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Phytosocial Diversity and Distribution of Herbaceous Species in Dryland Ecosystem of Kebbi, North-western Nigeria

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Abstract:
Background: *Phytosociology describe species population dynamics and their relationship to other species. This study aimed at determine phytosocial diversity and distribution of herbaceous species.* ***Materials and Methods:*** *Herbaceous species were determined in randomly selected 400 quadrats (1m×1m) by identifying, analyzing frequency and evaluation species diversity using various indices.* ***Results:*** *A total of 4372 herbaceous species belonging to 44 genera were distributed in 18 families. Fabaceae recorded the highest species occurrence (13.3%), followed by Poaceae and Amaranthaceae each with 11.1%, while the rare species were found under Asteraceae, Cucurbiataceae, Rubiaceae, Cleomarceae, Cyperaceae, and family Phyllanthaceae, each with 2.22% relative frequency. Site A recorded the highest species 34.90%, followed by Site C, D and B with 25.07%, 21.55% and 18.32% respectively (P<0.05). Teprosia pedicelata had the highest species distribution with 8.71%, followed by Mitracarpus scabrunzuce, and Leucus martinicensis, with 5.38% and 3.68% respectively. Eragrotis tremula, Phyllanthus amarus and Sesbania sesban were found rare only in Site D(0.37%), A(0.09%) and C(0.34%) respectively. However, Citrilus colosyntnthus found in Site A, B and D shows rare distribution of 0.50%. Approximately 70.45% of herbaceous species shows aggregate distribution and 29.55% random distribution pattern. Diversity indices varies where, Simpson and Shannon index ranges from 0.941 in Site D to 0.961 in Site C and 2.941 in Site D to 3.335 in Site C respectively.* ***Conclusion:*** *Herbaceous species formed aggregate distribution than random distribution pattern. Environmental and human activities influence species diversity and distribution. Rare species should be conserve for future purposes by protecting their habitats.*

Key words: *Phytosocial, Herbaceous, Distribution, Species, Diversity, Composition.*

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I. Introduction

Phytosociology is the quantitative study of vegetation, aimed to predict its pattern of distribution[1]. Phytosociology refers to the characteristics, classification, relationship and distribution of plant communities of a particular environment[2]. It aids in forest and grassland management planning, environmental impact studies, restoration and reclamation of degraded areas, and may also indicate the potential species richness and abundance[3]. It is used to describe the population dynamics of species and their relationship to other species in the same community[4, 2]. Phytosociological studies are essential for protecting the natural plant communities and biodiversity as well as understanding the changes experienced in the past and future. Analysis of a plant community is the basis of ecological study of any piece of vegetation for understanding the functions of any community, it species composition and phytosociological interaction of species[5]. Anthropogenic activities like overexploitation, pollution, habitat destruction and degradation by physical and chemical means causing significant effect on the pattern of phytosocial distribution as well as biodiversity loss[6]. Conversion of local vegetation for other human activities is a major threat to biodiversity [7, 8, 9, 10].

Herbaceous vegetation fluctuates in a cyclic manner from one season to another in a successional way and modified to prevailing factors[11]. These fluctuations continuous in space and time due to a multitude of factors like overgrazing, fire, soil nutrients, rainfall and human activities which differs in intensity and duration[12]. Plant species behave differently in natural community to the varying environmental conditions[13, 14, 15], either abiotic[16, 17] or biotic factors[18], and consequently result in the evolution of diverse communities. Herbaceous species constitute up to 60% of the plants species diversity in terrestrial ecosystem[19]. Naturally, they serve as habitats for a wide array of animals, basis for complex food webs [20, 21, 22, 23], and are involved in protecting topsoil, maintain biodiversity, improving water penetration into soils and soil holding capacity [24, 25, 26], mitigation of CO_2, livestock feeds, runoff and wind reduction, and above-ground carbon storage [27, 28, 29, 30]. Despite these ecological importance of herbaceous layer, they are poorly studied and are usually not included in most floristic studies [31, 32]. Herbaceous species interacts with different species that share similar environmental requirements to forms different vegetation types and may also respond to various environmental changes [33].

