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Flora Diversity, Phytosociology and Distribution Pattern of the Woody Vegetation and Its Relation to Soil Types, in Kalogi District, Nuba Mountains, Sudan

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ABSTRACT

The work is documents the findings of ecological parameters, which have been carried out in the low rainfall woodland savanna of the Nuba Mountains, Sudan. Filling the information gap on the woody vegetation along different habitats in Kalogi district. The vegetation sampling and data analysis were done following standard procedures. Fourty five plant species belonging to 29 genera and 14 families have been documented. The most common plant species based on the importance value index are Dichrostachys cinerea (IVI-98), Vachellia seyal (IVI-28) and Balanites aegyptiaca (IVI-25) respectively in dark cracking clay soil habitat. On the other hand the most common species on GARDOUD soil habitats are Hyphaene thebaica (IVI-37), followed by Balanites aegyptiaca (IVI-35), Combretum hartmannianum (IVI-23), Vachellia oerfota (IVI-20) and Albizia amara (IVI-16) respectively. Fabaceae is found to be the most dominant family. The distribution pattern revealed that 95.6% of species showed contiguous distribution, while 4.4% were randomly distributed. GARDOUD habitats showed the highest values of species richness and diversity indices as flow: richness of 39 species, Shannon-Wiener's (H') (2.77), Pielou index (E) (.076), Simpson index (D) (0.9), Margalef index (M) (5.9).

INTRODUCTION

Nuba Mountains describes a mountainous region approximately 10° to 12° N, and 29° to 31° E, surrounded by plains. It is also a region that, for the most part, lies in the federal state of South Kordofan (Ille, 2015). Nuba Mountains can be classified as one of the richest and most diversified regions in terms of vegetation cover components, beside Jebel Merra in Darfur, Jebel ElDair in North Kordofan, Ingassana Hills in the Blue Nile, and Red sea hills in the Red Sea.

Kalogi district is where is study is conducted and is located in Gadeer locality which is one of the 16 localities of South Kordofan State.

The study of plant communities and their classification is termed phytosociology (Mishra et al. 2012; Ahmad and Shaukat, 2012). 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 Convention on Biological Diversity (1992) defined Biodiversity as "the variability among living organisms from all sources including inter alia, terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part; this

includes diversity within species, between species, and of ecosystems.

Species richness refers to the number of species in a particular area, whereas species diversity refers to a combination of richness and relative abundance (Newton, 2007). A comprehensive review of the methods used for estimating both of these variables is provided by Magurran (2004).

Lack of information on both taxonomical and ecological regarding the woody vegetation of the Kalogi district, besides the climatic changes during the last decades, which may change the floristic composition, encouraged to conduct of this study. The area is considered one of the most important sources of diversified timber and non-timber forest products to the Sudanese markets.

This study aimed to fill the information gap on the woody vegetation along different habitats in the Kalogi district. Furthermore, we expect to have more Comprehensive and detailed information about these native woody vegetation regarding floristic and ecological aspects.

MATERIAL AND METHODS

Study area

The study area is located in the Gadeer locality of Nuba Mountains, South Kordofan. the study area extends from Umdiheileeb village (11° 2'41.56"N, 30°59'7.03" E) in the north to Morong village (10°33'29.60"N, 31° 5'36.12" E) in South and from Tosi village (10°51'50.22" N, 30°49'48.10" E) in the western direction to Gadeer village (10°49'40.02" N, 31° 7'51.11" E) in the east. The vegetation of the area of this study was classified according to (Harrison and Jackson, 1958) as special areas of low rainfall woodland savanna.

Data collection

Systematic sampling has been carried out with 56 circular plots of 01 ha. covering different sites during the period from Nov.-Dec. 2019. In each plot, all woody plants and individual numbers of each have been recorded. According to soil types, the vegetation of the study area was divided into two vegetation communities are: vegetation of dark cracking clay soil and vegetation of GARDOUD soil.

Data analysis

Phytosociology analysis

Phytosociological analysis was conducted for the woody vegetation of the Kalogi district. The density, frequency, and abundance of each species were measured and values were converted to their relative values to obtain the Importance value index (IVI) (Curtis, 1959).

