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ECOLOGICAL DIVERSITY OF HERBACEOUS PLANTS IN OLD AFAKA FOREST RESERVE IN KADUNA NORTHERN GUINEA SAVANNA ECO-REGION OF NIGERIA

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Abstract

Ecological diversity of herbaceous plants in Old Afaka forest reserve in Kaduna Northern Guinea Savanna eco-region of Nigeria was studied. The study area was purposely divided into 4 main plots based on vegetation density and human interference. 50m x 100m plots were laid with 50m espacement between the plots. Line transect method was used in assessing the herbaceous vegetation. 3 main growth form (Shrub; Grasses and Sedges) were used to classify the herbaceous species for easy identification. Data collected were analysed using frequency distribution tables and percentages. Biodiversity indices were calculated using Shannon Weiner index; Simpson index; Margalef's richness index and Pielous's evenness index. The results revealed that there are 41 different species with Isoberlinia doka from shrub growth form having the highest occurrence (217) and highest percentage spread (32.7%) among all the species belonging into 24 families of which poaceae was the most dominant with 9 species belonging to the family these includes: Eragrotis spp. Paspalum orbiculae, Penisetum hordeides, Eragrotis trannula and so on in which the later had the highest percentage spread (13.3%.) Among the growth forms, shrubs are higher in the percentage spread (57.8%) than the grasses (35.0%) while the sedges are the least (7.2%). Order of percentage spread: Shrub > Grasses > Sedges. However, in terms of biodiversity indices: Shannon – Weiner index was found to be higher in grasses (0.37), lower in sedges (0.20) while, Simpson diversity index was higher in sedges (1.00) but lower in shrubs (0.67). Margalef's richness was higher in shrubs (85.1) but lower in sedges (11.5). Lastly, the Pielous' evenness shows higher index in grasses (0.061) but lower in sedges (0.043). Further research should be carried out in the reserve to promote the regeneration potentials of the diverse species of herbaceous plants.

Key Words: *Biodiversity, Poaceae, Herbaceous, Growth forms, Regeneratio*n

Introduction

Herbaceous plant is generally referred to as plants that does not form any of persistent woody stem (Bako and Vachi, 2002; Sodimu, 2016). They often known for their attractive flowers, pleasant smell and medicinal value. (Sodimu, 2016). In fact, in forests around the world, herbaceous plants are often the most species-rich of plant growth forms; they make up over 80% of all vascular plant species in temperate forests (Gilliam 2007; Spicer *et al*. 2020) and up to 45% in tropical forests (Linares - Palomino *et al*., 2009). They are vital components in forest ecosystems worldwide (Murphy *et al*., 2016), forest worldwide is known to be critically important habitats in terms of the biological diversity they contain and in terms of the ecological function they serve. Biological world can be regarded as a series of increasing complex level of organization with the key molecules of life at one extreme end and communities of species within ecosystem at the other (Grombridge, 2004). In forest ecosystems, large trees make up the bulk of living biomass, yet herbaceous plants are of critical importance to forest diversity, ecosystem processes, and conservation, despite their small stature (Gilliam, 2014). Herbaceous communities affect forest regeneration patterns through species interactions with woody plant seedlings (Holeksa, 2003), playing important roles in ecosystem function and biodiversity conservation (Landuyt *et al*., 2019). Manifestation of biological diversity can be found at different level and different scales. This diverse group engages in a myriad of biotic interactions (Whigham, 2004; Gilliam, 2014) and can act as biotic filters to tree regeneration (Royo and Carson 2008). Understanding where biological diversity occurs is both a central goal in ecology and the first step in designing effective strategies to sustain that biodiversity. In practice, the ecological diversity of species is central to the evaluation of diversity at other levels and is a constant point of reference in biodiversity study (Brain, 2004). Establishment and expansion of forest plot networks has greatly advanced our understanding of patterns of tree diversity in forest ecosystems around the world (Davies *et al*., 2021). However, herbaceous plants are typically excluded from these networks, and individual herbaceous studies use varying survey methods, precluding cross-site comparisons. Thus, compared to trees, much less is known about global patterns of sympatric herbaceous plant diversity in forests reserves.

Nigeria's forest resources have been declining steadily due to rapid growth of population and urban expansion, persistence of shifting cultivation and the ever-increasing demand for forest products (Kehinde *et al*., 2009). Biologists estimate that more than half the species occur in the tropical rain forest as opined by (Wilson, 2000 and Brain, 2004). Forest fragmentation due to land use is a key reason for the declining biodiversity in forest ecosystem and considered to be a primary threat to terrestrial biodiversity (Cakir *et al*., 2008; Pichancourt *et al*., 2006; Arms *et al*., 2004 and Harris, 1984). The knowledge of which plants, animals or fungi are useful and which one are dangerous or poisonous is very essential and communities employ what are called folk classification for the species used in everyday life and these species are referred to by vernacular/local names (GBA,1995). Herbaceous species

grown in Northern Guinea Savanna eco-region have been neglected, because forest ecologists have typically focused on trees, there is a relative paucity of research on the ecology of other plant growth forms, limiting our ability to understand and manage the threats to forest biodiversity as a whole and crops grown in the region. Herbaceous can serve as biodiversity indicators (Culmsee *et al*., 2014) and have been used as charismatic species of conservation concern to galvanize public support for sustainable forest management (Swarts and Dixon, 2009).

