Original article

Changes in Plant Species Richness and Density along Altitudinal Gradient in Rashad and Alabassia Localities, South Kordofan, Sudan

Ismail Mirghani Ismail[1*] and Alawia Abdalla ELawad[2]

1 Botany Section-Forestry Research Centre, Agricultural Research Corporation, Khartoum, Sudan

2 Faculty of Science and Technology-Alneelain University, Khartoum, Sudan. Email address: ismail.mirghani@yahoo.com

ARTICLE INFO

Article history:
Received 2016 October 26th
Reviewed 2017 February 3rd
Accepted 2017 April 8th

Keywords:
Margalef index,
Shannon index,
Pielou index,
vegetation assessment,

Abstract

This study was carried out at Rashad and Alabassia localities, South Kordofan, Sudan. The objective of the study is to assess the impact of elevation on species richness and density. To understand the dynamic trends of the vegetation across the studied area, the compositional and structural features of three plant layers (mature tree and shrubs, regeneration and herbaceous) at 14 investigation sites were compared, in terms of species richness, species evenness and density. Shannon Biodiversity index (H), Margalef index (Species richness (D) and Pielou index for species evenness (E) were calculated. Results of ecological indices show that their values in the mature trees and shrubs and regeneration layers increase with increment of elevation, while they decrease with increment of elevation in herbaceous layer, the density of mature trees and shrub and regeneration layers decreases with increment of elevation and increases with increment of elevation in herbaceous layer. More research is needed to assess the altitudinal effect in the natural vegetation in the other Localities of the Nuba Mountains.

[*] Corresponding author: ismail.mirghani@yahoo.com

Introduction

Large-scale vegetation inventory and monitoring programs are rare (Stohlgren, 1994) but valuable for regional and national condition assessments. Such large-scale assessments provide broad overviews to help strategic policy development and allow land managers to place local assessments into regional or national perspectives, which facilitate the prioritization of limited resources available to managers (Heinz Center 2006, Ingerson and Loya 2008). Plant community structure and diversity are influenced by many interacting biotic and abiotic factors. At the local scale, ecological variables and disturbance are key factors that interact with plant strategies to determine vegetation composition and structure (Ribichich and Protomastro, 1998). Species richness refers to the number of species present in a given area or habitat (Polley *et al*., 2003). Local plant species richness can vary considerably across a landscape, suggesting that local factors are important for these variations (Huston, 1999). The latitudinal gradient in species richness remains one of the most ubiquitous patterns in ecology (Pianka, 1966). The trend for species richness to decline at higher latitudes has been documented for woody plants (Currie and Paquin, 1987). According to Valdovinos *et al*. (2003), this trend is not universal but more pronounced in the Northern Hemisphere than the Southern Hemisphere (Platnick, 1991). Species evenness is a measure of how equitably abundances are distributed among species (Polley *et al*., 2003).

Biodiversity is a short form for biological diversity which is to describe the total number, variety and variability of living organisms as well as the diversity of the ecosystems they are living in (Krebs, 1999). The concept of biodiversity is considered to be the integration of biological variability across all scales, from genetic level, through species and ecosystems, to the landscapes that they form, or are part of, and the ecological processes that support them (Purvis and Hector, 2000). Generally, biodiversity measurement typically focuses on the species level and species diversity as the most important indices used for the evaluation of ecosystems at different scales (Ardakani, 2004). Plant diversity is determined by both species richness and species evenness. Local diversity can be studied with various indices, such as number of species per unit area (species richness) or the Shannon index. These are used as indicators of the degree of complexity of the under study communities and to provide information on the homeostatic capacity of the system to unforeseen environmental changes (Magurran, 1988).

The savanna areas are considered as important productive parts in Sudan, they are mainly classified as savanna woodlands, tree and shrub savannas, grasslands or steppes (Menaut, 1983). Nuba Mountains belongs to the low rainfall woodland savanna (Harrison and Jackson, 1958). In this work the community structure and composition of selected 14 sites in Rashad and Alabassia Localities, South Kordofan, Sudan were analyzed. The aim of this study was to assess the species richness, taxonomic composition and stand structure in the studied sites and to estimate the effect of elevation on the studied parameters. This study is expected to provide a botanical reference for future ecological research and conservation efforts of one of the productive areas in the Sudan, which is now facing political crisis.