The distribution pattern of the woody species was calculated as abundance/frequency ratio (A/F) as suggested by Whitford (1949) as a measure of contiguousness. The ratio indicates regular (< 0.025), random (0.025 – 0.05), and contiguous (> 0.05) distributions (Curtis and Cottam, 1956).

Diversity indices

Species diversity, equitability and concentration of dominance was computed by using Shannon-Weaver (1949), (Pielou, 1966) and Simpson indices (1949), respectively. Species richness was obtained as a number of species an calculating Margalef's Index (1968). Similarity between habitats was obtained by using the Jaccard index (Jaccard, 1912).

Past 3 packages have been used for data analysis to obtain alpha diversity indices and the Biodiversity pro 2 package used for calculating the Jaccard index and past 3 packages have been used for data analysis.

RESULTS AND DISCUSSION

Floristic composition

In this study, a total of 45 woody species belonging to 29 genera and 14 families were sampled. The most represented family was Fabaceae with 15 species followed by Malvaceae 6 and Anacardiaceae, Combretaceae with 5 species for each. Fabaceae is considered as one the dominant and most important families in Sudan (Table 1), it is also recorded as a dominant family in different studies (Ismail and ElSheikh, 2016; Ismail, 2020a; Ismail, 2020b).

Phytosociology analysis

Density and frequency

A total of 38 tree species were sampled in gardoud soil habitats. The absolute density of total woody

plant species in GARDOUD habitats was 248.1 stem/ha. The highest relative density was recorded by *Hyphaene thebaica* (19%) which is frequent in 30% of sampled plots and *Balanites aegyptiaca* (19%) which is frequent in 53.8% of sampled plots followed by *Combretum hartmannianum* (11%) which frequent in 46.2% of sampled plots (Table 1).

A total of 30 tree species were recorded from habitats of dark-cracking clay soil. The absolute density of total woody plant species in dark-cracking clay soil habitats was 510.1 stem/ha.

The highest relative density was recorded by *Dichrostachys cinerea* (56%) which frequent in 75% of sampled plots followed by *Vachellia seyal* (11%) which frequent in 46% of sampled plots and Balanites aegyptiaca (7.9%) which frequent in 64% of sampled plots (Table 1).

Dominance

The most dominant species in dark cracking clay soil habitat was Dichrostachys cinerea with IVI (98), followed by Vachellia seyal (28), Balanites aegyptiaca (25), *Senegalia senegal* (22) and *Combretum hartmannianum* (16) (Figure 2). While the dominant species in GARDOUD soil habitat was *Hyphaene thebaica* with IVI (37), followed by *Balanites aegyptiaca* (35), *Combretum hartmannianum* (23), *Vachellia oerfota* (20) and *Albizia amara* (16) (Figure 3).

It's clear that *Dichrostachys cinerea* dominated species with the highest value of IVI; this may be due to the suitability of dark cracking clay soil habitat to the requirements of this species, in addition to the fruits and leaves of this species is considered as one of the most important source of fodder for animals during the dry season. This area where species is dominant is considered one of the most important routes of seasonal migration of animals that feed by its fruits, and therefore animals play an important role in spreading their seeds all over the area.

From the results we found that *Balanites aegyptiaca* and *Combretum hartmannianum* listed with dominant species of both habitats, this assures its ability to live in diversified habitats.

