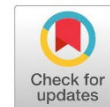**Research Article**   [6]**Open Access**

Ecological assessment and diversity of woody plants in plantations of frankincense trees (Boswellia papyrifera (Del.) Hochst.) in AlGerri Forest, Blue Nile State, Sudan

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Abstract: This study was aimed to evaluate the diversity of shrub and tree species growing under Boswellia papyrifera tree plantation of AlGerri forest reserve in Blue Nile State. 18 systematic circular sample plots of 0.1 ha. (Radius = 17.84) with intervals of 100 m between each plot were used to collect data. A total of 13 woody species belonging to 7 families were determined in two Boswellia papyrifera plantation communities. Boswellia papyrifera dominated the woody species in all vegetation communities, followed by Combretum hartmannianum and Vachellia seyal. The Shannon diversity indexes (H) of community number one and community number two were 0.328 and 0.429 respectively. Pielous Evenness index (E) values in both communities were 0.344 and 0.429 respectively. The density of both communities was 609.1 and 309.08 plant/ha. respectively. The distribution of woody species showed that 61.54% of species were aggregated and 38.46% of species were randomly distributed. Cluster analysis based on the Bray-Curtis single linkage was used to assess the similarity between woody species composition across the 18 sampled plots.

Keywords: Boswellia papyrifera; plantation; diversity; distribution; similarity.

التقييم البيئي وتنوع النباتات الخشبية في مزارع أشجار اللبان (Boswellia papyrifera
Hochst (Del.).) في غابة الجري، ولاية النيل الأزرق، السودان

المستخلص: هدفت هذه الدراسة إلى تقييم تنوع أنواع الشجيرات والأشجار داخل مزارع اشجار اللبان
(Boswellia papyrifera (Del.) Hochst.) في منطقة القري بولاية النيل الأزرق. 18 نمازج
دائرية منتظمة حددت لاخذ وتسجيل البيانات تبلغ مساحتة الواحد منها 0.1 هكتار. (نصف القطر =
17.84) مع مسافات تباعد تبلغ 100 متر بين كل نموذج والأخر، تم استخدامها لجمع البيانات. تم
تحديد ما مجموعه 13 نوعًا خشبيًا تنتمي إلى 7 عائلات في مجموعتين من مزارع اشجار اللبان.
ساد نوع اشجار اللبان (Boswellia papyrifera) على الأنواع الخشبية في جميع مجتمعات
الغطاء النباتي، وتليها انواع الهبيل (Combretum hartmannianum) والطلح (Acacia
seya). كان مؤشرا التنوع في شانون (H) للمجتمع (1) والمجتمع (2) 0.328 و0.429 على
التوالي. كانت قيم مؤشر (E) Pielous Evenness في المجتمع (1) المجتمع (2) 0.344
و0.429 على التوالي. كثافة المجتمع (1) والمجتمع (2) 609.1 و309.08 نبات / هكتار. على
التوالى. أظهر توزيع الأنواع الخشبية أن 61.54% من الأنواع تتواجد في تجمعات في توزيعها
و38.46% من الأنواع موزعة عشوائياً. تم استخدام التحليل العنقودي المستند إلى الرابط الفردي
Bray-Curtis لتقييم التشابه بين تكوين الأنواع الخشبية عبر 18 نموزج عينة.
الكلمات المفتاحية: التقييم البيئي، النباتات الخشبية، أشجار اللبان، منطقة القري، ولاية النيل الأزرق،
السودان.

INTRODUCTION

Sudan is a vast country that exhibits wide variation in climate, topography, and soils. It has a total area of approximately 1.882 million km2. It lies between latitude 4o -22o N. and longitude 22o-26o E. and covers a wide range of habitat varying from desert in the north to high rainfall wood land savanna in the south. Boswellia papyrifera in Sudan is a common savanna tree that occurs on rocks or hill, slopes in low rainfall wood land savanna (Harrison & Jackson, 1958). Naturally Boswellia papyrifera covers large areas in different parts of Sudan south latitude 14 N°, includes Blue Nile (around Jebel Gerri and Fung) and in the eastern Sudan extending from Gala-al-Nahal to Kurmuk (Khan, 1972). In South Kordofan it occurs in the Nuba mountains (El Amin, 1990). In North Kordofan on higher slopes of Jebel ElDair (Ismail & Mahmoud, 2010).

Boswellia papyrifera tree faces problem of natural regeneration, which was observed by Khan, who reported zero regeneration in Blue Nile State (Khan, 1972). This obviously means that the species is decreasing due to absence or difficulties of natural regeneration. This situation coupled with the recent tree use for fodder and repeated tapping for resin of this tree. In spite of this phenomenon of absence of natural regeneration of Boswellia papyrifera tree but still there is some regeneration of other woody species in both stands. This study aimed to evaluate the diversity of shrub and tree species growing under the Boswellia papyrifera tree plantation of AlGerri forest in Blue Nile State.