Biodiversity refers to the number of different species in a particular area (species richness) weighted by abundance of individuals species. Barnes *et al.* [34] defined biodiversity as the kinds and numbers of organisms and their patterns of distribution in an ecosystem. However, species diversity can be measure by species evenness i.e. abundance of each species represented in an area [35], and species richness; the biological measure of alpha (α) diversity, usually expressed as the number of species per unit sample [36]. Therefore, diversity is affected by species richness and evenness [37]. Diversity is an important structural attributes of a natural community which are related to functional properties of vegetation like productivity, niche structure, competition, stability and integration of the community [38]. Species diversity is minimum when individuals are of one species and maximum when individuals belong to a larger number of different species [39]. The assemblage of plants found at a given locality can be interpreted as the products of filtering the effects of climatic conditions, edaphic factors, biotic interactions and type of disturbance [40]. The development and deterioration of plant species alters the pattern of species distribution in community[11]. Increased in biodiversity has been found to increase primary productivity [41], changes plant allocation pattern [42], and reduce invisibility by unsown species that changing herbage composition [42, 43]. Biodiversity and distribution provide basic information for decision-making in management and conservation efforts and also provide information on the floristic composition and structures of vegetation [44].

Shannon-Weiner Index and Simpson Indices are the most common indices for studying species diversity [45, 46], while species richness and evenness are the components of biodiversity [47 48]. Simpson index is used to assess the dominance, while Shannon-Wiener index help to determine species evenness and richness, but does not provide information on rare species, which are also important [49]. This indicates that diversity cannot be determined by just one indices [50, 51]. Diversity indices are used as indicators of the community's composition and the effects of environmental changes on species [37]. Scientific studies on biodiversity is necessity in preserving, restoring and proper management of the existing plant species for their ecological values. The structural property of a community is the quantitative relationship between the species growing around. Assessments of plant diversity and vegetation composition of fragmented habitats are necessary for understanding the impacts of human disturbance and the vulnerability of desert habitats to habitat fragmentation. This research was aimed at studying the current status of phytosocial diversity and distribution of herbaceous species in dryland ecosystem.

II. Materials and Methods

Study Location

Kebbi state is located in North-western Nigeria, between latitude 12.45^0 N and longitude 4.2^0 E. It covers a geographical land area of 36,800 km^2, borders with nation of Niger Republic to the west and Benin Republic to the South-east and locally bordered Nigerian states; Niger, Sokoto, Zamfara to the South, North and East respectively. The state marked by a single rainy season last from May to October with mean annual rainfall of about 720mm and long dry season last for the remaining period of the year [52]. The mean temperature range is 26^{0}C during harmattan season (November to February) and 38^{0}C-40^{0}C during the month of April to June [53]. Its vegetation is Northern Guinea Savanna in the South and South-East and Sudan Savanna in the North, covers with short grasses and small trees. Although, the state face desertification but many areas are still being altered by cultivation, grazing, cutting of fuel woods, excavation of soil, bush fire and so on. The study was conducted in four Sites including Aleiro located between longitude 4.4388^0 E and Latitude 12.3562^0 N, Kalgo 4.2000^0 E and Latitude 12.3342^0 N, Argungu 4.5367^0 E and Latitude 12.7495^0 N and Bunza 4.0108^0 E and Latitude 12.0916^0 N, all the study Sites was protected from anthropogenic activities during the period of research, but all the study Sites experienced various anthropogenic activities before the research was commence.

Study Design

Phyto-social diversity and distribution of herbaceous species were conducted during the month of June to October, 2020. Completely Randomize Design (CRD) was adopted for monthly sampling due homogeneity of the experimental Sites, twenty 20 (1m^2 x 1m^2 quadrats) on each sampling date per plot were randomly chosen using an online random number table for generating 400 (1m^2 x 1m^2 quadrats) throughout the study periods and plants species occur at the 20 x 20cm central square quadrats were identified [54].

III. Methodology

Twelve plots (30m x 30m) were established and marked out with iron rods (2 meter above the ground), for monthly sampling from June to October, 2020. The plots were divided into quarters and each quarter were then divided into grids of 1m x 1m quadrats to give a total of 225 quadrats [54]. Phytosocial compositions of herbaceous species were identified, collected, pressed, dried and stitched on standard herbarium sheets of 28 ×

42 cm according to Jain and Rao [55]. Plant species occur in the central 20cm x 20cm randomly selected quadrat were identified *in-situ* based on their morphological, structural and floral characteristics with the aid of West African Weeds [56] and Flora of West Tropical Africa [57, 58]. The *in-situ* identified plants were transported to Herbarium, Department of Biology, Federal University Birnin Kebbi (FUBK), Nigeria, for authentication of species.

