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Species composition, structure and diversity of woody vegetation at El-Salam Locality, West Kordofan, Sudan

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ABSTRACT

This research investigated woody vegetation composition, frequencies, densities and importance value indices for woody species at El-Salam Locality, West Kordofan State, Sudan during 2016. Systematic sampling of point centered quarter methods were used, where 136 points were systematically distributed every 50 m apart in 6800m *zigzag* transects using GPS coordinates. Vegetation index attributes used for data analysis and comparison. Results of the study revealed that 25 species belonging to 19 genera and 11 families of flowering plants were recorded. Mimosaceae scored the highest contribution (8 species = 32%) to the total species,

Balanites aegyptiaca was the most frequent species represented 128 and it has the highest importance value index (57.3). The highest diameter t breast height was (55.5cm) for *Sclerocary birrea*. Shannon index were (0.351) for *Balanites aegyptiaca* showed highly positive correlation (R^2= 0.969) between tree growth variables for instance the volume and basal area. Development of rehabilitation process and conservation strategies will enhance the woody vegetation diversity in the study area. Further investigations are recommended to understand changes in vegetation pattern to assist policymakers to design suitable conservation tools of forests biodiversity.

Keywords: Mimosaceae, *Balanites aegyptiaca, Sclerocary birrea,* biodiversity

1. INTRODUCTION

The vegetation and plant community studies have recently considered by some researchers and authors for ex. Filmalter (2010) studied vegetation classification and management plan for the Hondekraal section of the Loskopdam Nature Reserve. Also Ismail and Elawad (2015) reported phytosociological Analysis and Species Diversity of Herbaceous Layer in Rashad and Alabassia localities, South Kordofan State, Sudan. The herbaceous flora of the area indicated its importance as one of the productive range region. From other site (Knight and Loucks, 2018) illustrated that quantitative analysis of Wisconsin forest vegetation on the basis of plant function and gross morphology. They reported that quantitative estimates of the importance of plant features such as regardless of species were obtained for each of 149 forest stands distributed throughout Wisconsin in all types of upland forest vegetation. And the spatial relationships in the ordination are used to derive indices that allow calculation of stand values along structural-functional coordinates.

The plant community as defined above is a realistic concept only at a certain scale of observation, i.e. the scale at which it is possible to judge the relative uniformity and distinctness. This 'community scale' will vary with the structure of the community, from some for short grassland to several thousand m^2 in giant forest. Within the relative uniformity many plant communities show differentiation, both vertically and horizontally. The vertical differentiation is most pronounced in woody vegetation where the different layers of trees, shrubs, herbs and moss layers are usually described separately. Horizontal differentiation arises through animal - excrements, bark formation on trees, fallen trees, dead shrubs and grasses (Barkman 1978 and van der Maarel, 2005).

Approach and scale of observation, vegetation, whether loosely defined or approached as a unit (sample) on a higher level of integration, should be described and measured. Vegetation characteristics are either derived from plant morphological characters, usually called structure, or from the plant species recognized, the floristic composition. Description or analysis will only include a relatively small piece of vegetation which is considered representative of a larger unit (Van der Maarel, 2005). This study aimed to estimate vegetation composition, frequencies, densities and importance value indices for wood species in El-Salam Locality, West Kordofan State, Sudan during season 2016.

2. MATERIALS AND METHODS

Study area

The study area was El-Salam Locality which is situated in West Kordofan State, Sudan. It lies between latitudes 11˚ 00'' - 11˚ 50'' N and longitudes 27˚ 30'- 28˚ 35' E, covering an area of 10930 km^2. Administratively, the locality divided into four administrative councils (El-Fula, Kejaira, Babanosa and El-Teboon) (Figure 1). West Kordofan is representative of semi-arid climate in terms of both landscape structure and land surfacecover. Vegetation cover varies according to altitude and rainfall quantity and quality. The climate of the area is typical semi-arid, characterized by hot summers, and cool winters, with a long dry period starting in November and lasting until July i.e. beginning of rainy season (Elagib and Elhag, 2011). The northern part of West Kordofan is covered mainly by sand and some farms lands, whereas southern part is covered mainly by woodland as well as forests of different tree species. The study area experienced severe drought during 1983-1984, 1990-1991 and 2004 2005 (Elagib, 2015).

