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Research Article

CURRENT STATUS OF PLANT SPECIES DIVERSITY AND CHANGE IN SPECIES COMPOSITION AT SELECTED COMMUNAL LANDS WITHIN THE SEMI-ARID ZONE OF SUDAN

[*]Abdelrahim A. Elbalola[1], Ibrahim, S. Yousef[2], Ahmed and A. Elshikh[2]
[1]Department of Biology, Faculty of Science, Tabuk University, Tabuk, KSA
[2]Department of Biology, Faculty of Education, University of Holy Quran and Islamic Sciences, Omdurman, Sudan
[2]Microbiology Department, Faculty of Pure and Applied Sciences, International University of Africa, Khartoum, Sudan
[*]Author for Correspondence: aalbalolh@ut.edu.sa

ABSTRACT
The objectives of this study are to evaluate the current status of plant species diversity and composition, to compare between sites and to report shift in species composition via comparisons with previous investigations in the area. Seven sites within the semi-arid zone of Sudan, Eastern Nile and Northwestern Omdurman (Khartoum State), five lowlands and two sand dune formations, namely wadi Tundub, wadi El-Farish, wadi Abuseweid, wadi Medaisees, wadi Buhat,Qoz Abudolou'a km 72 and Qoz Abudolou'a km 42 have been selected for the study. Randomly located quadrates and plots along lowlands and sand dunes were used to collect abundance data on herbaceous and woody species. Diversity indices, similarity matrices and plots were maintained using the Paleontological Statistics (Past 326b) package, and sites were compared accordingly. Dominance of species was decided based on the importance value index (IVI) for herbaceous species and percentage cover for woody species. Results showed that Eastern Nile sites Abuseweid and Tundub exceeded others in herbaceous and woody diversity. Northwestern sand dune sites Qoz Abudolou'a km 72 and Qoz Abudolou'a km 42 had the lowest herbaceous and woody diversity indices. Eastern Nile sites were similar to each other's and dissimilar to Northwestern sites. Number of species decreased and species composition changed compared to previous investigations. Different sites were dominated by different species.

Keywords: *Plant, Diversity, Composition, Semi-Arid, Sudan*

INTRODUCTION

Biodiversity is "the variety of living organisms, the genetic differences among them, the communities and ecosystems in which they occur, and the ecological and evolutionary processes that keep them functioning, yet ever changing and adapting'' (Noss and Cooperrider, 1994). It includes all of life's variation, expressed in genes, individuals, populations, species, communities and ecosystems (Sechrest *et al*., 2002). A wide range of values provided by biological diversity have been discussed (Cleber, 2008; Caceres *et al*., 2015). Species composition refers to the contribution of each plant species to the vegetation. It is generally expressed as a percent, so that all species components add up to 100%.

Growth in human population has exerted heavy exploitation of almost all components of natural systems and created multiple threats to biodiversity and composition, e.g. extinction, which is a natural process that occurs without intervention of humans, but extinctions made by humans are occurring at a rate that far exceeds any reasonable estimates of background extinction estimates (Swingland, 2000). Other threats to biodiversity include genetic degradation of taxa, habitat destruction, degradation and fragmentation, pollution, global climate change and many others (Sechrest *et al*., 2002).

Semi-desert belt of Sudan spreads in the Northern parts of the country, the Southern limits of it crosses latitude 14° N (Abdel Magid *et al*., 2005). The composition of semi-desert zone of Sudan between (Harrison and Jackson, 1958), who produced an ecological classification of natural vegetation recognizing five major divisions (zones) based on floristic composition, rainfall and soil type, to (Mohamed *et al*.,