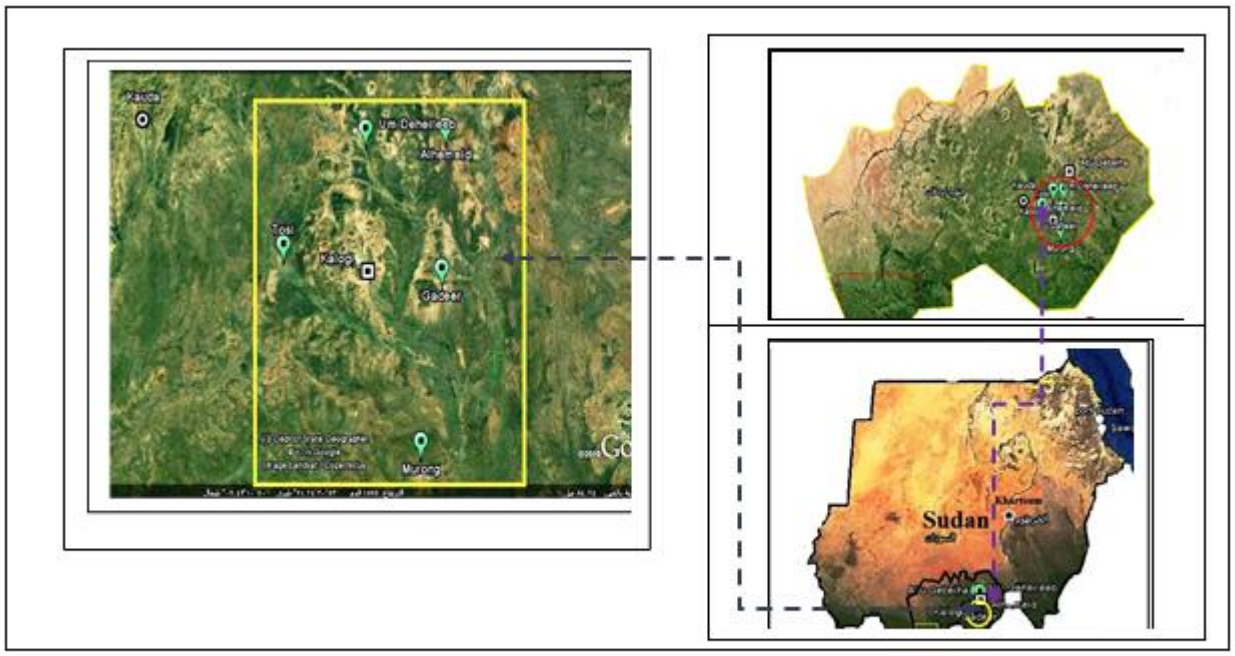

Figure 1. Map of the study area.

***Source**: Google earth 2010.*

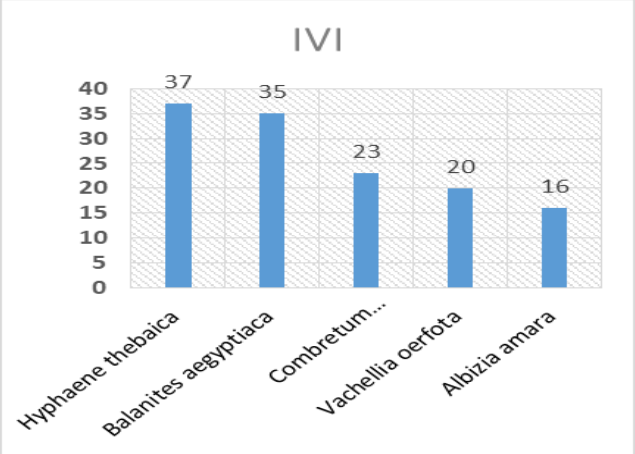

Figure 2: Dominant woody species of GARDOUD soil.