Materials and Methods

Description of the study area

The study area is located in the northern part of eastern Nuba Mountains of South Kordofan State and including two localities (Rashad and Alabassia), extending from latitude 11º 33` to 12º 33` N and from longitude 31º 08` to 31º 18` E. Most of the area under study is covered by scattered isolated hills and is dissected by many seasonal watercourses (KHORS). Rashad and Alabassia localities occupy a total area of 7872 km2 (UNDP, 2003). Annual average temperature and precipitation is are 29.9ºC and 542 mm, respectively (Sudanese Metrological Authority, 2004). The precipitation is seasonally distributed, with a distinct wet season from May to October and a dry season from November to April.

Data collection

The study was conducted during the years 2010-2011. After the reconnaissance survey, 14 sites were selected, based on observed variations in vegetation types, topographical features and soil types to represent most of the study area (Table, 1). For vegetation assessment within the natural stands 70 circular 0.1 ha (17.84 m in radius) sample plots modified from Adam and Eltayeb (2008). 14 transects were made to cover the whole study area. Along each transect 5 circular 0.1 ha plots were conducted for studying trees and shrubs and natural regeneration. The first plot was established randomly, the number of trees and shrubs species and the number of individual of each species per/plot were counted. For assessing herbaceous plants four 50X50 cm quadrate were randomly established in each 0.1ha. main plot.

Data analysis

Shannon Biodiversity index (H) was calculated as given by Shannon & Weaver (1963). Species richness is a biologically appropriate measure of alpha (α) diversity and is usually expressed as number of species per sample unit (Whittaker 1972). Margalef index (Species richness (D)): was calculated as given by Margalef, (1958). Pielou index for species evenness (E): was calculated as given by Pielou (1966).

Results and Discussion

The results of the different studied ecological parameters are presented in table (2):

For mature trees and shrubs layer both site 6 (Elawai north Rashad) and site 8 (Rashad Dam), had the highest species richness (21 species), while site 1 (Um-Fakareen) and site 13 (Tandek) are species poor sites (6 species) (table 2).

The rest of the areas had comparable species richness values. Although site 1 and site 13 had evident variation in their elevation, they are similar in soil type as cracking clay. The results of this study have proved that species richness is positively linearly correlated with elevation (r = 0.675, P = 0.008). The Regeneration layer showed that Site 9 (Jebel Rashad) has the highest species richness (19 species), while the lowest value (6 species) was recorded by site 1 (Um-Fakareen) and site 2 (Jebel Damra).

Table (1): Characteristic feature of selected sites

Site	Location	Latitude (N)	Longitude (E)	Elevation (M)	Type of soil
1	Um Fakareen	12 º 33` N	31º 18` E	500 m	Cracking clay
2	Jebel Damra	12º 10` N	31º 15` E	739 m	Rocky soil
3	Elmigreh	12º 02` N	31º 14` E	826 m	Rocky soil
4	Um Zamboor	12º 00` N	31º 13` E	885 m	Rocky soil
5	Sug-Eljabal	11º 57` N	31º 12` E	914 m	Rocky soil
6	Elawai North Rashad	11º 52` N	31º 08` E	849 m	Rocky soil
7	Tabaldia	11º 50` N	31º 09` E	860 m	Rocky soil
8	Rashad Dam	11º 52` N	31º 02` E	894 m	Rocky soil
9	Jebel Rashad	11º 49` N	31º 03` E	852 m	Rocky soil
10	South Rashad	11º 45` N	31º 02` E	781 m	Rocky soil
11	Um Abdalla	11º 45` N	30º 52` E	664 m	Gardud soil
12	Awai South Rashad	11º 43` N	31º 03` E	723 m	Rocky soil
13	Tandek	11º 42` N	31º 02` E	695 m	Cracking clay
14	Dibekkir	11º 33` N	31º 08` E	618 m	Cracking clay

The present findings revealed that species richness is also positively linearly correlated with elevation in this layer (r=

0.561, P= 0.0369).