Herbaceous plants are under increasing pressures resulting from anthropogenic activities. Humans have been reorganizing natural plant communities for millennia, both increasing and decreasing plant diversity across landscapes (Flinn and Vellend, 2005; Maezumi *et al*., 2018). Direct and indirect effects of anthropogenic activities have become the dominant driving force behind community turnover, population decline, and increased extinction risk in forests (Ellis *et al*., 2012). Previous studies showed that the diversity pattern and species coexistence mechanism of herbaceous plants might be quite different from woody plants (Spicer *et al*., 2021). On the one hand, herbaceous plants and woody plants show quite differences in the root system (Cicuzza *et al*., 2013), leaves, and stature, which may lead to a significant difference in responding to light resources and available nutrition (Siebert, 2002; Ramadhanil *et al*., 2008), and ultimately present a different diversity pattern. furthermore, local environmental factors, such as elevation, slope (Wiharto *et al*., 2021), soil (Beck and Givnish, 2021; Mao *et al*., 2021), community edge (De Pauw *et al*., 2021), thinning intensity (Wang *et al*., 2021), and climate change (Cacciatori *et al*., 2022), also have been shown to have significant effects on the diversity of herbaceous plants.

The economic significance of these species include medicine, food flavoring, bio-fuel, animal feeding, energy sources, green manure and so on. Herbaceous species exhibit cosmopolitan distribution; they could be found in disturbed forest (Mohammed *et al*., 2015), Savannah (Pokorny *et al*., 2004, Keddy *et al*., 2009, Mohammed *et al*., 2015) and crop land (Gibson, 2009). They constitute up to 60% of the plant species diversity in our ecosystem (Clark 2004, Mohammed et al. 2015). Due to their diverse nature, they serve as habitats for a wide array of animals, basis for complex food webs (Smith, 2011, Blair *et al*., 2014, Choy *et al*., 2015, and Arwulan *et al*., 2015, Mohammed *et al*., 2015, Yang *et al*., 2015) and are involved in the stabilization of topsoil, improving water penetration into soils as well as water holding capacity of the soil (Mashwani *et al*., 2010, Mohammed *et al*., 2015, Ford *et al*., 2016, Gilardelli *et al*., 2017). Despite these huge ecological prominence and significant proportions to plant biodiversity, they remain understudied and are usually not included in most floristic studies (Batalha and Martins 2002, Linares-palomino *et al*., 2008, Moro *et al*., 2014, Queiroz *et al*., 2015). Floristic studies are essential in providing information on plant biodiversity in an ecosystem (Addo-Fordjour *et al*., 2009, Todou *et al.,* 2017). This study was, therefore designed to explain variation, using three (3) growth forms (Shrubs; Grasses and Sedges) in ecological diversity studies of herbaceous plants in old Afaka Forest reserve in

Kaduna Northern Guinea Savanna eco-region of Nigeria**.**

Material and Methods

Study Area

The study was conducted in old Afaka forest reserve. The reserve stretches from Igabi local government area via Buruku in Chikun local government area of Kaduna state, Nigeria. The reserve lies between latitude10° 36′ 40″/10°30′36″N and longitude 7°16′32″/7°18′38″E (Fig. 1.). The vegetation in the study area is the Northern Guinea Savanna Woodland type, characterized by short, scattered drought resistant trees with annual rainfall of 1000mm – 1500mm, temperature of 25.6°C, precipitation of 1,117.6mm and humidity of 69% respectively. The topographical relief is relatively flat having an elevation between 600m and 650m in large areas and over 650m above mean sea level and below 500m in places that slope downward towards the river (Sodimu, 2016).

