Original article

Ecological Diversity and Floristic Composition of Woody Vegetation through Six Ecosystems in Zalingei Locality, Darfur State- Sudan.

Ekhlas A. Khlyfa[1], Ismail M. Ismail[2] and Alawia A. Elawad [3]

[1] Department of Sciences University of Zalingei, Faculty of Education, Zalingei, Sudan.[2] Forestry and Gum Arabic Research center, Agricultural Research Corporation, Khartoum, Sudan.[3]Department of Biology and Biotechnology, Faculty of Sciences and Technology, Al Neelain University, Khartoum, Sudan.

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Abstract

This work aims to study some quantitative ecological characteristics of the woody plants in Zalingei Locality, Central Darfur State- Sudan. 6 sites: 3 in hill slopes and 3 in plains; were selected depending on differ topography and soil types. Quantitative data were collected according to the standard methods. The data was used to assess the floristic composition and dominance of species in each site, diversity and similarities between the sites using different methods. The results reveal the presence of 33 species inside sampled plots with relative differences between sites. Four species are dominating the studied area; *Acacia senegal* in site 1 and 4 in the low hill slopes, *Albizia amara* in site 3 in stony hill slope, *Dichrostachys cinerea* in sites 2 and 5 in plains and *Acacia nilotica* in site 6 in a sedentary plain. Species density is high in the area with varying amounts between sites. Four sites (1, 3, 5 and 6) recorded high diversity values. Site 4 recorded medium diversity values and site 2 recorded the lowest values. The percentage similarity between the sites is relatively high (68.29 – 77.77%). Signs of vegetation destruction were evident in sites 2 and 6. Conservation of the area is vital.

***Corresponding author:** alawiaelawad@gmail.com

Introduction

Woody plants are important economic and ecological renewable natural resource. They play very important role in sequestering large amount of atmospheric carbon through photosynthesis and act as sinks and sources of carbon (Jibrin *et al.*, 2018).

Diversity indices as stated by Peet (1975) are frequently applied in the form of ratios of absolute diversity to the maximum diversity possible. Diversity is measured by species richness (the number of species), species evenness (how relatively abundant each of the species is) in addition to species composition (Doherty *et al.*, 2011). Species richness is a biologically appropriate measure of alpha (α) diversity and is usually expressed as number of species per sample unit (Whittaker 1972). Composition is the assemblage of plant species that characterize the vegetation (Martin, 1996).

The sensitivities of the different ecosystems to disturbances in the Sudan often cause great degradation of the vegetation, so the need for extensive work on vegetation evaluation becomes vital. The vegetation classification in the Sudan follows the prevailing ecological conditions, the variation in rainfall and soil types and to lesser extent the effect of topography, which is confined to certain localities (Abdel Magid and Badi, 1989). No complete ecological survey of the vegetation was made in the Sudan since the comprehensive study of Harrison and Jackson (1958). As recorded by Andrews (1948) the mountain massifs of Jebel Marra is one of the areas affected by topography. Zalingei locality- Central Darfur State- Western Sudan selected for this study is located in the zone of the rainfall woodland savanna (Harrison and Jackson, 1958); it has been studied as part of the work of Wichens (1966 and 1976), UNEP. (2007) and Elsiddig (2007).

Specific study in the area include the work of Abusuwar and Mohammed (2011). Selection of Zalingei locality for this study is based on its high population with variable woody plants. In the last decades the area is affected by human activities in the form of woody species felling, expanded agricultural practices and the impact of the civil war. These factors are reflected on the vegetation composition and diversity. No attempt has been made so far in the field of composition and ecological diversity of woody plants in Zalingei locality apart of the works of Ali *et al*. (2015) in the woody vegetation changes across the Wadi system to the stony Hill slopes and Desougi *et al*. (2016) in effect of soil physical chemical properties on the distribution of trees. The aim of this study is to document the woody species composition, to document the environmental relations and to compare some ecological diversity variations in selected 6 sites.