The highest richness value in the herbaceous layer (19 species) was recorded in site 2 (Jebel Damra) while the lowest value (8 species) was recorded in site 9 (Jebel Rashad). This result showed that species richness is negatively linearly correlated with elevation in the herbaceous layer (r= -0.274, *P* =0.343).

The highest plant species richness of mature trees and shrubs layer in this study is less than the 32 species of Ismail & Mahmoud (2010) from Jebel El Dair. Also it was observed that the highest values of richness of mature tree and shrubs and regeneration layers occurred in mountainous sites and increases with the elevation increment, while the lowest values occurred in clay plains sites and decreases with elevation increment. This partly agreed with the fact stated by Meihe and Meighe (1994) that the proportion of endemic plants strongly increases with altitude. It has been suggested that different altitudes and slopes influence species richness and dispersion behavior of tree species (Eilu and Obua, 2005).

Elevation gradients create varied climates, along with resultant soil differentiation; promote the diversification of plant species (Brown, 2001). It has been reported that woody species richness showed a linear decrease in relation to elevation (Chiarucci and Bonini, 2005). Decrease of species richness of the woody plants at low elevations may be due to th e fact that low elevation sites are relatively densely populated and human interference in these sites facilitates negative impact on the species composition by selective felling of economically valuable species and overgrazing.

Margalef index (Species richness (D)) and its relation to elevation

Margalef index results (Figure 2) and (table 2) show that the highest value in mature trees and shrubs layer (D = 11.17), has been recorded in site 8 (Rashad Dam), while the lowest value (D = 2.84), has been recorded by site 1 (Um-Fakareen).

Table (2): Ecological indices and density of different vegetation layers along different elevations.

	Trees and shrubs layer					Regeneration layer					Herbaceous layer				
Altitude (m)	**Shannon index (H)**	**Pielou index (E)**	**Margalef index (D)**	**No. of Species**	**Density (stem/ha)**	**Shannon index (H)**	**Pielou index (E)**	**Margalef index (D)**	**No. of Species**	**Density (Stem/ha)**	**Shannon Index (H)**	**Pielou index (E)**	**Margalef index (D)**	**No. of Species**	**Density (plant /m^2)**
500	1.18	1.51	2.84	6	114	1.6	2.05	2.28	6	306	1.96	1.56	7.66	18	52
712	2.13	1.64	8.92	20	268	1.48	2.12	2.58	6	174	2.2	1.72	7.47	19	51.64
826	2.33	2.16	6.88	12	72	1.84	1.7	5.91	11	144	1.88	1.11	4.63	13	77.4
885	2.18	2.02	7.24	12	66	1.16	1.12	4.39	11	384	2.16	1.71	6.54	18	80.4
914	2.2	1.75	10.37	18	88	2.32	1.97	6.7	15	244	1.47	1.41	3.65	11	110
849	2.63	1.99	9.71	21	228	2.35	1.87	8.13	18	244	1.21	1.09	4.65	13	76
860	2.17	1.81	8.38	16	574	1.9	1.71	5.91	13	216	1.65	1.53	4.76	12	41.2
894	2.68	2.03	11.17	21	122	2.18	1.89	6.84	14	160	2.19	1.83	5.79	16	78.1
852	1.86	1.45	7.32	19	124	2.31	1.01	8.45	19	294	1.98	1.77	3.11	9	73.6
781	2.43	1.9	9.63	19	148	2.33	2.1	7.84	13	68	1.82	1.69	4.65	12	57.2
664	1.63	1.51	6.4	12	106	1.82	1.54	6.39	15	310	1.65	1.49	4.47	13	76.2
723	1.76	1.59	6.67	13	126	1.595	1.3	7.27	17	316	2.45	1.94	7.08	18	48.4
695	1.25	1.6	3.62	6	48	0.88	0.93	3.2	9	628	1.46	1.4	4.43	11	36
618	0.695	0.7	3.49	10	766	0.59	0.6	3.06	10	1738	1.8	1.67	4.64	12	46.8

The present finding revealed that Margalef index of mature trees and shrubs layer is positively linearly correlated with elevation (r = 0.798, *P* = 0.0006).