Statistical Analysis

Analysis of variance (One-way ANOVA) were used for analyzing species composition and distribution using MINITAB (Version 18) at 95% confidence interval. Diversity Indices were calculated using the software Community Ecology Parameter Calculator (ComEcoPaC) Version 2.0. Various species diversity indices were determined through Shannon wiener index (H) and community dominance index (CDI) based on the following formula; H = - [∑ Pi InPi], where H = diversity index, Pi = proportion of each species in the sample, InPi = natural logarithm of this proportion, while CDI $=\frac{Y1+Y2}{Y}$, where Y_1 = most dominant species, Y_2= second most dominant species and Y= total number of species recorded.

IV. Results

During the study period, 44 genera of herbaceous plants species were identified and distributed over 18 families. Fabaceae recorded the highest species occurrence with (13.3%) relative frequency, followed by Poaceae and Amaranthaceae each with 11.1%, while family Malvaceae recorded 8.89%, Euphobiaceae, Solanaceae, and Lamiaceae each had 6.67% relative frequency, and the rare species were recorded under family Asteraceae, Cucurbiataceae, Rubiaceae, Cleomaceae, Cyperaceae, and Phyllanthaceae, each with 2.22% relative frequency. Table 1 shows the distribution and abundance of 4372 herbaceous species in four study Sites. Sites A recorded the highest species composition of 34.90% relative frequency, followed by Site C and D with 25.07% and 21.71% respectively, while least species composition were recorded under Site B with 18.32% enumerated species. The distribution and abundance of species between the Sites were statistically significance ($p<0.05$) at 95% confidence interval (Table 2).

Table 1: Relative Frequency of Herbaceous Species Composition and Distribution Identified in the Four Study Sites, 2020

Family	Species Name	Sites and Species RF (%)				Total RF (%)
		A	B	C	D	
Acanthaceae	*Hygrophila auriculata (L.) Schum*	0.71	0.21	0.43	0.89	2.24
	Blepharis maderaspatensis L.	0.43	0.00	0.85	0.41	1.69
Amaranthaceae	*Amaranthus viridis L.*	0.66	0.85	0.94	0.00	2.45
	Celosia trigyna L.	0.39	0.71	0.00	1.26	2.36
	Achyrathes aspera L.	0.00	0.48	1.17	0.00	1.65
	Gomphrena celosiodes Mart	0.00	1.08	1.10	0.00	2.17
Asteraceae	*Acanthospermun hispidum Dc*	0.89	0.98	0.00	1.58	3.45
Cleomaceae	*Cleome viscosa L.*	0.85	0.00	0.85	0.00	1.69
Ceasalpiniaceae	*Cassia occidentalis L.*	2.01	1.17	0.16	0.00	3.34
	Cassia tora L.	0.25	0.11	1.21	0.80	2.38
Convolvulaceae	*Evolulus alsinoides L.*	0.80	0.00	0.07	0.94	1.81
	Ipomoea muricata L.	1.40	0.94	0.43	0.00	2.77
Cucurbiataceae	*Citrilus colosynthus L.*	0.16	0.32	0.00	0.02	0.50
Commelinaceae	*Cyanotis lanata L.*	0.98	0.00	0.82	0.00	1.81
	Commelina errecta L.	0.94	0.66	0.75	0.07	2.42
Cyperaceae	*Cyperus rotundus L.*	1.78	0.00	0.00	1.30	3.09
Euphorbiaceae	*Euphorbia hirta, L.*	0.07	0.00	1.33	1.01	2.40
	Phyllanthus pentendrus Sch and thon	1.17	1.26	0.00	0.00	2.42
	Chrozophora brocchiana Schweinf.	0.75	0.00	0.46	0.00	1.21
Fabaceae	*Teprosia pedicelata Baker*	4.14	1.42	0.94	2.22	8.71