MATERIALS AND METHODS

Study area:

Study area is confined to Zalingei locality central Darfur state – Sudan (Fig. 1). It lies between latitude 12° 42' - 13° 08' N and longitude 23° 39' - 23° 25' E; with altitude that range from 890 - 1121 m above the sea level. The area lies on the Hill Vegetation zone in the lowlands of Jebel Marra and affected by the hill elevation (Wichens, 1976). It is formed geologically of crystalline Basement Complex rocks which are buried by recent sediments. The soils in the area are derived from the gneisses, shists and granites of the basement complex; namely: sedentary and alluvial soils (Wichens, 1976); and are generally classified into four main types: 1. the sandy loam, 2. the sandy clay loam, 3. the loamy sand at contemporary flood plain and 4. the clay at clay plains (Desougi *et al*., 2016). The rainy season was usually 7 months (April to October), with an annual ranges of 379.4 to 772.4 mm. The mean annual relative humidity (2002-2018) was`50.5% and it reached the maximum 81.5% in August and the minimum value of 29 % in March. The mean annual temperature was 26.2 C^0, with a monthly mean varying from 30 C^0 in April, 29 C^0 in May to 22.8 during winter in January and December (Metrology station Zalingei, 2018).

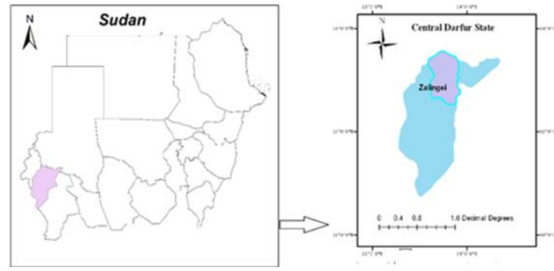

Fig. 1: Map of the Study area

Data collection:

The study area was divided into 6 different sites (Table 1); the selection of the sites was based on observed variations in vegetation types and topographical feature. Sites 1, 3 and 4 in the lower hill slopes are located on Khor Kaba west Zalingei - southwest 8 kilo station, Wadi Azum north Zalingei and southeast Zalingei respectively. Site 2 flood plain on Teraje west Wadi Sery. Sites 5 and 6 sedentary plains are located in Traje near Wadi Gallabat and Shawa East Wadi Dahab Sharo respectively (Fig. 2).

Table: (1) Locations and Coordinates of Studied Sites

Site	Location	Latitude - N	Longitude - E	Altitude -m
1	Lower hill slopes – Zalingei (8 Kilo)	12° 50'	23° 25'	902
2	Flood plains - Teraje	12° 43'	23° 28'	972
3	Stony hill slopes – Zalingei Azum	12° 57'	23° 28'	906
4	Lower hill slopes - Zalingei	12° 49'	23° 27'	957
5	Sedentary plains - Teraje	12° 44'	23° 26'	994
6	Sedentary plains – Zalingei Shawa	12° 56'	23° 37'	930

Fig. 2: Studied Sites

In each site 10 circular sample plots of 0.1ha. (radius = 17.84m) modified from Adam *et al*. (2008). The first plot was established randomly with 200 m space between each two circulars along 6 line transect using Global Position System (GPS). Also the sites were marked using GPS as evident in table 1 and fig. 2. Plant species in each plot, number of trees and shrubs species and the number of individual of each species per/plot were counted. Topography and soil characters were taken into account. The collected plants were identified using available references (Andrews (1950, 1952 and 1956), Wichens (1976), Elamin (1990) and Von Mydell (1990)). Standard up-dated scientific binomials were given to collected plants. Updated plant names followed The Plant List, version 1.1 (2013). Collection of Vernacular or Arabic names were derived from questionnaires and checking in the field as well as standard literature. From each plot herbarium specimens of the recorded trees and shrubs were taken. Herbarium material were deposited at Al Neelain University Herbarium.

Data analysis:

From the counted data the vegetation parameters (density, relative density (RD%), abundance, relative abundance (RA%), frequency and relative frequency (RF%) were calculated to obtain the importance value index (IVI) for each species in each site to assess the dominance of species in the vegetation communities using the formulas used by (Desougi *et al*., 2016) and (Chaudhry *et al*., 2006). Shannon Biodiversity index (H) was calculated as given by Shannon Weaver (1963). Margalof index (Species richness (D)) was calculated as given by Margalof (1958). Pielou index for species evenness (E): was calculated as given by Pielou (1966b). Bray-Curtis (CN, Quantitative version of (Sorenson, 1948) index was used to determine the degree of similarity in the species composition between the sites

RESULTS AND DISCUSSION:

Woody Vegetation Composition:

The vegetation in the studied sites was characterized by diversified woody species cover based on differences in environmental conditions that led to differences in the number and abundance of plants. The results are presented in table 2 ; they reveal the presence of 33 woody species within 11 families inside the sampled plots. Fabaceae (Leguminosae) was represented with the highest number of species (16), mostly Acacias. *Acacia senegal*, *Albizia amara*, *Dichrostachys cinerea* and *Balanites aegyptiaca* were present in the 6 studied sites. *Combretum aculeatum*, *Anogeissus leiocarpus*, *Acacia gerrardii*, *A. nilotica*, *A. seyal* var. *seyal*, *Ziziphus mauritiana* and *Z. spina-christi* are recorded in 5 sites. *Cordia abyssinica*, *Commiphora africana*, *Ficus sycomorus*, *Flueggea virosa* and *Catunaregam nilotica* are present in one site each (Table 2). *Ziziphus mauritiana*. *Faidherbia albida* present in the 4 studied sites. These results agree with Wichens (1979) who described *Faidherbia albida and Balanites aegyptica* association on alluvial soils of Wadi Azum system. The results are also in line with Ali *et al.* (2015) who reported *Faidherbia albida* at Zalingei area around valleys (Azum, Aribo and Uyer).

Species Density:

The density of woody species varied both within and among the studied sites (269-558 stem/ha). The highest density was recorded in site 2 and the lowest density was found in sites 1 and 6 (Fig. 3). These results are within the range of Natta *et al.* (2003) who reported 253-785 stem /ha. in Riparian Forests in West Africa and Ismail and Elawad, (2017) 48-766 stem/ha. in Rashad and Alabassia Localities (Nuba Mountains), South Kordofan, Sudan; this confirm the fact that high woody species density is positively correlated with high moisture content due to amount of rainfall and/or altitudinal level.

The results are higher than the 183.75 stem/ha. of Ismail and El Sheikh (2016) in Jebel Al Gerri Reserved Forest, Blue Nile, Sudan; this may be due to differences in soil type and elevation. Relative low density in sites 1 and 6; is due to iniquitous felling of woody plants in order to expand agricultural land in site 6 and to produce charcoal, fuel wood and animal browsing in dry seasons in site 1.

Table (2) Species List, Relative Density (RD) and Important Value Index (IVI)

Taxa	Vernacular name	Site 1		Site 2		Site 3		Site 4		Site 5		Site 6	
		RD	IVI	RD	IVI	RD	IVI	RD	IVI	RD	IVI	RD	IVI
Boraginaceae													
Cordia abyssinica R. Br.	Gembeel			29.97	4.198								
Burseraceae													
Commiphora africana (A. Rich.) Endl.	Gafal	0.74	3.893										
Capparaceae													
Boscia senegalensis Lam.	Mukheit	0.37	1.942			0.4	4.26						
Capparis corymbosa. Lam.	Mardo	0.74	2.683			0.6	5.6						
Capparis decidua (Forssk.) Edgew.	tundub					0.2	2.93						
Maerua crassifolia Forssk.	Sraih	0.37	1.942			3.8	16	0.23	3.23			0.21	12.35
Combretaceae													
Anogeissus leiocarpus(DC.) Guill & Perr.	Sahab	1.49	6.587	1.08	8.485			0.68	6.41	0.59	5.17	0.7	5.18
Combretum aculeatum Vent	Habeel Shehait	0.37	1.942	9.14	29.97	2.8	13.9			13.5	38.26	2.46	10.54
Fabaceaeae													
Acacia ataxacantha DC.	Abu ndroa	5.2	15.22			3.6	17						
Acacia gerrardii Benth.	Salgam	16.7	41.89	0.18	2.999			7.22	26.68	0.4	4.08	3.16	17.73
Acacia mellifera (Vahl) Benth.	Kitir					0.2	2.93	1.58	10.52				
Acacia nilotica (L.) Del.	Sunt	2.23	6.87			0.2	2.93	4.29	19.46	3.37	14.42	30.2	58.57
Acacia oerfota (Forssk) Schweinf.	Laut					0.6	6.5						
Acacia senegal (L.) Willd.	Hashab	23.1	58.15	0.36	4.198	8.7	27.7	55.8	107.9	2.77	14.07	2.11	10.59
Acacia seyal var. *fistula* (Schweinf.) Oliv.	Talih abyed	2.97	9.554	16.7	43.27	0.6	5.48						
Acacia seyal var. *seyal* (Del.) Brenan.	Talih Ahmer	7.43	24.5	4.48	18.38			2.71	13.36	19.2	44.29	13.4	32.05
Acacia sieberiana DC.	Kuok									0.59	5.39	3.87	14.12
Albizia amara (Roxb.) B. Boivin	Arad	13	32.04	0.9	7.816	55	103	15.1	39.65	9.31	27.06		
Bauhinia reticulatem (DC.) ….	Kharub			0.9	9.316							0.35	3.38
Bauhinia rufescens Lam.	Kulkul	0.74	3.893			0.6	5.6	0.45	5.09	0.59	6.06	7.03	22.15
Dalbergia melanoxylon Guill. & Perr.	Babanous	7.06	21.35	0.36	4.958					0.4	4.42		
Dichrostachys cinerea (L.) Wight & Arn.	Kaddad	0.37	1.942	45.7	95.56	12	32	1.81	11.1	24.8	54.84	8.43	25.33
Faidherbia albida (Delile) A. Chev.	Haraz					0.2	2.93	0.9	8.82	0.4	4.42	1.41	8.07
Tamarindus indica L.	Aradaib	1.86	9.739									0.21	12.35
Malvaceae													
Grewia flavescens Juss.	Khelisan	6.32	19.87			2.6	14.6			0.2	2.77		
Grewia tenax (Forssk.) Fiori.	Guddeim					0.2	1.79			0.2	2.77		
Grewia villosa Willd.	Tico, Grgdan	1.86	6.129			1	7.65					0.21	12.35
Moraceae													
Ficus sycomorus L.	Gimeez											0.35	3.38
Phyllanthaceae													
Flueggea virosa (Roxb. ex Willd.) Royle	Carson									0.2	2.77		
Rhamnaceae													
Ziziphus mauritiana Lam..	Krno			3.23	14.98	0.2	2.93	0.23	3.23	1.39	9.13	13	32.17
Ziziphus spina-christi (L.) Desf.	Sider	2.23	10.48	5.02	21.62			4.97	23.04	5.74	20.5	3.16	12.21
Rubiaceae													
Catunaregam nilotica (Stapf.) Tirveng.	Shagart Elmarfaein							0.68	6.41				
Zygophyllaceae													
Balanites aegyptiaca (L.) Delile	Hegleeg	4.83	19.3	11.6	34.28	6.8	23.4	3.39	15.12	16.4	39.62	9.49	25.44

