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Phytosociology and Biodiversity Indices of the Woody plants of Alfula Area, West Kordofan, Sudan

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ABSTRACT

This study was conducted in Alfula area, west Kordofan state. This study aimed at determining the floristic composition, phytosociology, and species diversity of woody species and to produce a checklist of the encountered woody flora. Qualitative and quantitative data collected from fourty circular sample plots of 0.1ha (17.84m radius), The Shannon-Wiever and Pielous indices were used to assess species diversity, also similarity between sampled sites and distribution pattern of species was assessed. Fifty-eight species belongs to16 families were recorded. The diversity indices values varying along studied sites. The total highest density of all trees and shrubs was 866 stem/ha. most dominant species is *Geuara senegalensis*. Most species were aggregately distributed.

1. Introduction

Sudan is one of largest African countries, with an area of 1882000 km^2. Ecologically the vegetation of Sudan was classified into five zones, these zones are: desert, semi-desert, low rainfall woodland savanna, riverian forest, mountain vegetation. The area of this study located in low rainfall woodland savanna (Harrison and Jackson, 1958). Previously several regional studies regarding vegetation and flora has conducted in Sudan in general, while few study has been conducted in the Alfula area, these studies including (Doka and Yagi, 2009; Ibrahiem, 2003). The diversification and highly richness of vegetation cover are the important reasons led to selection of this area for the present study. In-addition to that, the area is considered as an important source of animal wealth. This study aimed at determining the floristic composition, phytosociology, and species diversity of woody species and to produce a checklist of the existing woody flora.

2. Methods

2.1. Study area

The study was carried out in Alfula area, western Kordofan State (Fig.1). The study area is generally flat and dominated by Gardoud soil with exception of limited areas characterized by clay soil around seasonal water courses (Wadies) (table 1). The area of this study was classified as low rainfall woodland savanna where the annual precipitation rate ranging from 250-1000 mm (Harreison and Jackson, 1958; Sahni, 1968).

Table 1. Characteristic feature of selected sites

Site	Location	Latitude (N)	Longitude (E)	Altitude (M)	Habitat
1	Khoe Gaghmni	11 41 061	028 17 882	1639	Khor bank (Clay)
2	Alwadi Alazrag	11 33 505	028 17310	1559	Khor bank (Clay)
3	Shag Alganna	11 40 826	2813383	1736.8	Gardood
4	Tirgado	1147330	2818833	1873.4	Gardood
5	Alodaya road	1150966	2818860	1863.6	Gardood
6	Baboya	1146572	028 27 597	1783.4	Gardood
7	Kadam	12 03 891	028 47 649	1743.8	Gardood
8	Dahia	12 10 402	028 56310	1757.5	Khor bank (Clay)