	Crotolaria mucronata Desv	0.46	0.00	0.59	0.00	1.05
	Alysicarpus vaginalis L.	1.08	1.05	0.00	1.26	3.39
	Cassia mimosoides L.	0.82	0.00	0.50	0.00	1.33
	Tephrosia linearis (wild) Pers.	1.58	0.00	0.30	1.90	3.77
	Sesbania sesban L.	0.00	0.00	0.34	0.00	0.34
Lamiaceae	*Hyptis spicigera L.*	1.24	0.00	0.94	0.00	2.17
	Ocimum basilicum L.	0.41	0.00	0.00	0.59	1.01
	Leucus martinicensis (Jacq) R.	1.51	0.94	1.24	0.00	3.68
Malvaceae	*Waltheria indica L.*	0.94	0.32	0.89	0.62	2.77
	Urena lobata L.	0.46	0.00	1.78	1.05	3.29
	Sida acuta L.	1.40	0.00	0.64	0.00	2.04
	Corchorus olitorius L.	0.00	0.30	0.98	0.73	2.01
Phyllanthaceae	*Phyllanthus amarus*	0.09	0.00	0.00	0.00	0.09
Poaceae	*Cynodon dactylon (L.) Pers.*	0.00	1.26	0.25	0.78	2.29
	Eleusin indica (L.) Gaertn	1.74	0.00	1.30	0.00	3.04
	Pennisetum pedicellatum Trim	0.66	1.12	0.98	0.00	2.77
	Eragrotis tremula Hochst	0.00	0.00	0.00	0.37	0.37
	Digitaria debelis Haller	0.78	0.00	1.10	0.57	2.45
Portulaceae	*Portulaca olerceae L.*	0.78	0.50	0.00	0.00	1.28
	Securidaca longepedunculata Fres	0.00	0.00	0.00	0.30	0.30
Rubiaceae	*Mitracarpus scabrunzuce*	1.94	1.58	0.53	1.33	5.38
Solanaceae	*Physalis angulate L.*	0.00	0.00	0.00	1.72	1.72
	Schweinkia americana L.	0.00	0.00	0.48	0.00	0.48
	Solanum nigrrum L.	0.64	1.08	0.71	0.00	2.42
Total Percentage Species Distribution		34.90	18.32	25.07	21.71	100.00

Keys: RF= Relative Frequency, Site; A= Aliero, B= Kalgo, C= Argungu and D= Bunza

Among the species *Teprosia pedicelata* had the highest number of species with 8.71% relative frequency (Table 1), followed by *Mitracarpus scabrunzuce,* and *Leucus martinicensis,* with relative frequency of 5.38% and 3.68% respectively. While *Eragrotis tremula* and *Securidaca longepedunculata* was found rare only in Site D with 0.37% and 0.30% respectively, *Phyllanthus amarus,* and *Schweinkia Americana* and *Sesbania sesban* were only recorded in Site A(0.09%), and D(0.48%) and (0.34%) respectively. However, *Citrilus colosyntnthus* found in Site A, B and D but shows lowest species composition of 0.50% relative frequency. Regards to phytosocial distributions, the results shows that most annual plant species shows aggregate distribution pattern with approximately 70.45%, few species revealed that 29.55% were randomly distributed across the study area.

Table 2: One-Way Analysis of Variance (ANOVA)

Source of Variation	AdjSS	Df	AdjMS	F	P-Value
Sites	8520.297	3	2840.099	4.150251	**0.007226**
Species	114965.7	168	684.3198		
Total	123486	171			