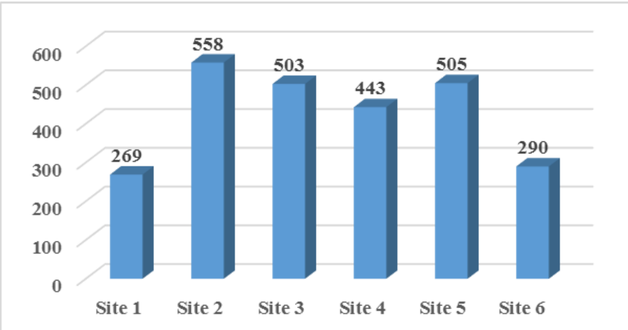

Fig. 3: Density of Woody Species in the Studied Sites

Species Dominance:

Soils of sites 1, 3 and 4 in the lower hill slopes is form of complex sandy grits, site 2 flood plain with clay loam, alluvial soil and sites 5 and 6 sedentary plains with sandy clay loam soil

The results show that the woody species with high importance values (IVI) differs from site to site.

In site1 *Acacia senegal* dominated the site with the highest IVI

(46.66); associated with *Acacia gerrardii* with an of IVI 37.15 and *Albizia amara* (IVI 32.08). *Boscia senegalensis*, *Maerua crassifolia*, *Combretum aculeatum* and *Dichrostachys cinerea* recorded the lowest (IVI 3.43) (Fig. 4).