2010) has decreased relatively by 13.2%. It passed from 417.297 km^2 to 250.196 km^2. Areas of natural vegetation in the Eastern portion of the semi-arid zone of Sudan have been reduced from 26.1% in 1979 to 12.6% in 1999 and further to 9.4% in 2007 (Sulieman *et al*., 2013). This lost area was substituted by the advancing desert class from the North to the Center of Sudan. Expansion of rain-fed agriculture has played a devastating role in removing and eliminating forest cover, shrubs, rangeland and destroy ecosystems and habitats of wild animals for the last five decades (UNEP, 2007). Vegetation cover in this area plays a vital role in meeting the basic needs of people and supporting their herds, thus it is subject to human activities such as clearing for agriculture and energy, overgrazing and brush fires (Sulieman, 2008). Considerable cutting of grasses for thatching and shrubs for building operations or as a source of fire wood are also widely practiced in the area (Halwagy, 1961). Overgrazing is not confined to the magnitude (number) of animals, it also includes duration of grazing i.e. grazing in unsuitable times (before seed dispersion). This practice negatively affects the plant community (Elnour, 2008) and ultimately leads to shift in species composition (Noy. 1979). Influence on species composition takes place by removal of photosynthetic tissues leading to stunted plants. Heavy grazing pressure was mentioned by Abusuwar and Darrag (2004) to be among the major factors of rangeland degradation causes. Another destructive practice that takes place in the area is the repeated grass and bush burning, it changes the cycle of annual deposition of litter (Heady, 1975), replaces the perennials by annuals (Skerman, 1962), affects soil micro biota (Meiklejohn, 1955), in addition to its effects on species composition and other plant attributes (Blaisdell, 1953; Heavy, 1949).

Shrinkage and altering of ecological zones naturally or due to human activities is supposed to be in the expense of plant species diversity. A land within a certain ecological zone, with a particular soil class, type and specified rainfall regime is capable of supporting a define set of species with a certain relative abundances. Each component of this species assemblage is repeatedly cycling, interacting with other ecosystem components and gaining sufficient needs. This species structure is a final existence and product of competitive interactions. Thus, decreasing and enforced change of land areas that support any assemblage of species will ultimately lead to change in species composition through competitive displacement, disappearance, decreasing and invasion, hence, formulate new transitional or permanent assemblages.

This study copes with the objectives of biodiversity conservation which requires the management of natural resources, and this in turn requires the measurement of these resources. Biodiversity measurement implies the need for some quantitative values that can be ascribed to the various measurements so these values can be compared (Swingland, 2000). In addition, management practices (monitoring, inventories and assessment) necessitate the implementation of frequent measurements of species diversity and composition to visualize trend and magnitude of change with the passage of time.

MATERIALS AND METHODS

The Study Area

The study area is located within the semi-arid part of Sudan, administratively belongs to Khartoum state, bordered by Gedarif state from the east, River Nile state from the North, Gezira state and White Nile state from the south and Northern Kordofan state from the West. Khartoum state is divided by the river Nile (Blue, White and the main river) into two parts namely Eastern Nile and Western Omdurman. It is characterized by warm dry winters and hot rainy summers, the bulk of rain (about 90% of the total annual) falls in July, August and September (Halwagy, 1961). The area studied belongs to the *Acacia* Desert Scrub (Andrew,1948; Smith,1949) or to *Acacia tortilis- Maerua crassifolia* Desert Scrub (Harrison and Jackson,1958). According to the Comprehensive Agricultural Census of 2009, area of Khartoum state occupied by natural rangelands and forests was estimated by 2.1 M ha. More than 1384000 heads of livestock are found in the state, of which, 24000 are cattle (17%), 7000 camels (1%), 513000 sheep (37%) and 624000 goats (45%).