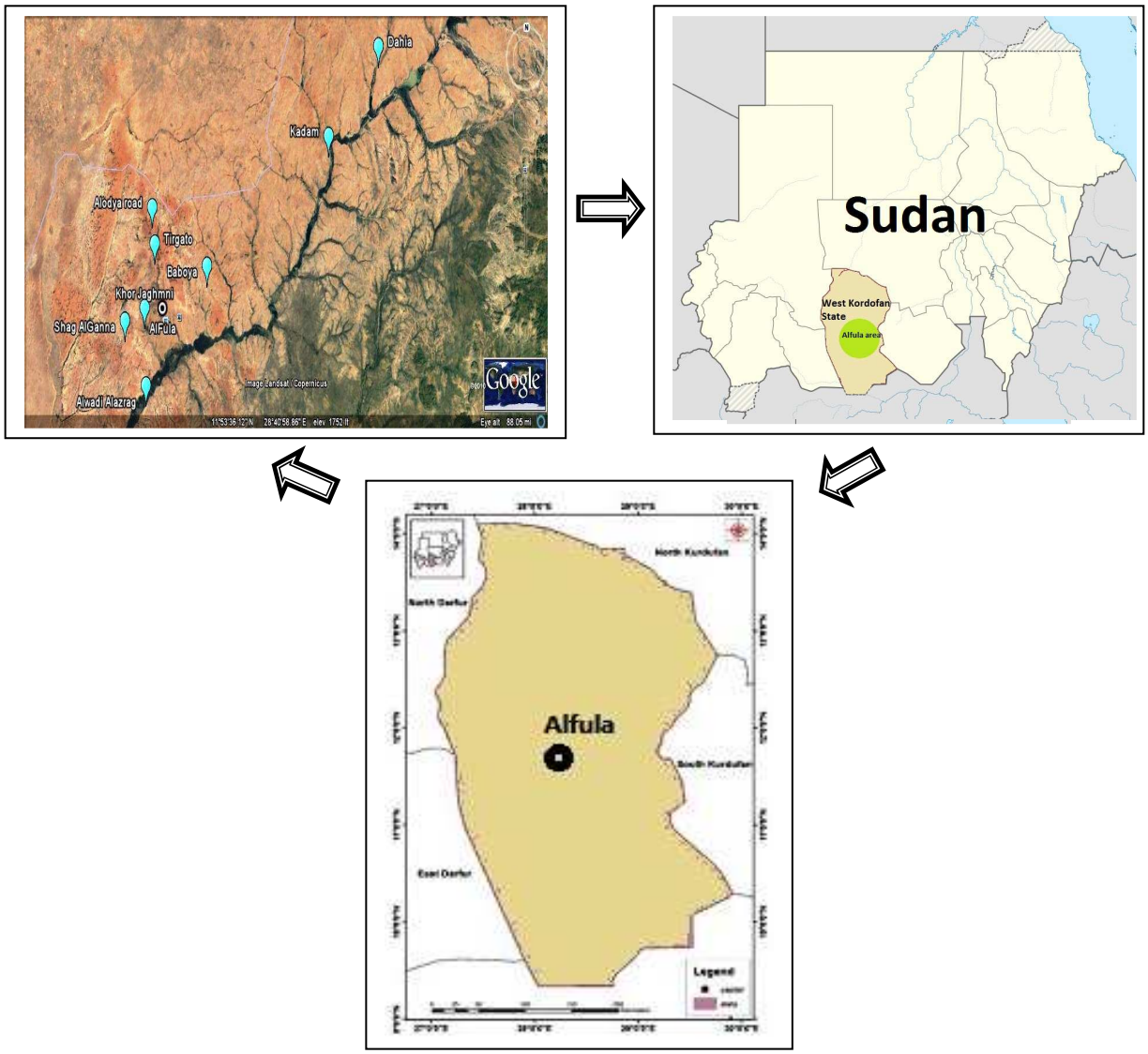


Figure 1. Study area: Alfula area, West Kordofan state, Sudan

2.2. Data collection

The vegetation data collected from 40 systematic circular sample plots of 0.1 ha (radius = 17.84 m) with intervals 0.15 mile between each plots, along 8 line.

2.3. Data analysis

Phytosociological analysis

In order to assess the dominance of species in the vegetation communities, density (D), abundance (A), frequency (F %), relative density (RD %), relative.

$$\text{Density (D)} = \frac{\text{number of plant of a certain species}}{\text{Total area sampled}}$$

$$\text{Relative density (RD \%)} = \frac{\text{Density of species X100}}{\text{Total density of all species}}$$

$$\text{Abundance (A)} = \frac{\text{Total number of individual x 100}}{\text{No. of quadrate where species occur}}$$

$$\text{Relative abundance (RA \%)} = \frac{\text{Abundance of species x 100}}{\text{Total abundance of all species}}$$

$$\text{Frequency (F \%)} = \frac{\text{No. of quadrate where species occur x 100}}{\text{Total numbers of quadrate}}$$

Relative frequency (RF%) = frequency of species x 100
Total frequency of all species

Importance value index (IVI) = RD% + RA% + RF%

Diversity indices

Species richness was determined as the total number of species present in the studied site. The Shannon diversity index applied to estimate woody plant species diversity along the study area (Shannon and Weaver, 1963). This index was calculated by the equation Hs = -Σpi In pi. Where, pi is the proportion of individuals found in the ith species and 'In' denotes the natural logarithm. Pielou index used for estimation of species evenness (E) after (Pielou, 1966). This index was calculated by the equation E = H/lnS. Where: H' is the Shannon-Wiener diversity measure, S is Number of species. Species distribution test and Comparisons of woody plant species composition between different plots were estimated using single linkage cluster analysis based on Jaccard similarity, Biodiversity Pro version 2 (McAleece, 1998).