On the other hand site 9 (Jebel Rashad) shows the highest value (D = 8.45) of regeneration layer, while site 1 (Um-Fakareen) shows the lowest value (D = 2.28). Also Margalef index of regeneration layer is positively linearly correlated with elevation (r = 0.636, *P*= 0.0146). Margalef richness index in the herbaceous layer showed the highest value (D = 7.66) in site 1 (Um-Fakareen), while site 9 (Jebel Rashad) recorded the lowest value (D = 3.11). Margalef richness index of herbaceous layer is negatively linearly correlated with elevation ((r =-0.43, p= 0.133). These results suggest that the species richness index was found to be fluctuating from stand to stand as well as among mature trees and shrubs, regeneration and herbaceous layers (Bharali *et al.,* 2011).

The highest values of Margalef index of trees and shrubs layer and regeneration layer occurred in mountainous sites and increases with the elevation increment, while the lowest values occurred in clay plains sites and decreases with elevation increment. These results agreed with that of species richness (species number).

Shannon Wieners Biodiversity index (H) and its relation to elevation

Shannon index results (Figure 3) and (table 2) show that the highest diversity value of mature tree and shrubs layer (H = 2.68) has been recorded in site 8 (Rashad Dam), while site 14 (Debekir), shows the lowest value (H=0.695). The results of this study shows that the Shannon index of mature trees and shrubs layer is positively linearly correlated with elevation (r= 0.796, P = 0.0007).

Regeneration layer shows that the highest value of the Shannon diversity index (H = 2.35) has been recorded in site 6 (Elawai north Rashad), while the lowest value (H=0.59) was recorded in site 14 (Debekir). Shannon index of regeneration layer is positively linearly correlated with elevation r = 0.543, *P* = 0.0448).

The herbaceous layer, site 12 (Elawai North Tandek) has the highest value of Shannon diversity index (H= 2.45), while the lowest value (H=1.21) has been recorded by site 6 (Elawai north Rashad). Shannon index of herbaceous layer is negatively linearly correlated with elevation (r = -0.099, *P* = 0.735).

The highest Shannon diversity index (H) of trees and shrubs layer in this study is more than that of Ismail & Mahmoud (2010) (H=2.39) from Jebel El Dair, which is a conserved area. Also it is observed that the highest values of the Shannon index (H) of trees and shrubs layer and regeneration layer occurred in mountainous sites and increases with the elevation increment, while the lowest values occurred in clay plains sites and decreases with elevation increment.

Lower diversity in lower elevation could be attributed to heavy grazing; in addition to the felling of larger trees for charcoal production and shifting cultivation may reduce species diversity especially in the plains. This agrees with McNaughton, (1985) who stated that uncontrolled grazing has its own effect on plant species diversity as some well palatable species are expected to be more severely affected by cattle than other species, perhaps in the long run resulting in the dominance of grazing resistant species.

Pielou index of Species evenness (E) and its relation to elevation

Species evenness measures the equity of species in a given sample area or it is the opposite of dominance by few species. Pielou index results (Figure 4) and (table 2) show that the highest value of evenness in mature trees and shrubs layer (E=2.16) has been recorded in site 3 (Elmigreh) and the lowest value (E = 0.7) has been recorded in site 14 (Debekir). Pielou index of mature trees and shrubs layer is positively correlated with elevation (r = 0.634, P = 0.0148).

Regeneration layer shows the highest value (E = 2.1) in both site 2 (Jebel Damra) and site 10 (South Rashad), while the lowest value (E = 0.6) has been recorded in site 14 (Debekir). Pielou index of regeneration layer is positively linearly correlated with elevation (r = 0.127, *P* = 0.665). Pielou index of the herbaceous layer shows the highest value (E = 1.94) in site 12 (Elawai North Tandek) and the lowest value (E =1.09) in site 6 (Elawai north Rashad). Pielou index is negatively correlated with elevation (r = -0.105, P = 0.720).

The highest Pielou evenness index (E) of mature trees and shrubs layer in this study is more than that of (Ismail & Mahmoud, 2010) (E= 0.696) from Jebel El Dair, which is a conserved area.