The Study Sites

A total of seven communal land sites were selected for the study, three lowlands (*wadies*) in the Eastern part of the study area namely Wadi Tundub (denoted by **T** in this study) (15° 42.330″ N,033° 6.278″ E) (about 71Km to the East from the Blue Nile), Wadi El-farish (**F**) (15° 42.289″ N, 033° 6.283″ E) (about 70 Km from the Blue Nile) and Wadi Abuseweid (**A**) (15° 37.133″ N, 032° 55.005″ E) lies on the most Eastern part and represents the Western edge of Butana region; and four sites (two lowlands and two sand dunes) in the Northwestern part, Wadi Medaisees (**M**) lies on the Northwestern part of Khartoum state (16° 12.223' N, 31° 41.392' E), Wadi Buhat (**B**) 16° 20.395' N, 31° 48.686' E, (about 108 Km Northwestern Omdurman), Qoz Abu Dolou'a Km 72 (sand dune) (**Q72**) (16° 11.234′ N, 31° 49.258′ E) extends up to nearly Km 110 along Shririan El Shimal highway to the North. The highway divides the Qoz into two Eastern and Western portions; and Qoz AbuDolou'a Km 42 (**Q42**) (sand dune) (16° 09.275′ N, 31° 49.317′ E).

Vegetation Sampling

A metal 1m x 1m quadrate for herbaceous sampling was used. Number of quadrates enough to include all herbaceous species in each site was determined according to the species – area curve method (Barbour, 1987). Quadrates were located randomly along a line transect established parallel to lowland direction of flow or sand dune extension. Every individual rooted within the quadrate was considered, and the species present in each quadrate were recorded with their numbers of individuals. Species not identified in the site were pressed and coded to be identified later by specialists or references. Total number of individuals of each species was recorded for all quadrates at each site. For perennial woody species 20 X 20 m plots were used, where percentage canopy covers were measured using the method described by Husch *et al*, (1986).

Dominance of Herbaceous Species

Herbaceous species densities, species frequencies, relative densities, relative frequencies and importance value index were calculated as follows according to Curtis, (1959).

$$species\ density = \frac{No\ of\ individuals\ of\ the\ sp.}{No\ of\ quadrate\ \times quadrat\ area}$$

$$species\ frequency\ = \frac{No.of\ quadrate\ including\ the\ species}{total\ No.of\ quadrate}$$

$$species\ relative\ density\ = \frac{spesies\ density}{total\ density} \times 100\%$$

$$species\ relative\ frequency = \frac{species\ frequency}{total\ frequency} \times 100\%$$

$$importance\ value\ index\ (IVI) = realtive\ density + relative\ frequency$$

Then species were divided into 6 classes (dominant, co-dominant, abundant, frequent – occasional and rare) based on their importance values and each species was given a certain class accordingly. Dominance of woody species was assigned to different species in the same way based on their percentage canopy covers.

Species identification

Species identification was made by experts in the Department of Botany, Faculty of Science, Khartoum University and the Administration of Rangeland and Fodder of Khartoum State and aided by making use of references such as Flora of Tropical East Africa (FTEA).

Statistical Analysis

Abundance data of herbaceous species (number of individuals at each site), presence/absence data of perennial species in addition to taxonomic information (genus and family names) were entered to the Paleontological Statistics package version (Past326b). Diversity indices (Taxa-S, No of individuals, dominance, Shannon_ H, equitability, and global beta diversity) were determined and taxonomic distinctness was maintained. In addition, Bray-Curtis similarity and Whittaker pair wise matrices and

Bray-Curtis nearest neighbor clustering were also produced for herbaceous and woody perennial species. Number of herbaceous and woody families were counted and recorded.