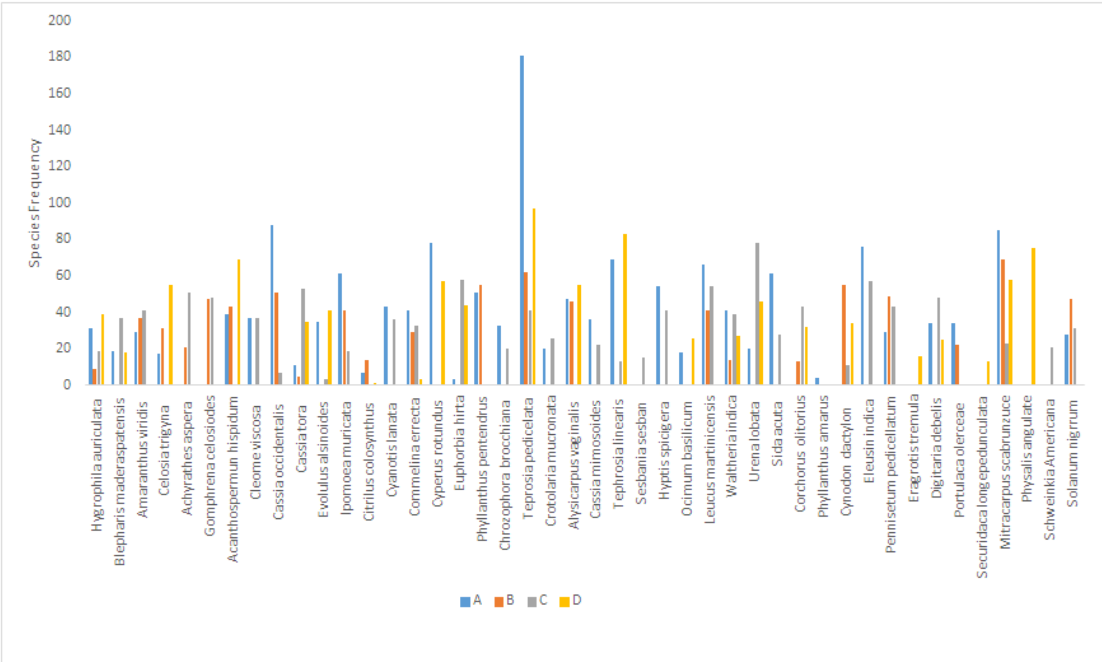

Fig. 1: Species Composition and Distribution in Four Study Sites

Table 3 shows that, the diversity indices varies between the study Sites, Simpson and Shannon diversity index varied from 0.941 in Site D to 0.961 in Site C and 2.941 in Site D to 3.335 in Site C respectively, while species evenness found to be higher in Site C (*E*= 0.878) and lower in Site A (*E*= 0.720). The species dominance was found maximum in Site D (*D*= 0.059) and minimum in Site C (*D*= 0.039). The results indicates that, the herbaceous communities of the study Sites experience less environmental stress and the species shows similar distribution and abundance since Simpson diversity index is closer to 1. CDI value ranges from minimum of 0.164 in Site B to maximum of 0.189 in Site D, Menhinick diversity index value were found between 0.747 in site D and 0.967 in site C and Margalef Index ranges from 3.141 in site B to 4.638 in site A respectively. Equitability index shows similar values but was found minimum (0.938) in site D and maximum (0.962) in site C. Berger-parker and Fisher alpha index recorded the highest value of 0.1186 in site A, and lowest value (0.086) value in site C and 6.386 in site A and lowest value (4.249) in site D.

Table 3: Diversity Indices of Herbaceous Species in Four Study Sites

	Sites			
Indices	A	B	C	D
Dominance	0.044	0.056	0.039	0.059
Simpson	0.956	0.944	0.961	0.941
Shannon	3.320	2.954	3.335	2.941
Evenness	0.790	0.872	0.878	0.834
Brillouin	3.262	2.887	3.263	2.883
CDI	0.176	0.164	0.124	0.189
Menhinick	0.896	0.777	0.967	0.747
Margalef	4.638	3.141	4.429	3.209
Equitability	0.939	0.956	0.962	0.938
Berger-parker	0.119	0.086	0.089	0.102
Fisher alpha	6.386	4.182	6.172	4.249