MATERIALS AND METHODS

Study area

The study was carried out in AlGerri, Blue Nile State, 30 km southeast of Eldamazin Town (Figure 1). It is characterized by heavy rainfall starting from April to November ranging from 300-800 mm/annum with peak months being July and September. The mean maximum temperature ranging between 32 C° to 40 C° and mean minimum temperature between 17 C° to 26 C° , with 20% to 80% relative humidity (Osman & Idris, 2012). The soil is cracking clay soil away from the hill, turning to gravelly light clay soil with good drainage.

Data collection

The vegetation data were collected from 18 systematic circular sample plots of 0.1 ha. (Radius = 17.84) with intervals 100 m between each plots, along 2 line transects across the plantations using GPS (Garmin version 12). Plant species in each plot were counted and recorded at individual level, and plant specimens were also collected, numbered, pressed and taken to Soba Forests Herbarium, Forestry Research Centre, for identification, confirmation and deposition following standard classification systems (Bridson & Forman, 1992).
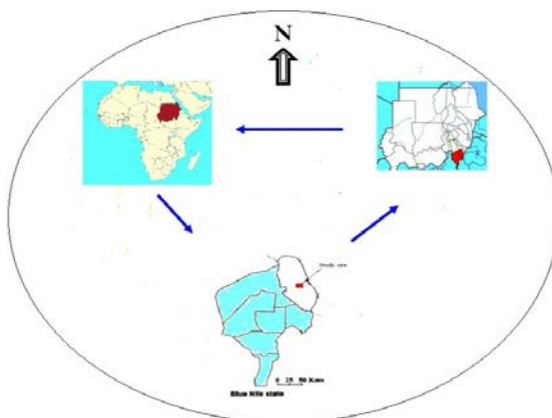

Figure: (1). Map of study area.

Data analysis

Phytosociological parameters
Relative density, relative abundance and relative frequency were estimated following Misra method (Misra, 1968), while the Importance Value Index (IVI) was estimated by adding the values of RD, RA and RF using the Shukla and Chandel method (Shukla & Chandel, 1980).

Diversity indices
Species richness was determined as the total number of species present in the studied site. The Shannon diversity index was applied to estimate woody plant species diversity along the study area (Shannon & 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 was used for estimation of species evenness (E) after Pielou (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 Bray-Curtis similarity (McAleece, 1998), Biodiversity Pro. version 2.

RESULTS

Floristic Composition and Diversity of Species
A total of 13 woody species belonging to 7 families were determined in both Boswellia papyrifera plantation communities (close to hill community number one and close to clay community number two (Table 1). 9 species were recorded in community [1] and 10 species in community [2]. The family with highest number of species in community [1] was Combretaceae with 3 species, followed by Fabaceae with 2 species. In stand (2) the highest representation was of Combretaceae and Fabaceae with 3 species for each.The Shannon diversity indexes (H) of both communities were 0.76 and 0.99 respectively. The results also revealed that the Pielous evenness index (E) values in community [1] community [2] were 0.344 and 0.429 respectively. While the density of community [1] and community [2] were 609.1 and 309.08 plant/ha. respectively (Figure 2).

Table: (1). Characteristic feature of the studied samples.

| Sample plot	Soil Type	Community
1	Pure Rocky and stony	1
2	Pure Rocky and stony	1
3	Pure Rocky and stony	1
4	Pure Rocky and stony	1
5	Pure Rocky and stony	1
6	Pure Rocky and stony	1
7	Pure Rocky and stony	1
8	Pure Rocky and stony	1
9	Rocky and stony mixed with cracking clay	2
10	Rocky and stony mixed with cracking clay	2
11	Rocky and stony mixed with cracking clay	2
12	Rocky and stony mixed with cracking clay	2
13	Rocky and stony mixed with cracking clay	2
14	Pure Rocky and stony	1
15	Pure Rocky and stony	1
16	Rocky and stony mixed with cracking clay	2
17	Pure Rocky and stony	1
18	Rocky and stony mixed with cracking clay	2
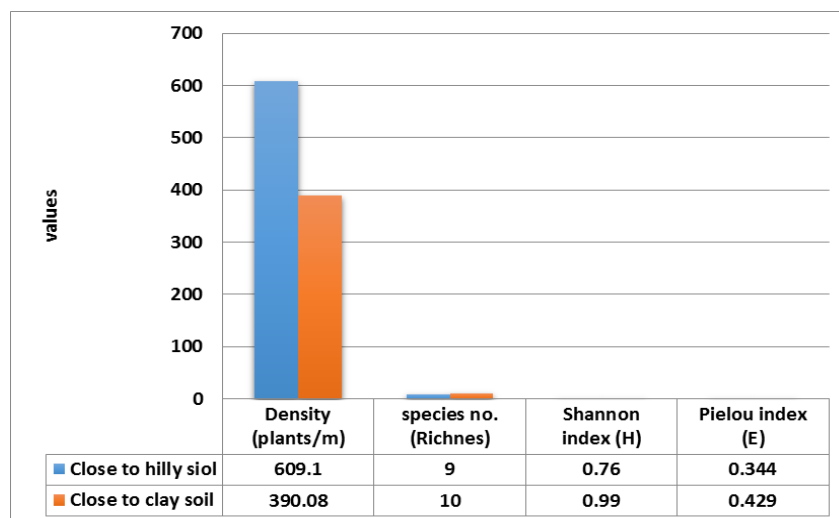
Figure: (2). Species richness, diversity indices and density of the two communities