RESULTS AND DISCUSSION

Plant Species Diversity

Abuseweid exceeded other sites in number of herbaceous species, number of individuals per species, number of herbaceous families and Shannon diversity index (Table 1). Shannon index, which also takes into account both number of individuals and number of taxa, ranged from 0.08831 at Buhat to 1.541 at Abuseweid. The reason behind the relative advantage of Abuseweid over other sites, is that it represents the '*Butana'* plain which is known in the local knowledge of pastoralists and farmers to be of excellent vegetation cover (Sulieman *et al*., 2013), it's soil was classified as *Vertisols* which is dark cracking clays referred to as black cotton soil, mostly alluvial in origin from materials transported by the Blue and the White Nile. This soil is characterized by clay contents of 60% or more, alkaline in pH, have gypsum and calcium carbonate concentrations and their vegetation is a result of edaphic rather than climatic factors (Zaroug, 2000). Buhat showed the highest dominance value (0.9727) because one taxon (*Amaranthus graecizans*) almost dominates this site completely (Table 4), given that this site showed high number of individuals next to Abuseweid (6392) in addition to the lowest Shannon index. Equitability, which measures evenness with which individuals are divided among the taxa present (Harper, 1999), was the highest at Qoz Abudolou'a km 42 coupled with the lowest number of taxa (4) and number of individuals (207). Equitability was the lowest at Buhat again because individuals mostly belong to one species. Taxonomic distinctness is 'the average path length between any two randomly chosen individuals on them being from different species', and it can be seen as a measure of pure taxonomic relatedness (Clarke *et al.,* 1998). It ranged from 2.9 at Medaisees to 3 at Tundub, Qoz Abodolou'a km 72 and Qoz Abudolou'a km 42. This means that taxa of these sites (T, Q72 & Q42) are less taxonomically related. Tundub exhibited the highest number of woody perennial species (6) followed by Medaisees and Buhat where woody species were found to be less taxonomically related to each other's.

Table 1: Diversity indices of herbaceous and woody species of different sites.

		Sites						
	Indices	**T**	**F**	**A**	**M**	**B**	**Q72**	**Q42**
Herbaceous species	Taxa_S	11	9	20	16	6	4	4
	Individuals	4177	6775	6987	4434	6392	643	207
	Dominance_D	0.5641	0.2691	0.314	0.4485	0.9727	0.8484	0.3697
	Shannon_H	0.8327	1.469	1.541	1.139	0.08831	0.3452	1.079
	Equitability_J	0.3472	0.6687	0.5144	0.4109	0.04928	0.249	0.7786
	Tax. Distinctness	3	2.999	2.952	2.9	2.995	3	3
	Families	9	8	13	12	4	4	4
Woody species	Taxa_S	6	4	4	5	5	1	1
	Individuals	6	4	4	5	5	1	1
	Dominance_D	0.1667	0.25	0.25	0.2	0.2	1	1
	Shannon_H	1.792	1.386	1.386	1.609	1.609	0	0
	Equitability_J	1	1	1	1	1		
	Tax. Distinctness	2.2	2	2	3	2.8		
	Families	3	2	2	5	5	1	1

Beta Diversity

Global beta diversity describes change in species composition and abundance across the study sites and change in number of species from site to another (Whittaker, 1956&1960). Also it describes the species turnover (Whittaker, 1972). According to Tuomisto, (2010), it is the effective number of distinct composition units (sites). Table 2 showed that the Eastern Nile sites (low lands) (Tundub, Abuseweid and El-Farish) had high (herbaceous) Whittaker beta diversity pair wise comparison values (which range from zero for typical species compositions to one for complete species composition difference) against Northwestern sites (Buhat, Qoz Abudolou'a km 72 and Qoz Abudolou'a km 42), and they had small values against each other's. Magurran, (1988) stated that the more dissimilar two sites are, the higher beta diversity. This means that Eastern Nile sites are more similar to each other's in terms of herbaceous species number and abundance and they differed from Northwestern sites. Buhat showed complete dissimilarity to Qoz Abudolou'a km 72 and Qoz Abudolou'a km 42 with 1 pair wise comparison value. The Northwestern Medaisees was found to be close to the Eastern sites. Table 2 further showed the dissimilarity between the Eastern against Northwestern sites, as it showed high Whittaker comparison values (based on woody species) between each Eastern site (1) against each Northwestern site.