Sampling

Systematic sampling, of point centered quarter method, was used where 136 points were distributed systematically every 50 m apart in 6800 m zigzag. Each point represents the centre of four compass directions (N, E, W, S) that divided the sampling site into four quarters according to (Mitchell, 2015 and JoVE Science Education Database, 2017). In each quarter, distance was measured from the point to the nearest tree, regardless of species. Tree species composition by number, diameter at breast height (dbh) (cm) and tree height (m) were measured in each quarter.

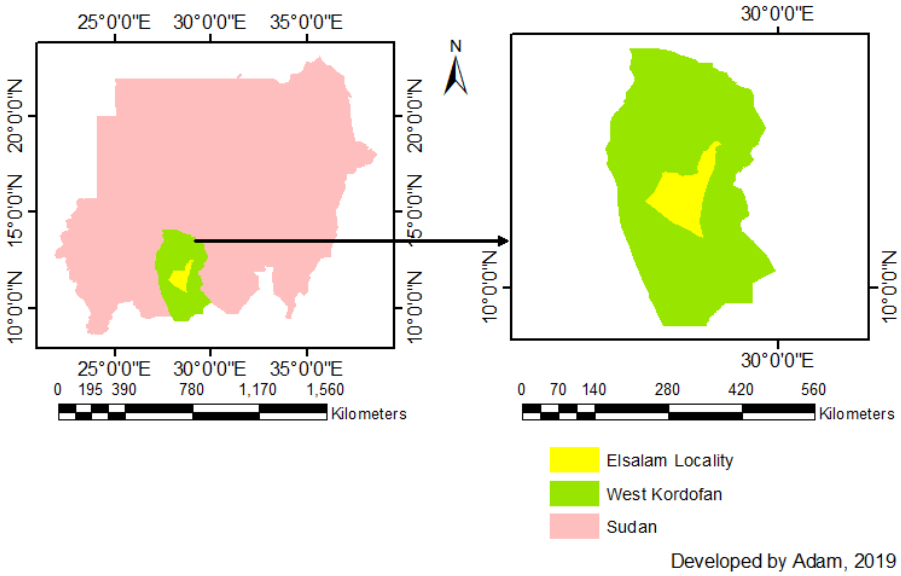

Figure 1 Location of study area in West Kordofan State, Sudan

Calculations and analysis

Point to tree distance for the entire samples were sum up and mean distance was calculated. The average density (number of trees/hectare) was determined using the following equation:

$$\text{Average density} = \frac{10{,}000\ \text{m2/hectare}}{(Average\ point\ to\ tree\ distance\ in\ m)^2/tree} \quad (1)$$

Then density by species for trees was determined. Then, number of individuals in the sample for each species were counted and recorded.

Relative Density = (number of individuals of a species/486) x 100% (2)

Density = (Relative Density/100) x Average Density (3)

Basal Area = Density x Average Basal Area (4)

Relative Basal Area = (Basal Area/Total Basal Area) x 100 (5)

Trees and shrubs were identified according to Sudanese flora by using keys and illustration (El Ghazali, 1987, El-Amin, 1990 and Vogt, 1995) and their uses also were recorded. Summary of format were obtained and reported. Species and families names were check out and update according to Tropicus, ILD and Kew Botanical Nomenclature websites. Biodiversity indicators include abundance, frequency; diversity and dominance were calculated using the following formula:

The data were also used to compute vegetation community indices like species diversity (H') of different tree species and was calculated using the Shannon-Weiner Index (Shannon and Weiner 1963):

$$H' = -\sum\left(\left(\frac{ni}{n}\right) \div \left(n\ \left(\frac{ni}{n}\right)\right)\right) \quad (6)$$

Where, (ni/n) denotes the importance probability of each species in a population, ni is the importance of value of species, and (n) is the total number of individuals of all species in that vegetation type.