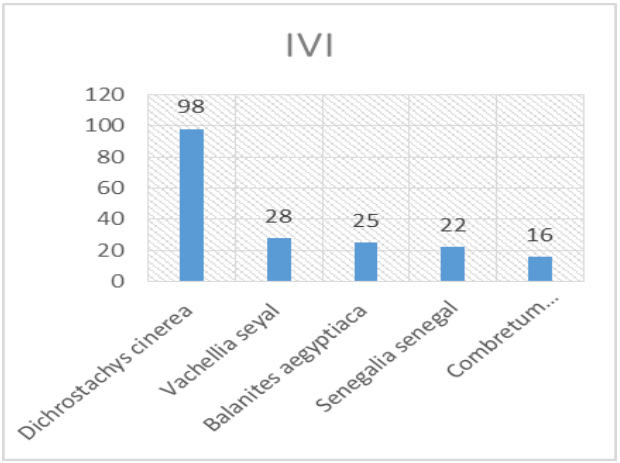

Figure 3: Dominant woody species of soil dark cracking clay habitats

Distribution pattern

Among the studied habitats, distribution pattern of all woody species was contiguous (95.6%) except *Terminalia leiocarpa* and *Combretum aculeatum* were random (4.4%) and no species showed a regular pattern. 15 (34.0%) of the species of contiguous pattern were distributed only in the GARDOUD soil habitat and 5 species (11.6%) were distributed only in dark cracking clay soil habitat, while 23 species (53.5%) of contiguous pattern and the two species of random pattern were distributed in both the two habitats (Table 1).

From the results, it's clear that a contiguous distribution pattern was recorded for the majority of species followed by only two species that showed a random pattern. There was no record of a regular distribution pattern, this may attributed to the absence of severe competition among species; this agreed with the fact that stated by Odum (1971) contiguous pattern of distribution is common in nature, random distribution is found only in very uniform environment and regular distribution occurs where severe competition exists between individuals.

Diversity Analysis

In the study area, species richness and diversity was found higher in GARDOUD soil habitat as compared to Dark cracking clay soil habitat of study area. GARDOUD soil habitat showed higher values in all diversity indices as follow, Shannon-Wiener's (H') (2.77), Pielou index (E) (.076), Simpson index (D) (0.9), Margalef index (M) (5.9) and richness of 39 species (Figure 2); while habitat of Dark cracking clay soil

showed lower values in all diversity indices as follow, Shannon-Wiener's (H') (1.76), Pielou index (E) (.0.52), Simpson index (D) (0.66), Margalef index (M) (3.99) and richness of 30 species (Figure 4). The lowest values of diversity indices may be attributed to intensive human activities such as the continuous expansion of mechanized and shifting agricultural activities in high fertile and productive dark-cracking clay soil; whereas GARDOUD soil rarely be cultivated by seasonal crops. The values of diversity indices in dark cracking soil habitat were relatively low due to the dominance of Dichrostachys cinerea with the largest value of IVI, exceeding the values of all species studied, a similar case was stated by Ismail and Alawad (2017). The low evenness value indicates the dominance of the environment by a few species (Van Breugel et al. 2007).

Similarity

The similarity of species between the two studied habitats is illustrated in Figure 5. revealed that 53.3% of the woody species were shared between the two habitats. This may due to the suitability of the habitats to the requirements of these species. *Balanities aegyptiaca* and *Combretum hartmannianum* can be considered as the most important species in the study area; especially they showed dominance in both habitats.

Table 1: phytosociological parameters and distribution pattern of the studied species