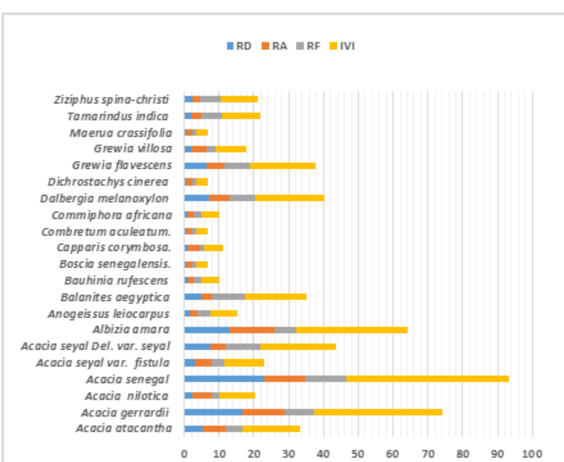

Fig. 4: RD%, DA%, RF% and IVI of woody layer in Site 1

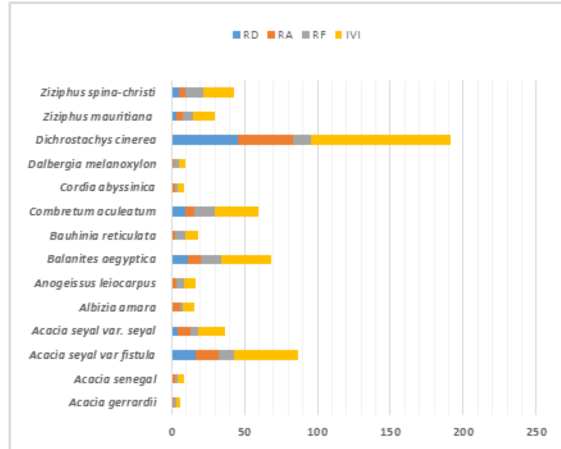

Fig. 5: RD%, DA%, RF% and IVI of woody layer in Site 2

Dichrostachys cinerea recorded the highest IVI (95.56) and dominated site 2; associated with *Acacia seyal* var. *fistula* (IVI 43.25) and *Balanites aegyptica (*IVI 34.28). *Acacia gerrardii* recorded the lowest IVI value (3) (Fig. 5).

Albizia amara dominated site 3 it recorded the highest IVI (102.7); associated with *Dichrostachys cinerea* (IVI 32.04) followed by *Acacia senegal* (IVI 27.7) and *Balanites aegyptiaca* (IVI 23.4). *Capparis decidua*, *Acacia mellifera*, *A. nilotica*, *Faidherbia albida*, *Grewia tenax*, *Ziziphus mauritiana* recorded the lowerst (IVI 2.93) (Fig. 6).

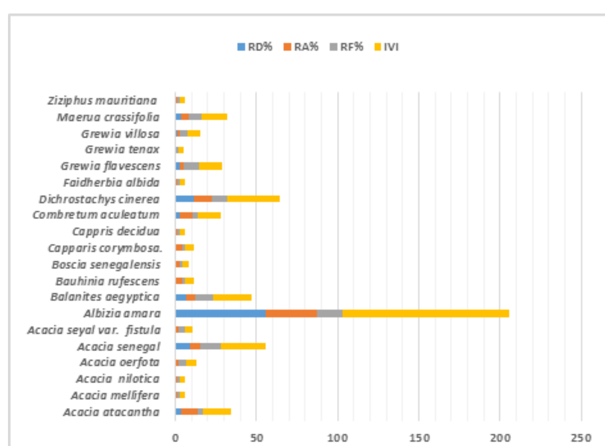

Fig. 6: RD%, DA%, RF% and IVI of woody layer in site 3

In site 4 *Acacia senegal* dominated the site it recorded the highest IVI (107.9) associated with *Albizia amara* (IVI 39.65) and *Acacia gerrardii* (IVI 26.68). *Maerua crassifolia* and

Tamarindus indica recorded the lowest (IVI 3.23) (Fig. 7).

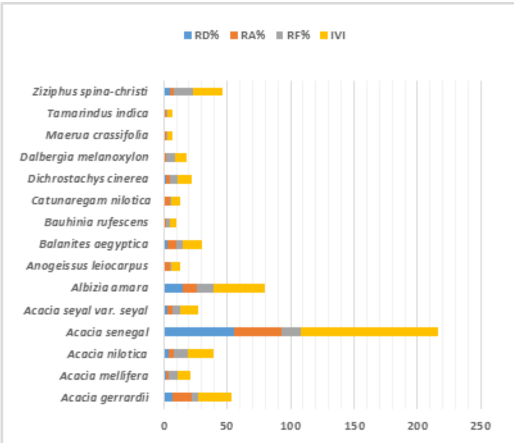

Fig. 7: RD%, DA%, RF% and IVI of woody layer in site 4

In site 5 *Dichrostachys cinerea* is the dominant species that recorded the highest IVI (54. 84); associated with *Acacia seyal* var. *seyal* (IVI 44.29), *Balanites aegyptiaca* (IVI 39.62) and *Combretum aculeatum* (IVI 38.26). *Grewia flavescens*, *G. villosa* and *Flueggea virosa* recorded the lowest (IVI 2.77) (Fig. 8).