Phytosociological parameter

Relative density ranges between 76.72 and 0.15 in community [1] and between 72.88 and 0.38. The highest values of relative density were recorded by Boswellia papyrifera (76.72 and 72.88%) in both communities respectively and followed by Combretum hartmannianum (17.76%) in community [1] and by Vachellia seyal (19.92%) in stand [2]. While the lowest value in stand [1] was (0.15%) recorded for Combretum collenum and in stand [2] was (0.38%) recorded for Lannea fruticosa. Also Boswellia papyrifera recorded highest relative abundance and relative frequensy in both stands, followd by Combretum hartmannianum in community [1] and Vachellia seyal in community [2].

Dominance of species was determined based on the calculated IVI values. It was found that in community [1] Boswellia papyrifera was the dominant species with highest IVI (172.45) followed by species like Combretum hartmannianum. (61.6), Lannea fruticosa (27.14), Pterocarpus lucens (8.83) etc. Boswellia papyrifera also dominated stand [2] with highest value of IVI (151.56) followed by Vachellia seyal (45.74), Combretum hartmannianum (30.74), Anogeissus leiocarpa (17.17), Zizphus spina-christi (10.88) etc. (Table 2).

Species distribution

Distribution of woody species was assessed and results showed that 61.54% of species were aggregated, included Boswellia papyrifera, Balanites aegyptiaca, Calotropis procera, Vachellia seyal, Combretum aculeatum ,Combretum hartmannianum, Lannea fruticosa and Pterocarpus lucens. While 38.46% of species were randomly distributed, these includes Senegalia senegal, Anogeissus leiocarpa, Combretum collenum, Lonchocarpus laxiflorus and Zizphus spina-christi.(Table 2).

Similarity

Cluster analysis based on the Bray-Curtis single linkage similarity value, revealed the similarity between woody species composition across the 13 sampled plots. Sample plot 7 and sample plot 14 shows highest similarity with percentage 93.1% (Figure 2), this may be due to the similar habitat of both samples, especially the two samples located in the same type of soil (Table 1), followed by 91.7% which indicated the similarity between sample 10 and sample 15. While sample plot 1 and sample plot 8 shows lowest similarity with percentage 46.8%.
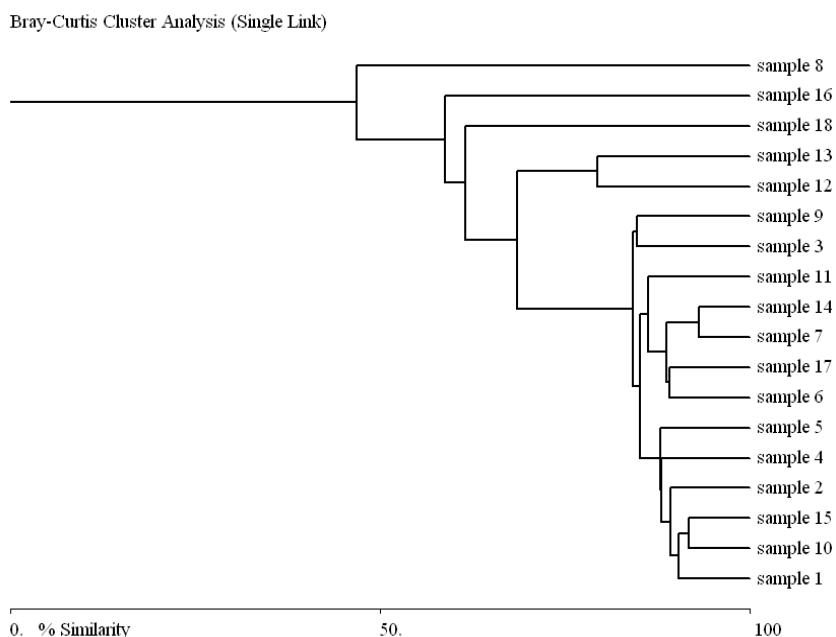
Bray-Curtis Cluster Analysis (Single Link)

sample 8
sample 16
sample 18
sample 13
sample 12
sample 9
sample 3
sample 11
sample 14
sample 7
sample 17
sample 6
sample 5
sample 4
sample 2
sample 15
sample 10
sample 1

0.   % Similarity   50.   100

Figure: (3). Similarity between different sampled plots of study area, using Bray-Curtis (CN, quantitative version of Sorensen index) index.