Species dominance (Cd) was calculated following the index by Simpson (1949):

$$Cd = \sum\left(\frac{ni}{n}\right) \quad (7)$$

Where, n_i and n are the same as those for Shannon e Weiner information function.

Equitability of evenness refers to the degree of relative dominance of each species in that area. It was calculated according to Pielou (1966) as:

Evenness (e) = H'/log S (8)

Where, H'= Shannon index, S = number of species.

Species richness was determined by Margalefs' index (1968) as:

$d = S_1/\log N$ (9)

Where, (S) is the number of species and (N) is the number of individuals.

3. RESULTS AND DISCUSSION

The study identified the species composition, families and the frequency and density of species (Fig. 2 and Table 1). The total number of identified species in the study was 25 species belongs to 19 genera and 11 families of flowering plants. Mimosaceae has the highest contribution to the total species (8 species = 32%) followed by Combretaceae (4 species = 16%), Caesalpinaceae (3 species = 12%) and Capparaceae and Tiliaceae (2 species = 8%).

It appears that *Balanites aegyptiaca* is the most frequent species with 128 followed 101and 68 of *Acacia nilotica* and *Albizia amra,* respectively while the least frequent species were *Grewia tenax*, *Tamarindus indica* and *Hyphaene thebiaca* in the study area (Table 1). Also *Balanites aegyptiaca* is the most dense species with 1510.4 tree/ha followed 1191.8, 802.4 and 519.2 tree/ha of *Acacia nilotica, Albizia amara* and *Boscia senegalensis,* respectively.

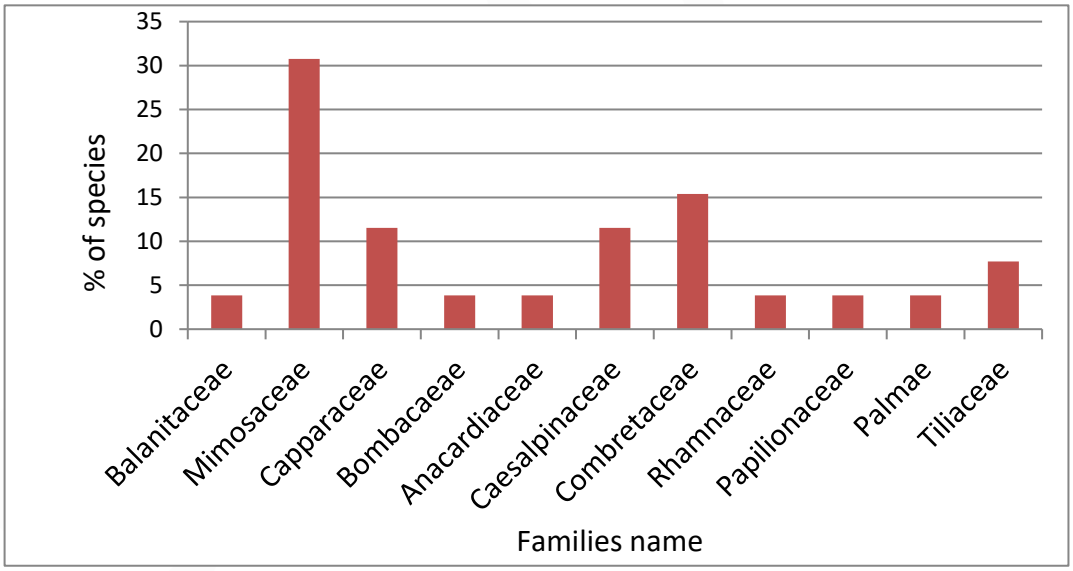

Figure 2 Percentages of families of woody species in El-Salam Locality 2016

Table 1 Woody species composition, frequency and absolute density in El-Salam Locality 2016

Species	Family	Frequency	Density
Balanites aegyptiaca	Balanitaceae	128	1510.4
Acacia nilotica	Mimosaceae	101	1191.8
Albizzia amara	Mimosaceae	68	802.4
Boscia senegalensis	Capparaceae	44	519.2
Adansonia digitata	Bombacaeae	9	106.2
Sclerocarya birrea	Anacardiaceae	5	59.0