Table 2: Whittaker beta diversity pair wise comparison matrices between sites

		T	F	A	M	B	Q72	Q42
Herbaceous spp.	**T**	0	0.4	0.355	0.407	0.882	0.867	0.733
	F		0	0.448	0.36	0.733	0.846	0.692
	A			0	0.333	0.846	0.917	0.833
	M				0	0.818	0.8	0.7
	B					0	1	1
	Q72						0	0.5
	Q42							0
		T	**F**	**A**	**M**	**B**	**Q72**	**Q42**
Woody spp.	**T**	0	0.4	0.2	0.636	0.636	1	1
	F		0	0.5	0.778	0.556	1	1
	A			0	0.556	0.778	1	1
	M				0	0.6	0.667	0.667
	B					0	1	1
	G72						0	0
	G42							0

Alpha Diversity

Bray-Curtis similarity matrices, which have been considered to be very satisfactory (Clarke and Warwick, 2001a), contain pair wise comparisons of alpha diversities made between all pairs of sites in table 3. These matrices confirmed what found by previously discussed indices, since Tundub and Abuseweid were found to be the most similar to each other's regarding herbaceous species, then Tundub/El-Farish and Abuseweid/ El-Farish. Lowlands (wadies) were found to be completely dissimilar to sand dune sites (Q72 & Q42). The Northwestern sites Medaisees and Buhat were the most similar to each other's in woody species with 0.50914 value, and Eastern sites were also similar to each other's in woody species, while much dissimilar to Northwestern sites.

Table 3: Bray-Curtis similarity matrices of sites based on species distribution and abundance

		T	F	A	M	B	G72	G42
Herbaceous spp.	**T**	1	0.6	0.8	0.364	0.364	0	0
	F		1	0.5	0.222	0.444	0	0
	A			1	0.444	0.222	0	0
	M				1	0.4	0.333	0.333
	B					1	0	0
	G72						1	1
	G42							1
		T	**F**	**A**	**M**	**B**	**G72**	**G42**
Woody spp.	**T**	1	0.331	0.407	0.103	0.0006	0.0004	0.039
	F		1	0.407	0.091	0.007	0.002	0.025
	A			1	0.108	0.016	0.002	0.024
	M				1	0.600	0.006	0.047
	B					1	0	0
	Q72						1	0.096
	Q42							1

Clustering of Sites

Similar comparative outcomes between different sites were demonstrated by Bray-Curtis nearest neighbor clustering based on both herbaceous species (Fig. 1) and woody perennial species (Fig. 2). Clustering was based on the smallest distance between the two sites. The two clusters described neighborhood linkages and closeness between different sites.

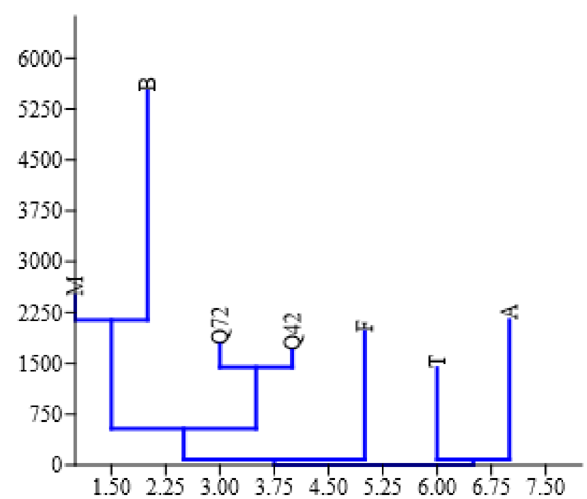

Figure 1: Bray- Curtis nearest neighbor clustering of sites based on herbaceous species.