3. Results and discussion

3.1. Common flora

Botanical account on encountered flora during vegetation survey is given as a checklist. 58 plant species belongs to16 families. The family *Fabaceae* (through its 3 subfamily) is the highest represent with 19 species, followed by *Combretaceae* which represented by 6 species and *Poaceae* which represented by 5 species; while the other families represented by number of species ranging between 1 to 4 (Tab. 2).

Table 2. A checklist of encountered common flora of AlFula area

Family	plant species	Vernacular name	Habit
Asparagaceae subfamily Asparagoideae	*Asparagus flagellaris* (Kunth) Baker.	Dayog	Herb
Poaceae subfamily Chloridoideae	*Eragrostis tremula* Steud.	Bannu	Grass
	Schoenefeldia gracilis Kunth.	Danab Alnaga	Grass
Poaceae subfamily Panicoideae	*Pennisetum pedicellatum* Tan.	Danab Elkadees	Grass
	Cenchrus biflorus Roxb.	Haskanit	Grass
	Cenchrus ciliaris L., Mant. Alt.	Haskanit	Grass
Vitaceae subfamily Vitoideae	*Cissus quadrangularis* L.	Salala	Herb
Zygophyllaceae Subfamily Tribuloideae	*Balanites aegyptiaca* (L.) Delile	Heglig	Tree
Fabaceaea Subfam. Caesalpinoideae	*Bauhinia rufescens* Lam.	Kulkul	Tree
	Cassia seiberiana	Um Kashau, Um Masareen	Tree
	Piliostigma reticulatum (DC.) Hochst.	Kharoub	Tree
	Senna obtusifolia (L.) Irwin & Barneb.	Kawal	Herb
	Tamarindus indica L.	Aradeib	Tree
Fabaceaea subfam. Mimosoideae	*Acacia mellifera* (Vahl) Benth.	Titir	Shrub
	*Acacia nilotica*subsp.*adstringens*(Schum. & Thonn.) Roberty.	Sunot	Tree
	Acacia nilotica subsp. *tomentosa*	Sunot	Tree
	Acacia oerfota (Forssk.) Schweinf.	Laot	Shrub
	Acacia sieberiana DC.	Kuk	Tree
	Acacia senegal (L.) Willd.	Hashab	Tree
		Talih	Tree
	Albizia amara (Roxb.) Boiv.	Arad	Tree
	Albizia anthelmintica Brongn.	Um Takirna	Tree
	Dichrostachys cinerea (L.)White & Arn.	Kadad	Shrub
	Entada africana Guill. & Perr.	Seisban. Entada	Tree
	Faidherbia albida (Del.) Chev.	Haraz	Tree
Fabaceae sub-fam. Faboideae	*Dalbergia melanoxylon* Guill. & Perr.	Abanus	Tree
	Lonchocarpus laxiflorus Guill. & Perr.	Khashkhash Azrag	Tree
	Zornia glochidiata Reichb. ex DC.	Sheleni	Herb
Rhamnaceae	*Ziziphus spina-christi* (L.) Desf.	Sidir	Tree
	Ctenolepis cerasiformis (Stocks) C. B. Clarke.	Sim Elter	Herb
Euphorbiaceae subfamily Euphobioideae	*Euphorbia venenifica* Tremaux ex Kotschy		Shrub