Pilostigma reticulatum	Caesalpinaceae	26	306.8
Tamarindus indica	Caesalpinaceae	1	11.8
Anogeissus leiocarpus	Combretaceae	6	70.8
Terminalia brownii	Combretaceae	5	59.0
Acacia nubica	Mimosaceae	21	247.8
Guiera senegalensis	Combretaceae	20	236.0
Ziziphus spina-christi	Rhamnaceae	17	200.6
Combretum spp	Combretaceae	6	70.8
Albizzia anthemantica	Mimosaceae	2	23.6
Dalbergia melanoxylon	Papilionaceae	2	23.6
Hyphaene thebiaca	Palmae	1	11.8
Maerua crassifolia	Capparaceae	3	35.4
Acacia seyal	Mimosaceae	5	59.0
Bauhinia rufescens	Caesalpinaceae	2	23.6
Acacia senegal	Mimosaceae	5	59.0
Acacia mellifera	Mimosaceae	4	47.2
Dichrostachys cinera	Mimosceae	2	23.6
Grewia villosa	Tiliaceae	2	23.6
Grewia tenax	Tiliaceae	1	11.8
Total/average		486	20.576

Balanites aegyptiaca showed a high relative frequency 26.3% and density 26.3% than *Acacia nilotica, Albizia amara, Boscia senegalensis* which had relative frequencies and densities 20.8, 14 and 9.1, respectively (Table 2). While, *Adansonia digitata* has high relative value (13.7) than *Sclerocarya birrea* (12.9%), relative dominance. and *Dichrostachys cinera* and *Grewia villosa* had the least relative dominance (0.1) in the study area.This is in the line of Almula, *et al*.,(2017) who found that *Acacia seyal, Balanites aegyptiaca* and other species were one of the main woody species found in the study area.

Furthermore, it can be observed that species with the highest importance value index in this locality were *Balanites aegyptiaca* (57.3), *Acacia nilotica* (46.3), *Albizzia amara* (31.4) while the least one *Grewia tenax* and *Grewia villosa* (0.6 and 0.9 for each) (Table 2). It is reported that *Balanites aegyptiaca* fruits collection and sale is generated incomes and a subsistence strategy for households in most part of Kordofan region (Adam et al., 2013 and Ibrahim et al., 2014).

The highest dbh was (55.5cm) in *Sclerocarya birrea*, (54.0cm) in *Tamarindus indica* while the lowest dbh was (5.0cm) in *Grewia villosa* and *Dichrostachys cinera* (Table 3). Also the height was ranged from maximum (11.2m) reported for *Sclerocarya birrea*, to (10.9m) in *Anogeissus leiocarpus* and (10.0m) in *Acacia nilotica* while the minimum height was (2m) in *Grewia tenax* and (2.7m) in *Boscia senegalensis*.

Table 2 Woody species relative frequency, density, dominance and importance value index in El-Salam Locality in the year 2016

Species	Relative Frequency	Relative density	Relative Dominance	Importance value index (IVI)
Balanites aegyptiaca	26.3	26.3	4.6	57.3
Acacia nilotica	20.8	20.8	4.7	46.3
Albizzia amara	14.0	14.0	3.5	31.4
Boscia senegalensis	9.1	9.1	0.3	18.4
Adansonia digitata	1.9	1.9	13.7	17.4
Sclerocarya birrea	1.0	1.0	12.9	14.9
Pilostigma reticulatum	5.3	5.3	2.2	12.9
Tamarindus indica	0.2	0.2	12.2	12.6
Anogeissus leiocarpus	1.2	1.2	8.4	10.8
Terminalia brownii	1.0	1.0	8.3	10.4
Acacia nubica	4.3	4.3	0.3	8.9