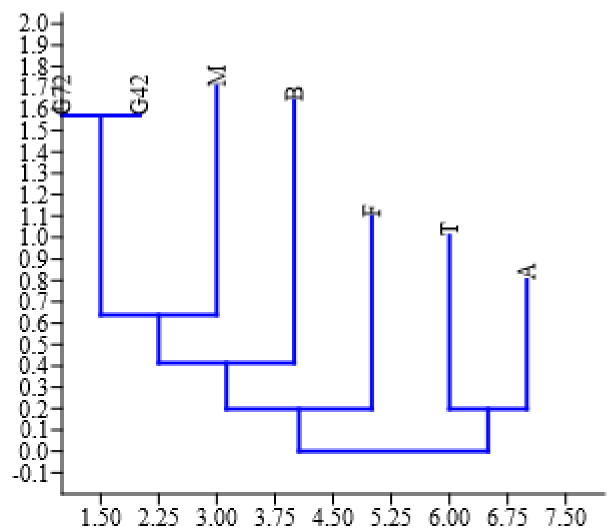

Figure 2: Bray-Curtis nearest neighbor clustering of sites based on perennial woody species.

Dominance, Distribution and Species Composition

A total of 30 herbaceous species and 11 perennial species were recorded at all Eastern Nile and Northwestern Omdurman sites (Tables 4&5). The herbaceous species *Aristida mutabilis* dominated Tundub and it was co-dominant at El-Farish, Abuseweid and Qoz Abudolou'a km 42; *Portulaca oleracea* dominated at Abuseweid; *Indigofera hochsteterri* at El-Farish; *Amaranthus graecizans* at Buhat, *Zaleya pentandra* at Q42 and *Portulaca quadrifida* at Q72. Regarding woody species, *Acacia ehrenbergiana* dominated at Tundub; *A. seyal* at Abuseweid; *A. tortilis* at Buhat; *A. nubica* at Medaisees; *A. spirocarpa* at El-Farish and *Maerua crassifolia* at Q72 & Q42. Kassas, (1956) investigated the vegetation cover of Omdurman semi-desert (4 Northwestern sites included in this study are part of it), he mentioned that the number of species during August (rainy season) of that year was 78 which explains the decrease in number of species when compared to this study. Halwagy (1961) studied the vegetation cover of the semi-desert Northeast of Khartoum. He recorded 12 perennial species of which *Acacia laeta, Cadada rotundifolia and Cadada farinosa* were not found during the current investigation. He also recorded 23 annual species, from which, 15 were not found during this investigation. Furthermore, the herbaceous species *Portulaca oleracea, Aristolochia bracteolata, Amaranthus graecizans, Urochloa tricopus, Ocimum basilicum, Momordica tuberosa, Zaleya pentandra, Morettia canescens and Mollugo nudicaulis* recorded in this study were not found in his record. Hence, disappearance and replacement are evident. It was early stated that herbaceous vegetation was reported to undergo remarkable change due to range deterioration (Darrag and Alsadig, 1996). Suliman *et al*., (2013) investigated (as a part of their study area) the rainy season communal grazing land of *Butana* region, they interviewed a considerable number of experienced pastorals and herders. They found that 57 plant species which are palatable have disappeared or decreased, and 17 plant species which are unpalatable have increased. This confirms what was reported before by Abusuwar, (2007) that overgrazing leads to domination of low quality species in expense of good grazing ones.