Species	Ver. name	On Gardoud							On clay							Distribution pattern
		D	F	A	D%	F%	A%	IVI	D	F%	A	D%	F%	A%	IVI	
Anacardiaceae																
Lannea fruticosa (Hochst. ex A. Rich.) Engl.	Layoun	2.3	19.2	1.2	2.4	3.2	1	6.6	1.1	4	3	0.2	0.7	2.2	3	Contiguous
Lannea humilis (Oliv.) Engl.	Layoun	0.4	3.85	1	0.2	0.6	0.9	1.6	0	0	0	0	0	0	0	Contiguous
Lannea schimperi (Hochst. ex. A. Rich.) Engl.	Amzak	0.4	3.85	1	0.2	0.6	0.9	1.6	0	0	0	0	0	0	0	Contiguous
Lannea schweinfurthii (Engl.) Engl.	Rutrut	1.5	7.69	2	0.6	1.3	1.7	3.6	3.2	14	2.3	0.6	2.7	1.7	5	Contiguous
Sclerocarya birrea (A. Rich.) Hochst.	Humeid	5.8	38.5	1.5	2.3	6.3	1.3	9.9	1.4	11	1.3	0.3	2	1	3	Contiguous
Arecaceae																
Hyphaene thebaica (Linn.) Mart.	Dom	46	30.8	15	19	5.1	13	37	8.9	11	8.3	1.7	2	6.2	10	Contiguous
Bignonaceae																
Steriospermum kunthianum	Kashkash Abyad	0.4	3.85	1	0.2	0.6	0.9	1.6	0.7	7	1	0.1	1.4	0.7	2	Contiguous
Burseraceae																
Boswellia papyrifera (Del.) Hochst.	Tarak trak	10	11.5	8.7	4	1.9	7.4	13	0.4	4	1	0.1	0.7	0.7	1	Contiguous
Commiphora africana (A. Rich) Engl.	Gafal	0.4	3.85	1	0.2	0.6	0.9	1.6	0	0	0	0	0	0	0	Contiguous
Capparaceae																
Boscia angustifolia A. Rich.	Sareh	1.2	11.5	1	0.5	1.9	0.9	3.2	0.7	4	2	0.1	0.7	1.5	2	Contiguous
Capparis deciduas (Forsk.) Edgew.	Tandub	0.4	3.85	1	0.2	0.6	0.9	1.6	0	0	0	0	0	0	0	Contiguous
Celastraceae																
Maytenus senegalensis (Lam.) Exdl.	Youi	0.4	3.85	1	0.2	0.6	0.9	1.6	0	0	0	0	0	0	0	Contiguous
Combretaceae																
Combretum aculeatum Vent.	Shuheit	3.5	15.4	2.3	1.4	2.5	1.9	5.9	4.6	25	1.9	0.9	4.7	1.4	7	Random
Combretum hartmannianum Schwein f. Beitr.	Habeel	26	46.2	5.7	11	7.6	4.8	23	10	11	9.3	2	6.9	6.9	16	Contiguous
Combretum molle R.Br. ex G. Don.	Habeel Kharsha	1.5	7.69	2	0.6	1.3	1.7	3.6	0	0	0	0	0	0	0	Contiguous
Guiera senegalensis J. F. Gmel.	Gubeish	3.1	11.5	2.7	1.2	1.9	2.3	5.4	0	0	0	0	0	0	0	Contiguous
Terminalia leiocarpa Baill.	Sealak/Sahab	9.2	50	1.8	3.7	8.2	1.6	14	4.6	21	2.2	0.9	4.1	1.6	7	Random
Fabaceae																