The highest values of evenness (E) of mature trees and shrubs layer and regeneration layer recorded in mountainous sites increases with the elevation increment, while the lowest values occurred in clay plains sites and decreases slightly with elevation increment

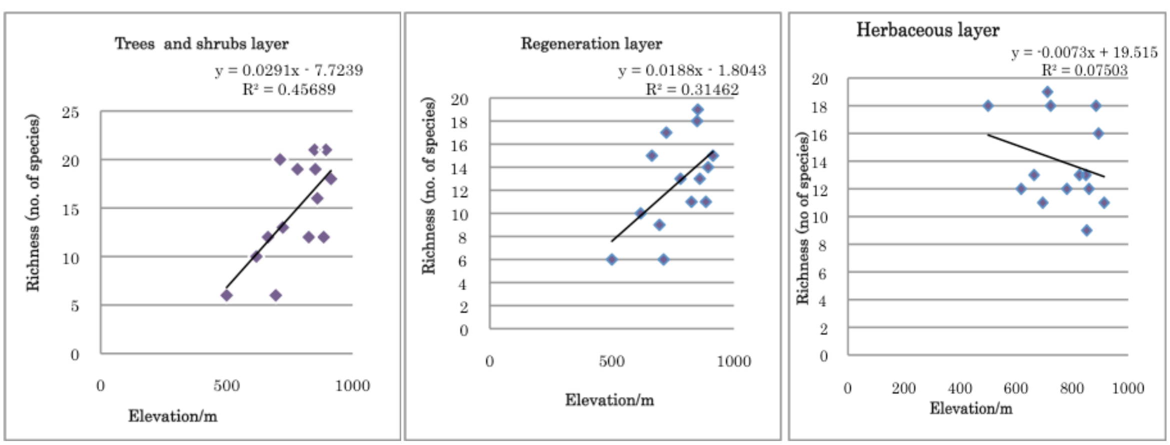

Figure 1: Correlation between elevation and species richness for mature trees and shrub, regeneration and herbaceous layers.

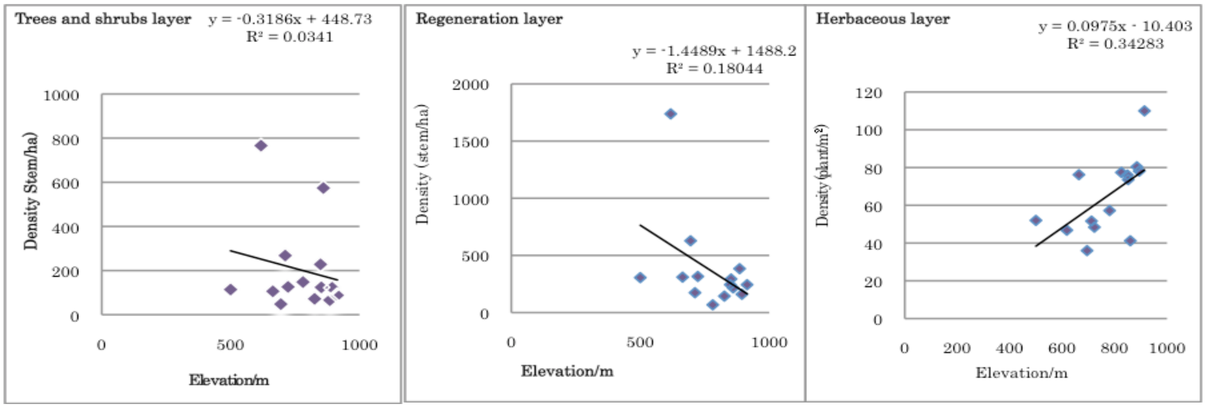

Figure 2: correlation between elevation and Margalef index for mature trees and shrub, regeneration and herbaceous layers.