Table: (2). Phytosociological parameters and Distribution pattern of woody plant species in both communities.

Family	Plant species	Relative density		Relative abundance		Relative frequency		IVI		Distribution pattern
		hilly	clay	hilly	clay	hilly	clay	hilly	Clay	
Anacardiaceae	*Lannea fruticosa* (Hochst. ex A. Rich.) Engl.	2.54	0.38	3.01	1.92	21.59	3.45	27.14	5.75	Aggregated
Apocynaceae	*Calotropis procera*(Aiton) Dryand.	1.19	0	2.83	0	0.15	0	4.17	0	Aggregated
Burseraceae	*Boswellia papyrifera* (Del.) Hochst.	76.72	72.9	66.1	54.5	29.7	24.2	172.5	151.6	Aggregated
	Anogeissus leiocarpus(DC.) Guill. & Perr	0.3	1.46	1.41	1.92	5.4	13.8	7.11	17.17	Random
	Combretum aculeatum Vent.	0	0.73	0	3.84	0	3.45	0	8.02	Aggregated
Combretaceae	*Combretum collinum* subsp. *Binderianum* (Kotschy) Okafa.	0.15	0	1.41	0	2.702	0	4.262	0	Random
	Combretum hartmannianum Schwein f.*Beitr*.	17.76	6.59	16.8	6.91	27.02	17.2	61.6	30.74	Aggregated
	Senegalia senegal (L.) Britton	0	0.73	0	1.92	0	6.9	0	9.6	Random
	Vachellia seyal (Delile) P.J.H.Hurter.	0	13.9	0	14.6	0	17.2	0	45.7	Aggregated
Fabaceae	*Lonchocarpus laxiflorus* Guill. & Perr.	0.3	0	1.41	0	5.4	0	7.11	0	Random
	Pterocarpus lucens Guill. & Perr.	0.6	1.1	2.83	5.75	5.4	3.45	8.83	10.3	Aggregated
Rhmnaceae	*Ziziphus spina-christi* (L.) Desf.	0	1.1	0	2.88	0	6.9	0	10.88	Random
Zygophyllaceae	*Balanites aegyptiaca* (L.) Delile	0.45	1.1	4.24	5.75	2.702	3.45	7.392	10.3	Aggregated

DISCUSSION

From the results maintained above both communities, the values of Shannon diversity and Pielous evenness indices, were relatively low when compared with that of Jebel ElGerri which recorded the values (1.733245) for Shannon index and (0.5201) for Pielous index, this may have attributed to the highly dominance of one species (Boswellia papyrifera), which agreed with the fact the low evenness value indicates the dominance of the environment by few species (Van Breugel et al., 2007).

The results showed the IVI value of Boswellia papyrifera in community [1] is higher than that of community [2]. This observation due to that community [1] is characterized by pure rocks and hill slopes, which is the favorite habitat for this species as mentioned previously (El Amin, 1990; Harrison & Jackson, 1958; Wickens, 1976). However, in stand [2] the presence of clay may reduce favorite properties of the soil beside the extensive tapping for frankincense yield in both stands, which may cause the death of trees, which result in open spaces, that encourage the appearance of other species to compete the original plantations.

Appearance of Combretum hartmannianum in stand [1] with highly density and secondly in dominance beside Boswellia papyrifera, this attributed to that these species common savanna trees that occurs on rocky steep slopes of the hills in high rainfall savanna (Harrison & Jackson, 1958). On the other hand, the high values of relative density, abundance, frequency and IVI of Acacia seyal in stand [2] this attributed to suitability of site properties especially cracking clay soil, which limit the natural distribution of this species.

Boswellia papyrifera was distributed aggregately, because it was cultivated in close constant spacing (2*2 m). Balanites aegyptiaca and Acacia seyal these two species characterized by their association especially in cracking clay soil of low rain fall woodland savanna under clay as described by Harrison and Jackson (Harrison & Jackson, 1958). Meanwhile, it found in stand [2] only in patches, where its soil consists of large amount of clay, gravel and stony compounds, this is due to its location away from the hill and close to clay soil. While Senegalia senegal, Anogeissus leiocarpa, Combretum collenum, Lonchocarpus laxiflorus and Zizphus spina-christi were randomly distributed and this may have attributed to that these species adapted to site properties of both stands especially soil, in addition to ability of its seeds dispersal by man and animals and easy regeneration.

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