Senegalia laeta (R.Br. ex Benth.) Seigler & Ebinger	Shubahi	0	0	0	0	0	0	0	0.4	4	1	0.1	0.7	0.7	1	Contiguous
Senegalia mellifera (Benth.) Seigler & Ebinger	Kitir	4.6	15.4	3	1.9	2.5	2.6	7	5	14	3.5	1	2.7	2.6	6	Contiguous
Senegalia polyacantha subsp. *campylacantha* (Hochst. ex A. Rich.) Kyal. & Boatwr.	Um Sinena	0	0	0	0	0	0	0	13	36	3.5	2.4	6.8	2.6	12	Contiguous
Senegalia senegal (L.) Britton	Hashab	13	26.9	4.7	5.1	4.4	4	**14**	38	43	8.8	7.4	8.1	6.5	22	Contiguous
Vachellia gerrardii (Benth.) P.J.H.Hurter	Salgam	0.8	7.69	1	0.3	1.3	0.9	2.4	0.4	4	1	0.1	0.7	0.7	1	Contiguous
Vachellia oerfota (Forssk.) Kyal. & Boatwr.	Laout	16	11.5	14	6.4	1.9	12	20	4.3	7	6	0.8	1.4	4.4	7	Contiguous
Vachellia sieberiana (DC.) Kyal. & Boatwr.	Kouk	0	0	0	0	0	0	0	0.4	4	1	0.1	0.7	0.7	1	Contiguous
Vachellia seyal var. seyal	Talih	0	0	0	0	0	0	0	55	46	12	11	8.8	8.8	28	Contiguous
Albizia amara (Roxb.) Boiv.	Arad	15	46.2	3.2	5.9	7.6	2.7	16	7.1	21	3.3	1.4	4.1	2.5	8	Contiguous
Bauhinia reticulata DC.	Kadawdaw	3.8	7.69	5	1.6	1.3	4.3	7.1	1.8	4	5	0.3	0.7	3.7	5	Contiguous
Dalbergia melanoxylon Guill. & Perr.	Abanous	4.6	26.9	1.7	1.9	4.4	1.5	7.8	0.7	7	1	0.1	1.4	0.7	2	Contiguous
Dichrostachys cinerea (L.)White & Arn.	Kadad	8.8	23.1	3.8	3.6	3.8	3.3	11	284	75	38	56	14	28	98	Contiguous
Lonchocarpus laxiflorus Guill. & Perr.	Khaskhash azrag	0.4	3.85	1	0.2	0.6	0.9	1.6	0.4	4	1	0.1	0.7	0.7	1	Contiguous
Prosopis africana (Guill. & Perr.) Taub.	Abu Srouj	0.4	3.85	1	0.2	0.6	0.9	1.6	0	0	0	0	0	0	0	Contiguous
Tamarindus indica L.	Aradeib	0.8	7.69	1	0.3	1.3	0.9	2.4	0.4	4	1	0.1	0.7	0.7	1	Contiguous
Loganiaceae																
Strychnos innocua Del.	Abugawi gawi	1.5	3.85	4	0.6	0.6	3.4	4.7	0	0	0	0	0	0	0	Contiguous
Malvaceae																
Adansonia digitata Linn.	Tabaldi	2.3	11.5	2	0.9	1.9	1.7	4.5	0	0	0	0	0	0	0	Contiguous
Grewia flavescens Juss.	Khleikhsan	2.3	11.5	2	0.9	1.9	1.7	4.5	0	0	0	0	0	0	0	Contiguous
Grewia mollis Juss.	Basham	0.4	3.85	1	0.2	0.6	0.9	1.6	0	0	0	0	0	0	0	Contiguous
Grewia tenax (Forsk.) Fiori.	Gideim	6.9	23.1	3	2.8	3.8	2.6	9.2	2.1	14	1.5	0.4	2.7	1.1	4	Contiguous
Grewia villosa Willd.	Tuka	2.3	7.69	3	0.9	1.3	2.6	4.8	5.4	14	3.8	1	2.7	2.8	7	Contiguous
Adansonia digitata Linn.	Tartar	0.8	7.69	1	0.3	1.3	0.9	2.4	0	0	0	0	0	0	0	Contiguous
Rubiaceae																

Catunaregam nilotica (Stapf.) Tirveng.	Shajart almarfaeen	1.2	11.5	1	0.5	1.9	0.9	**3**	0	0	0	0	0	0	0	Contiguous
Gardenia ternifolia var. *jovis-tonantis* (Welw.) Verdc.	Abungawi	0	0	0	0	0	0	0	0.7	7	1	0.1	1.4	0.7	2	Contiguous
Meyna tetraphylla (Schweinf. ex Hiern) Robyns.	Simeim	0.4	3.85	1	0.2	0.6	0.9	1.6	0	0	0	0	0	0	0	Contiguous
Rhamnaceae																
Ziziphus spina-christi (L.) Desf.	Sidir	2.3	15.4	1.5	0.9	2.5	1.3	4.7	15	43	3.6	3	8.1	2.7	14	Contiguous
Ulmaceae																
Celtis toka (Frossk.) Hepper &Wood	Muhagria	0	0	0	0	0	0	0	0.4	4	1	0.7	0.7	0.7	2	Contiguous
Zygophyllaceae																
Balanites aegyptiaca (L.) Delile	Higleig	47	53.8	8.6	19	8.9	7.4	**35**	40	64	6.3	7.9	12	4.7	25	Contiguous
		248.1							510.1							