Guiera senegalensis	4.1	4.1	0.2	8.5
Ziziphus spina-christi	3.5	3.5	1.5	8.5
Combretum spp	1.2	1.2	4.2	6.7
Albizzia anthemantica	0.4	0.4	5.0	5.8
Dalbergia melanoxylon	0.4	0.4	4.8	5.7
Hyphaene thebiaca	0.2	0.2	5.1	5.5
Maerua crassifolia	0.6	0.6	2.8	4.0
Acacia seyal	1.0	1.0	1.4	3.5
Bauhinia rufescens	0.4	0.4	2.2	3.0
Acacia senegal	1.0	1.0	0.6	2.7
Acacia mellifera	0.8	0.8	0.7	2.4
Dichrostachys cinera	0.4	0.4	0.1	0.9
Grewia villosa	0.4	0.4	0.1	0.9
Grewia tenax	0.2	0.2	0.2	0.6
Total	100	100	100	

Table 3 Species means diameters, heights, basal areas and volumes in El-Salam Locality 2016

Species Name	dbh (cm)	Height (m)	Basal area (cm^2)	Volume (m^3)
Acacia mellifera	13.2	3.8	136.088	2.608
Acacia nilotica	33.6	10.0	888.060	44.301
Acacia nubica	8.3	2.5	54.514	0.681
Acacia senegal	12.3	3.0	117.799	1.767
Acacia seyal	18.3	6.0	261.454	7.844
Adansonia digitata	57.2	7.6	2567.27	97.877
Albizzia amara	28.7	5.6	648.438	18.280
Albizzia anthemantica	34.5	7.0	934.346	32.702
Anogeissus leiocarpus	44.8	10.9	1572.01	85.478
Balanites aegyptiaca	33.1	7.2	860.555	30.786
Bauhinia rufescens	23.0	3.0	415.265	6.229
Boscia senegalensis	8.5	2.7	56.217	0.752
Combretum spp	31.7	9.8	787.181	38.70
Dalbergia melanoxylon	34.0	5.0	907.460	22.69
Dichrostachys cinera	5.0	3.0	19.625	0.294
Grewia tenax	7.0	2.0	38.465	0.385
Grewia villosa	5.0	3.0	19.625	0.294
Guiera senegalensis	7.6	3.4	45.143	0.771
Hyphaene thebiaca	35.0	8.0	961.625	38.47
Maerua crassifolia	25.7	7.0	517.141	18.10
Pilostigma reticulatum	22.8	5.3	406.733	10.70
Sclerocarya birrea	55.5	11.2	2417.99	135.0
Tamarindus indica	54.0	8.0	2289.06	91.56
Terminalia brownii	44.7	8.2	1566.16	63.95
Ziziphus spina-christi	18.8	4.6	278.435	6.419
Total	662.1	147.7	18766.7	756.6
Means	26.5	5.9	750.7	30.3

The maximum basal area and volume were (2289.06cm^2/ha) and (135.0m^3) in *Tamarindus indica* and *Sclerocarya birrea*. This is in the line with Kariuki et al., (2006) who reported that habitat characteristics such as altitude, disturbance, site orientation and topography may influence the soil water availability, solar radiation and probably soil nutrient availability, and these affected stand-level growth responses and characteristics.

Considering Shannon index, all species were arranged hierarchy according to index number, it appeared that the highest index were reported for *Balanites aegyptiaca* (0.351389), *Acacia nilotica* (0.326502) and *Albizzia amara* (0.275176), while the lowest one (0.012729) was found in *Grewia tenax*, *Hyphaene thebiaca* and *Tamarindus indica* (Table 4). The findings were in the line with (Eltahir et al., 2009) who studied Assessment of Woody Species Diversity in El Ain Natural Reserved Forest, North Kordofan, Sudan and also (Qose and Proko, 2018) who recorded Phyto-sociological Method for the Evaluation of the Biodiversity and Medicinal Plants.