Table 4: Herbaceous species distribution and dominance at different sites

Taxa	Sites						
	T	F	A	M	B	Q72	Q42
Portulaca oleracea L.	F	-	D	OC	-	-	-
Aristida mutabilis Trin &Rupr.	D	Co-D	Co-D	F	-	-	Co-D
Indigofera hochstetteri Baker.	F	D	A	OC	-	-	R
Cyperus rotundus L.	A	-	-	-	-	-	-
Sesbania sesban L.	OC	-	OC	OC	-	-	-
Corchorus olitorius L.	OC	A	F	-	A	-	-
Boerhavia repens L.	OC	F	A	OC	-	R	-
Ipomoea sinensis Fisch.	R	-	F	OC	-	-	-
Tribulus terrestris L.	OC	OC	F	OC	-	-	-
Solanum dubium Forssk.	R	OC	OC	OC	-	-	-
Aristolochia bracteolata Lam.	OC	-	R	-	-	-	-
Euphorbia aegyptiaca L.	-	OC	OC	OC	-	-	-
Amaranthus graecizans L.	-	R	F	D	D	-	-
Dactyloctenium aegyptium (L.) Willd.	-	R	-	OC	-	-	-
Urochloa trichopus (Hochst.)Stapf.	-	-	F	-	-	-	-
Celosia argentea L.	-	-	OC	OC	-	-	-
Ocimum basilicum L.	-	-	OC	-	-	-	-
Ipomoea cordofana Choisy.	-	-	OC	-	-	-	-
Momordica tuberosa Dennst	-	-	OC	-	-	-	-
Sorghum arundinaceum (Desv)Stapf.	-	-	R	-	-	-	-
Digera muricata (L.)Mart.	-	-	OC	-	-	-	-
Echinochloa colonum(L.)Link.	-	-	-	A	-	-	-
Zaleya pentandra (L.)C.Jeffry.	-	-	-	OC	-	OC	D
Cenchrus biflorus Roxb.	-	-	-	R	-	-	-
Citrullus lanatus (Thunb.)Masum.	-	-	-	OC	F	-	-
Corchorus depressus (L.)Peterm.	-	-	-	-	A	-	-
Morettia canescens Boiss.	-	-	-	-	OC	-	-
Mollugo nudicaulis (Poir.)Rohrb.	-	-	-	-	R	-	-
Portulaca .quadrifida L.	-	-	-	-	-	D	F
Tribulus pentandrus Forssk.	-	-	-	-	-	F	-

D= dominant, Co-D= co-dominant, A= abundant, F= frequent, OC= occasional, R= rare.

Table 5: Perennial woody species dominance and distribution at different sites.

Taxa	Sites						
	T	F	A	M	B	G72	G42
Acacia ehrenbergiana Hayne.	D	F	-	-	-	-	-
Acacia seyal Del.	R	-	D	-	-	-	-
Acacia tortilis (Forssk.) subsp. *radiana* (Savi)	R	O	A	-	D	-	-
Acacia nubica Benth.	R	-	F	D	-	-	-
Ziziphus spina-christi (Boiss.)	R	O	F	O	-	-	-
Balanites aegyptiaca (L.) Delile.	R	-	-	-	-	-	-
Acacia spirocarpa Hochst.	-	D	-	-	-	-	-
Maerua crassifolia (Forssk.)	-	-	-	O	-	D	D
Leptadenia pyrotechnica (Forrsk) Decne.	-	-	-	A	F	-	-
Salvadora persica L.	-	-	-	R	R	-	-
Bascia sp. Lam.	-	-	-	-	A	-	-

D= dominant, Co-D= co-dominant, A= abundant, F= frequent, OC= occasional, R= rare.

Conclusion

The Eastern Nile (*Butana*) site Abuseweid was the most diversified in herbaceous species based on different indices with a total of 13 families, and the Eastern Nile site Tundub was the highest in woody perennial diversity indices followed by the Northwestern sites Medaisees and Buhat with the highest number of woody families (5). The Northwestern sand dune sites Q72 and Q42 were less diversified and the poorest in both herbaceous as well as woody perennial species. The Northwestern site Buhat had the highest dominance value and the lowest Shannon herbaceous diversity values due to extreme uni-specific dominance, while the highest value of equitability (evenness) was found at Q42. Generally Northwestern sites were found to be more similar and close to each other's based on all diversity comparison matrices and clustering in both herbaceous and woody species. Low lands were completely dissimilar to sand dune sites, Buhat and Medaisees were the most similar to each other's in woody perennial species composition and richness. Different sites were found to be dominated by different herbaceous and woody perennial species. Number of herbaceous and woody species had considerably decreased and shift in species composition occurred based on comparisons to previous studies.

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