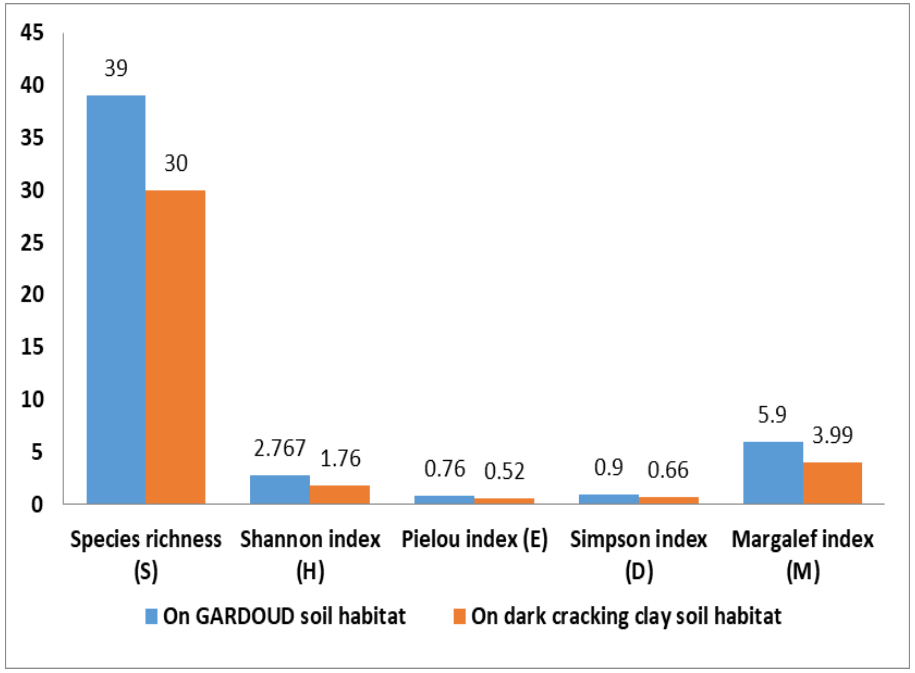

Figure 4: Richness and diversity indices of the two studied habitats

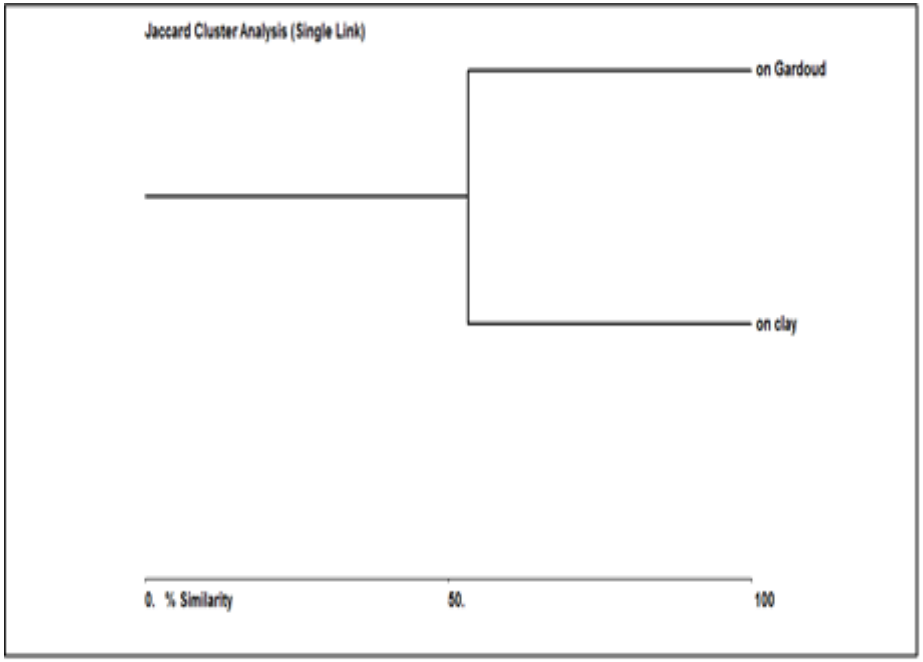

Figure 5: Dendrogram showing the percent of similarity between studied habitats.

CONCLUSION

The woody plants cover a diversity of the studied area and were represented by 45 plant species belonging to 29 genera under 14 families. While the dominant family Fabaceae is represented with 15 species, 7 families are monotypic. *Dichrostachys cinerea* showed the maximum IVI values at habitats of dark-cracking clay soil and the whole study area. The habitats of GARDOUD soil the more diverse than those of dark-cracking clay soil.

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