Combretaceae	*Anogeissus leiocarpus* (DC.) Guill. & Perr.	Sahab	Tree
	Combretum aculeatum Vent.	Habeel	Tree
	Combretum glutinosum Perr. ex DC.	Habeel	Tree
	Guiera senegalensis J. F. Gmel.	Ghibeish	Tree
	Terminalia brownii Fresen	Subagh	Tree
	Terminalia laxiflora Engl. & Diels Monogr	Darout	Tree
Anacardiaceae	*Lannea humilis* (Oliv.) Engl.	Layoun	Tree
	Lannea fruticosa (Hochst. ex A. Rich.) Engl.	Layoun	Tree
	Sclerocarya birrea (A. Rich.) Hochst.	Himeid	Tree
Malvaceae subfamily Bombacoideae	*Adansonia digitata* Linn.	Tabaldi	Tree
Malvaceae Subfamily Grewiodeae	*Grewia flavescens* Juss.	Khlekhsan	Shrub
	Grewia tenax (Forsk.) Fiori.	Gudiem	Shrub
	Grewia villosa Willd.	Tikko	Shrub
Malvaceae subfamily Malvoideae	*Sida alba* Linn.	Um Shadeda	Herb
	Sida cordifolia L.	Nayada	Herb
Malvaceae subfamily Sterculiodeae	*Sterculia setigera* Del.	Tartar	Tree
Capparaceae	*Boscia angustifolia* A. Rich.	Sareh	Tree
	Boscia senegalensis Lam.	Mikheit	Tree
	Capparis decidua (Forsk.) Edgew.	Tundub	Small tree
	Capparis tomentosa Lam.		Shrub
Rubiaceae subfamily Ixoroideae	*Catunaregam nilotica* (Stapf.) Tirveng.	Shagart Elmarfaein	Tree
	Feretia apodanthera Del.	Shai Elbitera	Tree
Apocynaceae subfamily Apocynoideae	*Adenium obesum* (Forssk.) Roem & Schult.	Shagart Alsim	Tree
Apocynaceae subfamily Asclepiadoideae	Leptadenia pyrotechnica (Forsk.) Decne.	Marikh	Shrub
Boraginaceae	*Cordia sinensis* Lam.	Andrab	Tree
Acanthaceae Subfamily Acanthoideae	*Hygrophila auriculata* (Schumach.) Heine.	Abu Shweika	Herb
	Peristrophe paniculata (Forssk.) Brummitt.	Abu Rukab	Herb
Bignoniaceae	*Stereospermum kunthianum* Cham.	Khashkhash abiad	Tree

3.2. Density

The total density of all woody plants was varying along different sites. Baboya (Site 6) recorded (866 plant/ha as a highest density of woody plants, while Dahia (Site 8) has recorded (182 plant/ha as a lowest density. *Guiera senegalensis* recorded highest values of relative density (92.61%), (60.74 %) and (47.13 %) in Baboya (Site 6), Tirgado (Site 4) and Alodaya road (Site 5) respectively; *Grewia flavescens* was a second species that recorded high relative density (41.67%) in Alodaya road (Site 5) (Fig. 2, Tab. 3). The highest relative density which recorded by above mentioned species may attributed to those species are not palatable enough for livestock, especially in regeneration stages.

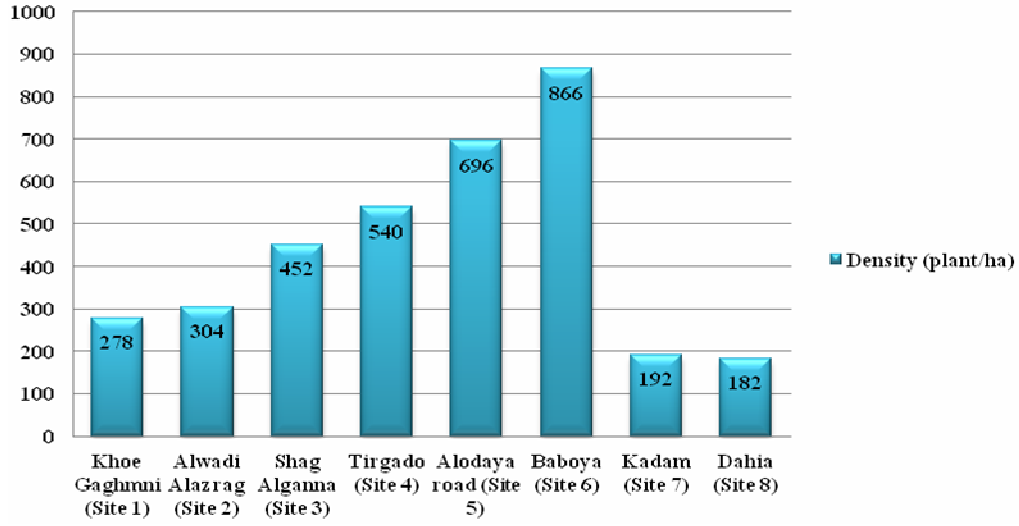


Figure 2. Density along different studied sites

Table 3. density, relative density(RD), relative abundance (RA), relative frequency (RF), importance value index (IVI) and distribution pattern of the plant species in the study area