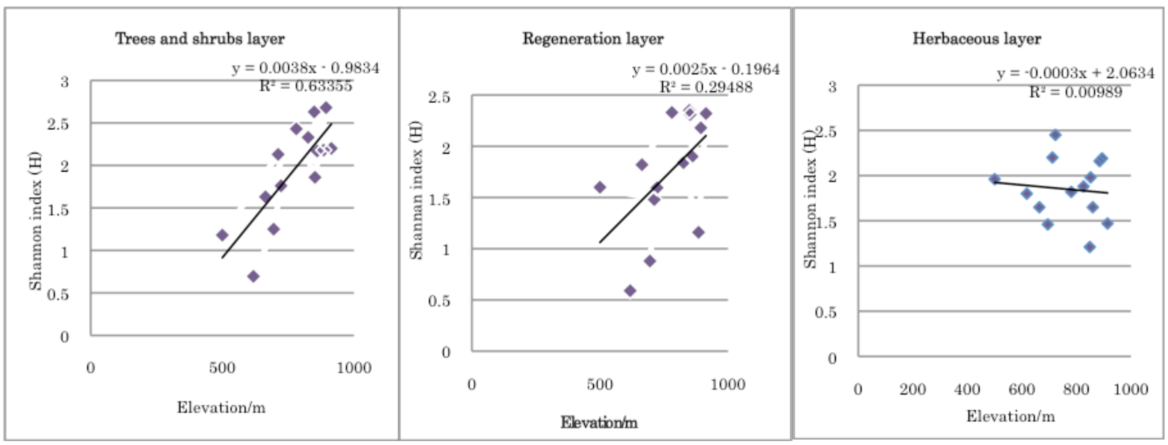

Figure 3: Correlation between elevation and Shannon index for mature trees and shrub, regeneration and herbaceous layers

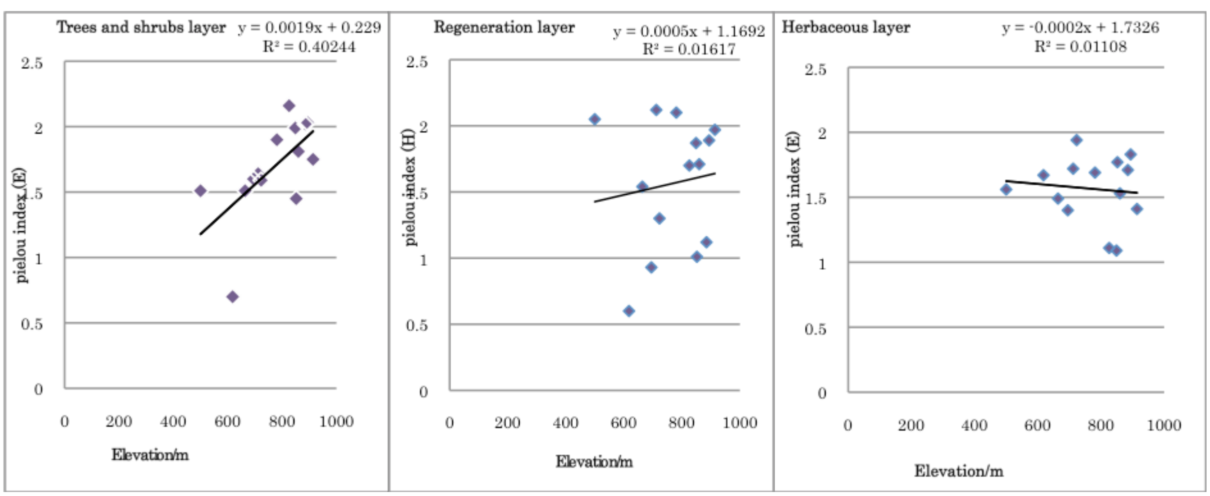

Figure 4: Correlation between elevation and Pielou index for mature trees and shrub, regeneration and herbaceous layers.

