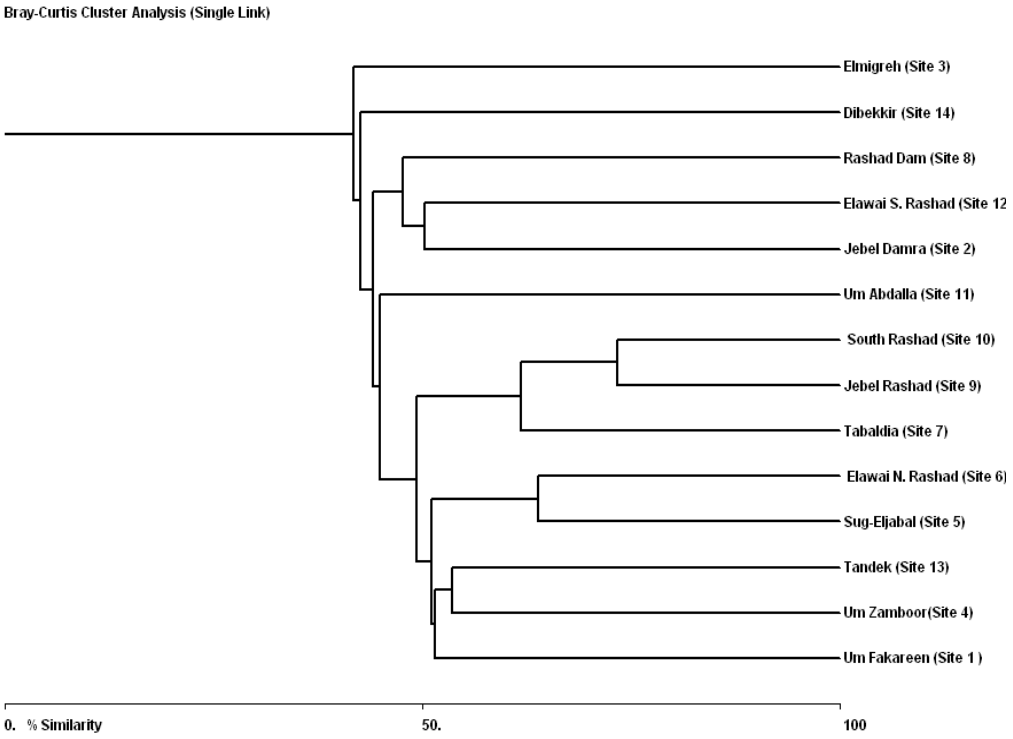


Figure 2. Similarity between different sites of study area, using Bray-Curtis (CN, quantitative version of Sorensen index) index

4. Discussion

According to Bhandari *et al.* (1999), any species in a community plays a specific role and there is a definite quantitative relationship between abundant and rare species. The differences in IVI may be due to the changes in the surrounding conditions and the anthropogenic activities around the sites. The dominance of *Pennisetum pedicellatum* in site 2 is in agreement with Harrison and Jackson (1958) who reported its presence in the rocky steep slopes and the seasonal watercourses. Most of the dominant species in the studied sites are members of the Poaceae family which is known for producing a large number of seeds for sexual reproduction and possessing different means for vegetative reproduction. The dominance of *Tetrapogon cenchriformis* and *Spermacoce pusilla* may be attributed to the fact that these two species are important fodder plants in the study area located in one of the important pastoralist routes in Sudan, which facilitates the dispersal of their seeds; grazing is known to activate the vegetative buds and increase the growth of some range plants, especially grasses.

Aggregation of plant species results (12.5% randomly distributed and 85.5% aggregated) indicate the suitability of these habitats for the aggregated species. The results are in line with Das *et al.* (2012) who stated that the aggregated distribution indicated the habitat preference, while the random distribution indicates that the environment in which these plant species grow is homogeneous and has many factors acting on the population (Ewusie, 1980).

According to Wilsey and Stirling (2007), richness and evenness can be negatively related across the plant communities, and evenness can account for more variation in Shannon's diversity index (H) than richness, which suggests that relationships among the diversity components can be complex. Generally, a strong correlation between species richness, evenness and productivity was not evident in the present study. The differences in the phytosociological parameters may be attributed to different biotic and/or abiotic factors other than soil and elevation.

The highest similarity (73.39%), recorded between site 9 and site 10, may be attributed to the fact that the two sites were characterized by similar soils and relatively close elevations. Site 1 in clay plain and site 3 in rocky soil showed the least similarity (41.83%), this may be due to the differences between the two sites in terms of elevations and soil types.

5. Conclusions

The herbaceous cover diversity of the studied sites was represented by 48 plant species belonging to 41 genera under 19 families. While the dominant family Poaceae is represented with 13 species, 9 families are monotypic. *Tetrapogon cenchriformis* showed the maximum IVI values at 4 sites and also *Spermacoce pusilla* dominated 4 sites. The number of species in the studied sites was in the range of 8-19 and most of them can be considered as fodder plants, which indicated that the area is productive.

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