Species	site 1 (Khor Jaghmni)		site 2 (Alwadi Alazrag)		site 3 (Shag AlGanna)		site4 (Tirgado)		site 5 (Alodya Road)		site 6 (Baboya)		site 7 (Kadam)		site 8 (Dahia)		Aggregation
	RD	IVI	RD	IVI	RD	IVI	RD	IVI	RD	IVI	RD	IVI	RD	IVI	RD	IVI	
Acacia mellifera	0	0	1.32	10.65	0	0	0.37	4.79	0	0	0	0	0	0	0	0	Random
Acacia nilotica subsp *adstringens*	16.6	43.27	0	0	5.75	21.61	4.07	20.13	0	0	0	0	0	0	20.88	50.35	Aggregated
Acacia nilotica subsp. *tomentosa*	0	0	33.55	69.9	0	0	0	0	0	0	0	0	0	0	0	0	Aggregated
Acacia oerfota	0	0	0	0	0	0	0	0	0	0	0	0	5.21	19.09	3.3	15.55	Aggregated
Acacia seiberiana	0.72	6.97	0	0	1.77	11.78	0	0	0	0	0	0			0	0	Random
Acacia senegal	8.63	35.65	0	0	1.33	8.93	0	0	0	0	0	0	5.21	21.13	1.1	7.96	Aggregated
Acacia seyal subsp. *seyal*	20.9	51	25	57.37	0	0	0	0	0.29	5.02	0	0	0	0	0	0	Aggregated
Adenium obesum	0	0	0	0	0	0	0.37	4.79	0	0	0.23	5.66	0	0	0	0	Random
Albizia amara	4.32	19.1	0	0	8.85	32.37	1.48	12.58	4.6	23.53	1.56	16.01	7.29	27.41	8.33	18.12	Aggregated
Albizia anthelmenthica	0	0	0	0	0.44	5.45	0	0	0	0	0.23	5.66	1.04	7.4	0	0	Random
Anogeissus leiocarpa	0.72	6.97	5.26	19.53	0	0	0	0	0	0	0.69	14.82	3.13	14.19	0	0	Aggregated
Balanities aegyptiaca	20.9	51.42	7.24	33.7	1.77	10.67	0.74	6.45	0	0	0	0	22.92	53.27	6.59	24.49	Aggregated
Bauhenia reticulata	0	0	0	0	0	0	0.37	4.79	0.29	5.02	0	0	8.33	26.62	6.59	23.02	Aggregated
Bauhenia rufescens	0	0	0	0	0	0	0.37	4.79	0	0	0	0	0	0	2.2	11.76	Random
Boscia angustifolia	0	0	0	0	0	0	1.11	11.78	0.86	9.69	0	0	0	0	0	0	Aggregated
Boscia senegalensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38.46	82.43	Aggregated
Cassia seiberiana	0	0	0	0	0	0	0.74	8.28	0.86	9.69	0	0	0	0	0	0	Aggregated
Catonaregam nilotica	0	0	0.66	6.15	0	0	0	0	0	0	0	0	0	0	0	0	Random
Combretum aculeatum	6.48	23.25	0	0	3.98	19.39	0	0	0	0	0	0	4.17	17.58	0	0	Aggregated
Combretum glotinosum	0	0	0	0	1.33	8.93	0.37	4.79	0	0	0.23	5.66	2.08	10.79	0	0	Random
Cordia sinensis	0	0	0.66	6.15	0	0	0	0	0	0	0	0	0	0	0	0	Random
Dalborgia melanoxylon	0	0	4.61	19.96	3.54	18.12	1.48	10.32	1.72	14.64	2.31	26.22	0	0	0	0	Aggregated
Dicrostachys cinerea	0	0	0.66	6.15	0	0	0	0	1.72	14.64	0	0	0	0	0	0	Aggregated
Feidherbia albida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.1	12.13	Random
Feretia apodanthera	0	0	14.47	40.25	0	0	0	0	0	0	0	0	0	0	0	0	Aggregated
Guiera senegalensis	0	0	0	0	38.5	81.59	60.74	126.3	47.13	106.53	92.61	201.33	31.25	74.55	0	0	Aggregated
Grewia flavescences	0	0	0	0	31.86	70.07	25.56	60.36	41.67	96.18	2.31	18.97	0	0	0	0	Aggregated
Grewia villosa	5.76	21.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Aggregated
Lannea fruticasa	0	0	0	0	0	0	1.48	10.32	0	0	0	0	0	0	0	0	Aggregated
Lannea humilis	0	0	0	0	0	0	0	0	0	0	0.23	5.66	0	0	0	0	Random
Lonchocarpus laxiflorus	0	0	0	0	0	0	0.37	4.79	0	0	0	0	0	0	0	0	Random
Sclerocarya birrea	0	0	0	0	0	0	0.37	4.79	0.29	5.02	0	0	0	0	0	0	Random
Asparagus flagellaris	0	0	0	0	0.44	5.45	0	0	0	0	0	0	0	0	0	0	Random
Streospermum kunthianum	0	0	0	0	0	0	0	0	0.29	5.02	0	0	0	0	0	0	Random
Tamarindus indica	0	0	4.61	18.05	0	0	0	0	0	0	0	0	0	0	1.1	7.96	Aggregated
Terminalia brownii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.2	11.76	Random
Terminalia laxiflora	0	0	0	0	0	0	0	0	0.29	5.02	0	0	0	0	0	0	Random
Ziziphus spina christi	15.1	40.69	1.97	12.13	0.44	5.45	0	0	0	0	0	0	9.38	27.97	12.09	34.48	Aggregated