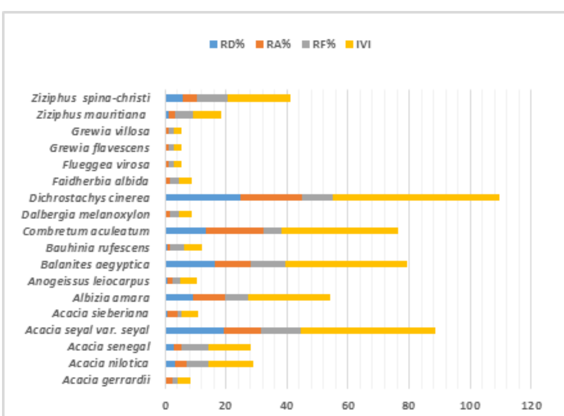

Fig. 8: RD%, DA%, RF% and IVI of woody layer in Site 5

Site 6 is dominated by *Acacia nilotica* with the highest (IVI 58.57); associated with*Ziziphus mauritiana* (IVI 32.17) and *Acacia seyal* var. *seyal* (IVI 32.05). *Maerua crassifolia*, *Bauhinia reticulatum*, *Tamarindus indica* and *Ficus sycomorus* recorded the lowest IVI (3.38) (Fig. 9).

It is clear that species dominance in the studied area was affected by the soil type. The lower hill slope sites 1, 3 and 4 characterized with complex sandy grits were dominated by *Acacia senegal* associated with *Albizia amara*; this result confirms the findings of Ali *et al.* (2015) and Desougi *et al.* (2016). High presence of *Dichrostachys cinerea* in site 3 indicates areas of clay soils.

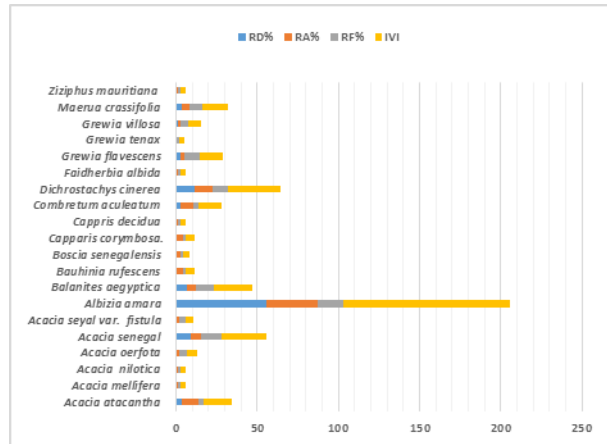

Fig. 9: RD%, DA%, RF% and IVI of woody layer in Site 6

While site 2 (flood plain) was characterized with clay loam, alluvial soil; soils of sites 5 and 6 (sedentary plains) were sandy clay loam. Site 2 and 5 were dominated by *Dichrostachys cinerea* associated with *Acacia seyal* and *Balanites aegyptica* agreeing with Wichens (1979); while site 6 was dominated by *Acacia nilotica* associated with *Acacia seyal*.

In this study *Faidherbia albida* is represented with low IVI in sites 3 (2.93) and 5 (4.42); *Anogeissus leiocarpus* is reported in sites 1 (IVI=7.58), 4 (IVI=6.41), 5 (IVI=5.17) and 6 (IVI=5.18). These findings disagree with Wichens (1979) who recorded *Faidherbia albida* pure stand at Zalingei and reported dominance of *Anogeissus leiocarpus* in sedentary plain and lower hill slope. Elsiddig (2007) reported that the Wadi systems in Jebel Marra, including Wadi Azum, were dominated by *Faidherbia albida*. Low IVI values of the two above mentioned species is attributed to extensive human interference in the recent 50 years as fuel, in charcoal production, building construction and animal feed in the dry season.

Species richness:

The species richness is not uniformly distributed in the studied sites. Maximum species richness (21) was reported in site 1 in the lower hill slope while minimum (14) in site 2 a flood plain (fig. 10). This result is very low in comparison with Natta *et al*. (2003) who reported 129 -358 in Riparian Forests in West Africa. These values are within the ranges of Ismail and Elawad, (2017) 6-21 and Ismail (2020) in Alfula Area, West Kordofan 9 – 16; and are relatively small compared to the number of species calculated in other studies in Sudan such as Ismail and Mahmoud, (2010) who reported 32, and Ismail and El Sheik, (2016) (28). Therefore, this study highlights that the sites were mosaic of different richness values.