Note: CDI= Community dominance Index

V. Discussion

In this study, the results showed that phytosocial diversity and distribution differed among the species as well as between the study sites (A, B, C and D), which may be influenced by human activities and soil condition. Composition and distribution of species was found to be higher (34.90%) in Site A compared to the others Sites. High composition and distribution in Site A, indicates the availability of soil nutrients that favors the composition and distribution of herbaceous species and also indicates its primary productivity. The lower species composition in Site B (18.32%) may be due human activities, low soil nutrients and production of less number of seeds for germination since availability of seeds favors the composition and distribution of species. Larger species composition are more able to reach multiple patches of habitat within a landscape to find the resources they need [59]. Plants species composition is associated with soil nutrients and other environmental resources that are needed to species richness [60, 61]. *Teprosia pedicelata* with highest (8.71%) number of species might indicates it adaptability of the environmental condition and also higher seeds production during the growing season, while *Eragrotis tremula*, *Securidaca longepedunculata*, *Phyllanthus amarus*, *Schweinkia americana* and *Sesbania sesban* with 0.37%, 0.30%, 0.09%, 0.48% and 0.34% respectively, are found rare during the study area and occurs only in a single sites, which may be due the influence of environmental factor and limited seeds dispersal. This study is in line with the findings of Casas and Ninot [33] and Alados *et al.* [40] that said the assemblage of plants found at any given locality is a product of filtering the effects of edaphic factors and disturbance type. *Citrilus colosyntnthus* found in Site A, B and D shows lower (0.50%) species composition, which might indicates high environmental sensitivity and or less seed production and limited seeds dispersal. Every plant species has a tolerance limit that expand or narrow its distribution and may form mutual relationship with different species that share similar environmental requirements [4, 62]. Anthropogenic disturbances critically affect the biodiversity and the structural characteristics of the community [63, 64]. Nakahama *et al.* [65] reported that, anthropogenic activities such as urbanization, industrialization, over-grazing, salinization, solid wastes, military activities, over-cutting of woody plants, road construction, and establishment of new settlements are the main drivers of change, transformation, and loss of natural habitats; decline in floristic composition and dramatic changes in vegetation structure. In this study, the results shows that most of the herbaceous species shows aggregate distribution pattern with approximately 70.45%, few species revealed that 29.55% were randomly distributed across the study area, this may be due to aggregates seeds dispersal or environmental resources. The results are in line with Das *et al.* [66] that said aggregated distribution indicated habitat preference, while random distribution indicates the environment in which plant species grow is homogeneous and has many factors acting on the population [36].

Simpson and Shannon diversity index varied from 0.941 in Site D to 0.961 in Site C and 2.941 in Site D to 3.335 in Site C respectively, while species evenness found to be higher in Site C (E= 0.878) and lower in Site A (E= 0.720). The differences in the phytosociological parameters may be attributed to different biotic and/or abiotic factors other than soil and elevation**.** Menhinick diversity index value were found between 0.747 in site D and 0.967 in site C and Margalef Index ranges from 3.141 in site B to 4.638 in site A respectively**.** The low diversity recorded in site D(H= 2.941) and B(H= 2.954), may be attributed to lesser number of species, the community is dominated by few individuals or may be due to environmental degradation as a result of anthropogenic pressures. Simpson diversity index is always higher where the community is dominated by less number of species and when the dominance is shared by large number of species [61]. This indicate that Shannon diversity index of this research is similar to the value of the research conducted in Savanna ecosystem by Salisu and Rabiu [61], where he found 'H' ranges from 2.63 to 3.10. Hooper *et al.* [39] reported that species diversity is minimum when the individuals are of one species and maximum when individuals belongs to a large number of different species. According to Bhandari *et al.* [67], every species in a community plays a specific role and there is a definite quantitative relationship between abundant and rare species. Wilsey and Stirling [68], reported that richness and evenness can be negatively related across the plant communities, and evenness can account for more variation in Shannon's diversity index (H) than richness, which suggests that relationships among the diversity components can be complex. Dash [69], reported that matured and stable communities have high diversity value (0.6 to 0.9), while the communities under stress conditions, exhibiting low diversity, usually show close to zero value. Margalef index uses species richness to compare variation of a community and reflecting sensitivity to sample size, while Menhinick index used to estimate species richness but is independent on the sample size [70]. The Maximum value 0.119 and minimum value 0.086 of Berger-Parker index recorded in site A and B respectively in this study, in line with Shannon Wiener Index of this study. Javaid and Asho [70], reported that the higher the value of Berger-Parker index, the higher the diversity and lower the dominance.

VI. Conclusion

The result of this research shows that, phytosocial diversity and distribution of herbaceous species are favored by larger seeds production, limited seeds dispersal and availability of soil nutrients, while anthropogenic activities and environmental pressure distract phytosocial diversity and distribution. The research revealed that, dryland area is not suitable for the growth and development of *Eragrotis tremula*, *Securidaca longepedunculata*, *Phyllanthus amarus*, *Schweinkia americana* and *Sesbania sesban*, are found rare and occurs only in a single sites. The diversity indices of this study shows that the study area is more or less stable for most herbaceous community, although some study sites (B and D) have low values of diversity indices due to environmental pressure and anthropogenic activities. The study on the influence of edaphic factors on physocial diversity and distribution should be conducted.

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