3.3. Dominance

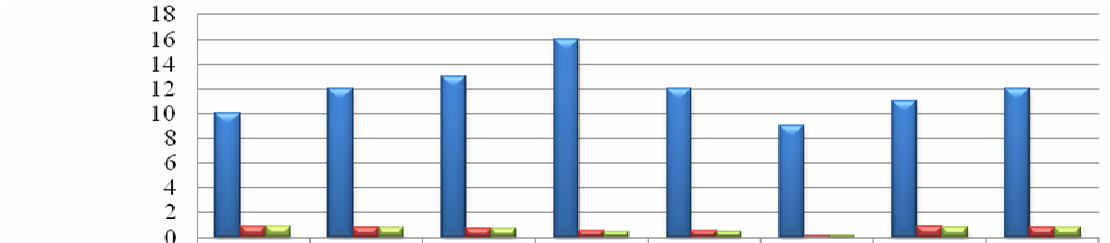
The dominance of the plant species was determined using the Importance Value Index (IVI) of assessed species. From the analysis results the most dominant species is *Geuara senegalensis* with values of IVI (201.33),(126.3) (106.53), (81.59) and (74.55) in site 6 (Baboya), site 4 (Tirgado), site 5 (Alodya Road), site 3 (Shag AlGanna) and site 7 (Kadam) respectively, and followed by *Grewia flavescens* with values of IVI (96.18), (70.07) and (60.36) in site 5 (Alodya Road), site 3 (Shag AlGanna) and site4 (Tirgado) respectively, and *Acacia nilotica* subsp. *tomentosa* with values of IVI (69.9) in site 2 (Alwadi Alazrag); while the other species have an IVI ranging between 51 - 4.79. The dominance of *Geuara senegalensis* may attribute to the suitability of environmental factors such as precipitation amount, temperature and soil type especially all those sites in which this species is dominant are Gardoud soil (Tab. 3).

3.4. Distribution Patterns

Distribution pattern of plant were assessed and results showed that 15 plants were randomly and 22 were aggregated (Tab. 3). It I clear from above mentioned results that most of plant species were aggregate distributed and this indicates that the habitat is suitable for these species.

3.5. Diversity indices

The results revealed that richness was highest at site 4 (Tirgado) (16), followed by site 3 (Shag Alghana) with richness value (13). The highest Shannon diversity index was 0.899 in site 7 (Kadam), followed by 0.867 in site 1 (Khor Jaghmni), whereas the least Shannon diversity index was 0.161 in site 6 (Babya). The highest species evenness index was recorded in site 1(Khor Jaghmni) (0.867), whereas the least evenness index was 0.179 in 6 (Babya) (Fig.3). These values are relatively small when compared to the values that calculated in other sites in Sudan such as Jebel ELDair (Ismail and Mahmoud, 2010), Nuba mountains (Ismail and Alawad, 2017), and Jebel AlGerri (Ismail and ElSheikh, 2016). The decrease of diversity richness may due to that the area of this study is considered as one of important animal routes in Sudan, where as the animal browsing the trees and removing the regeneration cover.