Diversity indices

In tropical forests, Shannon index values (H) are generally high (5.06 - 5.40) (Knight 1975). Fig. 10 showed that (H) values in this study was all most between 2.22 – 2.8 in the low hill slopes and 2.18 - 3.08 in the plains. These results are higher than the findings of Ismail and Mahmoud (2010) who recorded H values between 1.8147 - 2.3904, Ismail and El Sheikh, (2016) (H = 1.733), Hasoba *et al*. (2020) in Nuara Reserved Forest, southeastern Sudan (H = 0.204) and Ismail (2020) (H 0.161 – 0.899). The high Shannon index values in the present study could be due to the homogeneity of the studied sites.

Margalof index (D) was found to be between 5.29 - 8.23 in the low hill slopes and 2.72 - 6.9 in the plains. The finding of Ismail and El Sheikh (2016) (D = 4.091) is within the range. High D values in 5 studied sites indicate more diverse communities. As the value of the index increases it means there is more order in the community.

Evenness (E):

Pielou index was found to be 1.87 - 2.13 in the low hill slopes and 1.49 - 2.45 in the plains (Fig. 10). The result is in line with the findings of Ismail and Mahmoud (2010) who recorded E values between 1.8147 - 2.3904; this may be due to relatively similar elevation levels. The results are higher than the findings of Ismail and El Sheikh (2016) who reported E = 0.52 and Ismail (2020) (E 0.179-0.867). High evenness values indicate more species dominance in the ecosystem. Generally, there is no a correlation between species richness and evenness in the present study. Although, site 2 recorded the highest density it shows the lowest diversity values (fig. 10).

Fig. 10: Species Richness, Evenness and Biodiversity Indices in Studied Sites

Similarity Index:

The high similarities between sites based on the woody vegetation types **(**fig. 11) might be attributed to the topography and soil types. The highest similarity was 77.77% between site 5 and 6 sedentary plains followed by 72.22% between site 1 and 4 lower hill slopes; this may be attributed to the fact that these sites were characterized by similar soils, environment characteristics and relatively close elevations. The lower similarity was 68.29% between site 2 and 3 lower hill slope and flood plain respectively; this is due to the differ in topography, and soil type.

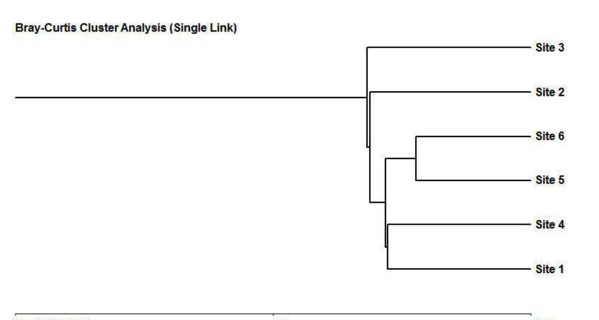

Fig.11: Similarity index between studied sites

CONCLUSION & RECOMMENDATIONS

Conclusion

In conclusion, the result of the studies carried out revealed the presence of 33 woody species in 6 selected sites (3 in low hill slope and 3 in plains) in Zalingei locality. The studied sites were rich in plant diversity and presence variation in density and IVI. Site 2 in the hill slope recorded the highest density and the lowest diversity values. The ecologically dominant woody species were *Acacia senegal*, *Albizia amara*, *Dichrostachys cinerea*, *Balanites aegyptiaca*, *Acacia gerrardii*, *A. nilotica*, *A. seyal* var. *seyal*, *A. seyal* var. *fistula*, *Ziziphus mauritiana* and *Z. spina-christi*. Percentage similarity between sites was relatively high.

Recommendations

Since most of the woody taxa of the study area are important source for livelihood in the form of building material, charcoal, fuel wood, carpentry and other industrial products. This study recommends the preservation of tree species such as *Anogeissus leiocarpus*, *Faidherbia albida* because they are indigenous, ecologically and economically important. Attention should be given to the protection and management of the natural woody vegetation in the form of defining sustainable forest management programs. The presence of vast spaces particular dominated with *Acacia senegal* which is a source of gum Arabic can contribute in the national economy.

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