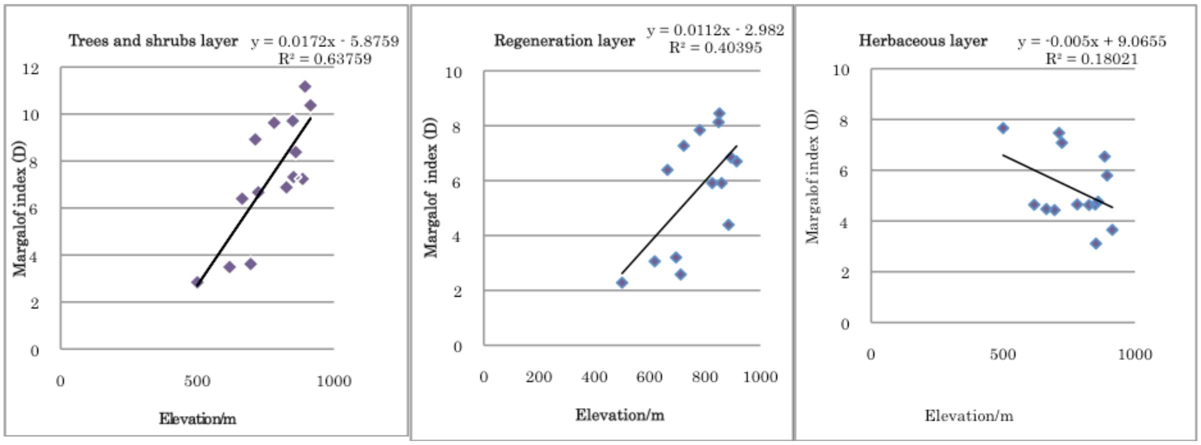

Figure 5: Correlation between elevation and Density for mature trees and shrub, regeneration and herbaceous layers.

The low value of the evenness index in lower elevation may be attributed to the fact that lower elevations or plains are dominated by few species as in case of site 14 which is dominated by few species as in case of site 14 which is dominated by *Dichrostachys cinerea* only. Species evenness measures the relative or the proportional abundance of species in the sample area. Hence, the low evenness value indicates the dominance of the environment by few species (Van Breugel *et al.,* 2007).

Density of plants and its relation to elevation

Results (Figure 5) and (table 2) shows that the highest value of density in mature trees and shrubs layer is (766 stems/ha.) recorded in site 14 (Debekir), while the lowest density (48 stem/ha.) is recorded in site 13 (Tandek). The results showed a negative relationship between density and elevation with correlation value r = - 0.18467 and Linear tests revealed a non-significant relationship (p= 0.5274).

The highest density in regeneration layer (1738 stem/ha) has also been recorded in site 14 (Debekir), while the lowest value (68) has been recorded in site 11 (Um Abdalla). The results showed a negative relationship between density and elevation with correlation value r= -0.425 and Linear tests revealed a non-significant relationship p= 0.13. Site 4 (Um Zamboor) shows the highest value of density in the herbaceous layer (110 plants/m), while site 13 (Tandek) shows the lowest density (36 plants/m). The results showed a positive linear relationship between density and elevation with correlation value r= 0.586 and Linear tests revealed a significant relationship p= 0.028.

The highest density (766 stems/ha) of mature trees and shrubs layer is more than that of Ibrahim, (2008) (77.38 trees/ha.) from Um Abdalla forest reserve and less than that of Bunderson *et al.* (1984) (1000 trees/ha) in the Nuba Mountains and of Ismail and Mahmoud, (2010) (6174.5 trees and shrubs/ha.) in Jebel El Dair. The highest values of density of trees and shrubs layer and regeneration layer occurred in clay plain sites and decreases with elevation increment, while the lowest values occurred in mountainous sites and decreases with elevation increment.

Conclusions

The study revealed the effect of elevation in the richness and density of the different natural vegetation layers. Ecological indices; Shannon Biodiversity index (H), Margalef index (Species richness (D)) and Pielou index for species evenness (E) show that in the 14 studied sites the mature trees and shrub and the regeneration layers increase with increment of elevation, while they decrease with increment of elevation in the herbaceous layer. The density of the mature trees and shrub and the regeneration layers decrease with increment of elevation and increases with increment of elevation in the herbaceous layer. This indicated that elevation has different impact on species richness and density of the vegetation layers in the study area. This is the first contribution in the evaluation of elevation effect in natural vegetation of the two selected Localities of South Kordofan State.

Recommendations

More research is needed in the ecology of the Nuba Mountains as it represents one of important and unique reproductive ecological zones in the Sudan.

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