	Khor Jaghni (Site 1)	Alwadi Alazrag (Site 2)	Shag AlGanna (Site 3)	Tirgado (Site 4)	Alodya Road (Site 5)	Baboya (Site 6)	Kadam (Site 7)	Dahia (Site 8)
Rishness	10	12	13	16	12	9	11	12
Shannon index	0,867	0,806	0,733	0,537	0,507	0,161	0,899	0,797
Evenness index	0,867	0,746	0,658	0,446	0,47	0,179	0,807	0,765

Figure 3. Species richness and diversity indices of woody plants

3.6. Site similarity

The similarity measures indicated that the higher percentage of similarity was found between Site 3 (Shag AlGanna) and Site 7 (Kadam), where as (44.4%) of species were shared between the two sites, followed by (38.09%) between site 3 (Shag AlGanna) and site 4 (Tirgado) (Fig. 4), this might be explained by the fact that these plots have similar altitudes and environment characteristics specially these sites are located in Gardood soil..

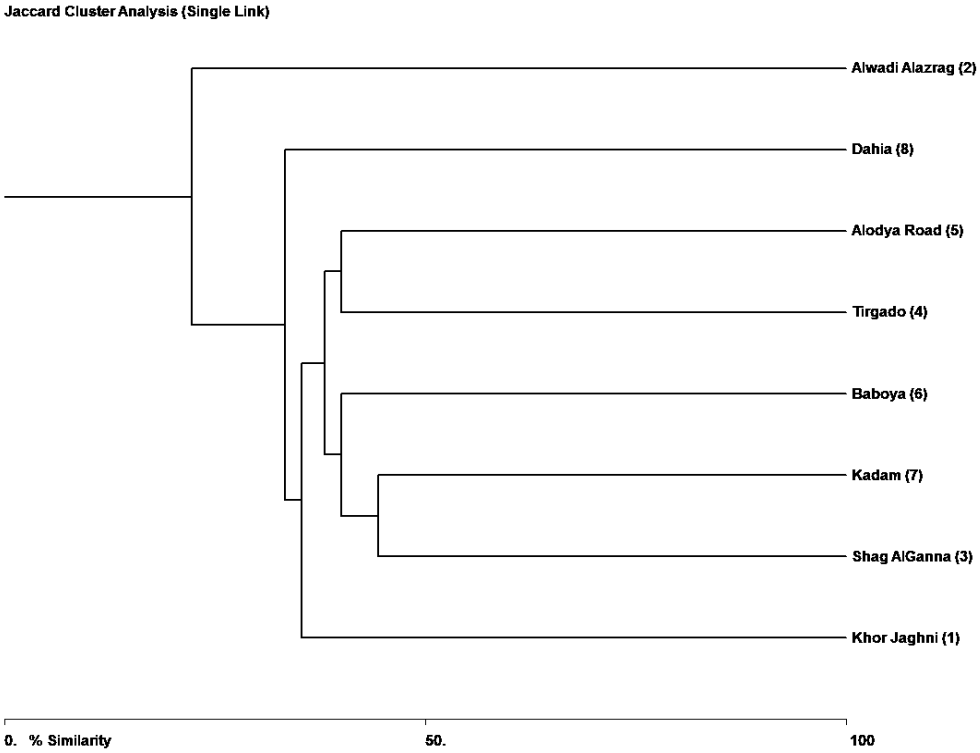


Figure 4. Dendrogram showing percentage of similarity between studied sites

4. Conclusion

The results of the study revealed that Alfula area was varying in richness of plant diversity of the woody species within different sites. In addition, the study showed that the density is ranging from 866 stem/ha as a highest value density to 182 stem/ha as a lowest value density and most of the species were aggregately distributed with higher percentage of similarity for most studied sites. the study area is characterized by relatively low diversity of woody plant when compared with the areas that located in the same ecological zone, A checklist of trees and shrubs that were existing in the study area is produced and the species are listed, (Tab.2).

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