Table 4 Shannon index (H') of all species presents in El-Salam Locality 2016

Species	N	Pi	ln(pi)	pi*ln(pi)	H'= -Σ(pi)*ln(pi)
Balanites aegyptiaca	128	0.263374	-1.33418	-0.35139	0.351389
Acacia nilotica	101	0.207819	-1.57109	-0.3265	0.326502
Albizzia amara	68	0.139918	-1.9667	-0.27518	0.275176
Boscia senegalensis	44	0.090535	-2.40202	-0.21747	0.217467
Pilostigma reticulatum	26	0.053498	-2.92811	-0.15665	0.156648
Acacia nubica	21	0.04321	-3.14169	-0.13575	0.135752
Guiera senegalensis	20	0.041152	-3.19048	-0.1313	0.131295
Ziziphus spina-christi	17	0.034979	-3.353	-0.11729	0.117286
Adansonia digitata	9	0.018519	-3.98898	-0.07387	0.07387
Anogeissus leiocarpus	6	0.012346	-4.39445	-0.05425	0.054252
Combretum spp	6	0.012346	-4.39445	-0.05425	0.054252
Acacia senegal	5	0.010288	-4.57677	-0.04709	0.047086
Acacia seyal	5	0.010288	-4.57677	-0.04709	0.047086
Sclerocarya birrea	5	0.010288	-4.57677	-0.04709	0.047086
Terminalia brownii	5	0.010288	-4.57677	-0.04709	0.047086
Acacia mellifera	4	0.00823	-4.79991	-0.03951	0.039505
Maerua crassifolia	3	0.006173	-5.0876	-0.0314	0.031405
Albizzia anthemantica	2	0.004115	-5.49306	-0.02261	0.022605
Bauhinia rufescens	2	0.004115	-5.49306	-0.02261	0.022605
Dalbergia melanoxylon	2	0.004115	-5.49306	-0.02261	0.022605
Dichrostachys cinera	2	0.004115	-5.49306	-0.02261	0.022605
Grewia villosa	2	0.004115	-5.49306	-0.02261	0.022605
Grewia tenax	1	0.002058	-6.18621	-0.01273	0.012729
Hyphaene thebiaca	1	0.002058	-6.18621	-0.01273	0.012729
Tamarindus indica	1	0.002058	-6.18621	-0.01273	0.012729
Total	486	1	0	0	0

Note: N = number of individuals; Pi = is the proportion of *S* made up of the *i*th species; and ln is natural logarithm Floristic richness, density, basal area and diversity indices of the woody vegetation species found in the study area were illustrated in table (5), in which the total species density was 21 trees/ha with total basal area equal 18766.7m^2/ha, Shannon (H') equal 2.304, Simpson (D) (0.149), Evenness (e) (1.648) and Margalef (Dmg) (3.8796).The variation in the floristic richness, growth attributes and diversity index may be threatened by natural and human-induced disturbances (Kozlowski, 2002).

The study showed that there were highly positive correlation between tree growth variables in the study area between Volume and basal area (R^2= 0.969), Basal area and diameter (R^2 = 0.966), height and diameter (R^2 = 0.845) and basal area and height (R^2 = 0.771) (Table 6).

Table 5 Floristic richness, number of individuals, and diversity indices in El-Salam Locality 2016

Variable	No.	Variable	No.
No. of species (S)	25	Basal area (m^2/ha)	18766.7
No. of Genera	19	Shannon (H' = $\sum pi \ln pi$	2.304355

No. of families	11	Simpson (D = $\sum(pi)^2$	0.149249
No. of Individuals (N)	486	Evenness (e = H'/log S)	1.648393
Density	20.58	Margalef (Dmg = (S-1)/ln N	3.879598

Table 6 Correlation coefficients for tree growth variables in Elsalam Locality/16

Variable	Diameter (cm)	Height (m)	Basal area (cm^2)	Volume (m^3)
Diameter (cm)	1			
Height (m)	0.845	1		
Basal area (cm^2)	0.966	0.771	1	
Volume (m^3)	0.921	0.825	0.969	1

4. CONCLUSION

The floristic analysis of land use systems showed distinctive variation in floristic composition, diversity, frequency and density status in the study area. It acknowledged that land use history has as much influence in species composition and diversity as biophysical variables. Therefore, opportunities to develop restoration and rehabilitation process through conservation strategies may enhance woody vegetation diversity in the study area. Further studies on vegetation trends are required to understand the changes in vegetation pattern.

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Conflict of Interest: The authors declare that there are no conflicts of interests.

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