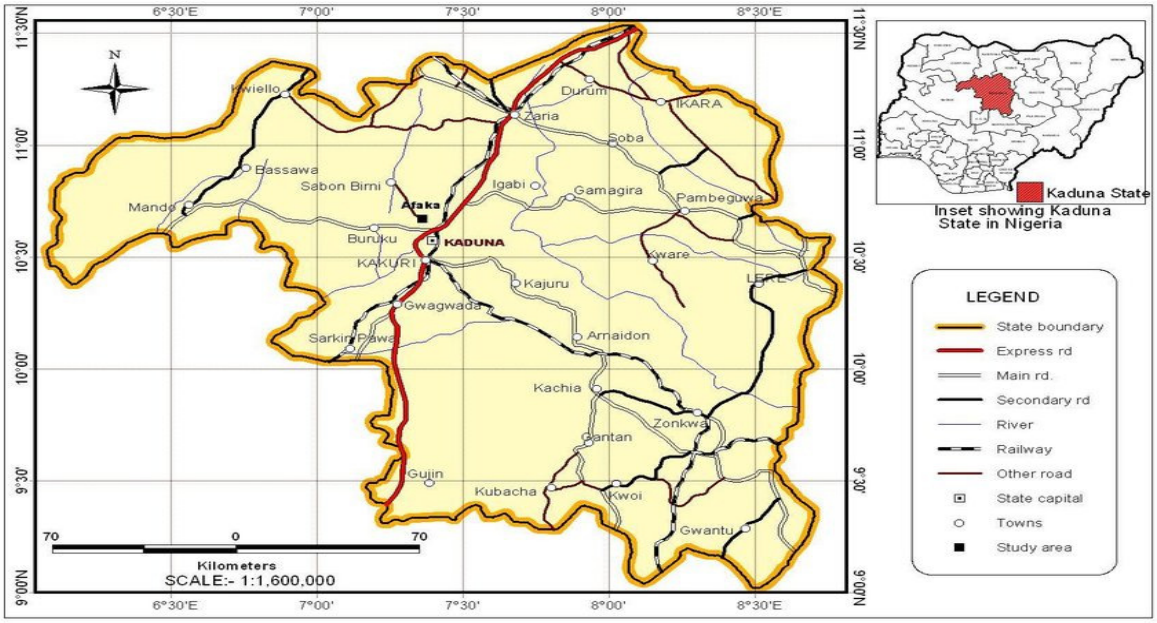

Fig. 1: Map of Kaduna state showing Afaka Forest Reserve

Sampling Technique

The study area was purposely divided into four (4) main plots based on vegetation density and human interference. 50m x 100m were laid with 50m espacement between the plots The line transect method was used in assessing the herbaceous vegetation (Bako and Vachi, 2002; Odiwo, 2004; Sodimu, 2016). Three main growth form (Shrub; Grasses and Sedges) were used to classify the herbaceous species for easy identification. The herbaceous were identified and compiled in accordance to Keay *et al*. (1964) at the Department of Forestry Technology, Federal College of forestry Mechanization, Afaka- Kaduna, Nigeria. Grasses identification was done with reference to Stenfield (1970). However, other herbaceous species were compiled in accordance with Hutchinson and Dalziel (1954; 1963) while the

local/vernacular names were presented in accordance with Gbile (1980).

Data Analysis

Descriptive statistic such as percentages; frequency distribution, and mean were used to analysed the data while the biodiversity indices were calculated using the following formulae:

Shannon-Weiner method (Shannon – Weiner,1963):

$$H^1 = \sum_{i=1} PilogPi$$

or

$$H^1 = \sum i PilnP \quad \ldots\ldots (1)$$

Where: Pi = ni/N

n = number of individual of species

N = Total number of individuals

H^1 = Measure of diversity

Pi = Proportion of the 1th species in a site (Daniel *et al.*, 1996)

(ii) Simpson's diversity index

$$D = 1 - \sum Pi^2 \quad \ldots\ldots (2)$$

Where:

Pi = ni/N

n =number of individual of species

N=Total number of individual

D =Measure of diversity

Pi= Proportion of the 1th species in a site

Margalef's species richness index (Margalef, 1958):

$$R = (S - 1) / In\ N \quad \ldots\ldots (3)$$

Where:

R = Species richness index

S = Total number of species

N = Total number of individuals of all species

Pielous' measure of evenness (Pielous,1984):

$$E = H/ In\ S \quad \ldots\ldots (4)$$

Where:

E = Species evenness

H = the Shannon – Weiner index of diversity

S = Total number of species

Results

Table 1 below shows the frequency counts of the species encounter in the laid plots. In shrubs growth form 26 species were identified. *Isoberlinia doka* had the highest frequency count of 217 closely followed by *Khaya senegalensis* (65) and Acacia seyal had the least (1). In the grasses growth form 11 species were identified, *Occimum basilicum* had the highest frequency count of 47 closely followed by *Eragrotiss species* (43) and *Eragrotis tranula* had the least. However, for the sedges growth form, only 4 species were identified. *Cissuss species* had the highest frequency count of 30; *Cuccurbita maxima* (20) and *Discorea species* had the least (15).

Table 1: Herbaceous Species List and Frequency Count in Old Afaka Forest Reserve

S/N	Herbaceous species	Site A	Site B	Site C	Site D	Total
	***Shrubs**					
1.	*Isoberlinia doka*	47	73	43	5	217
2.	*Monotes kersstingii*	6	22	3	11	42
3.	*Terminalia senegal*	18	12	0	10	40
4.	*Annona senegal*	1	19	31	17	68
5.	*Acacial seyal*	1	0	0	0	1
6.	*Parkia biglobosa*	0	1	0	3	4
7.	*Lannea barteris*	7	3	19	9	38
8.	*Vitellaria paradoxa*	6	8	9	7	30
9.	*Terminalia glaucescenes*	0	11	4	5	20
10.	*Uapaca togoensis*	0	13	0	0	13
11.	*Ximenia americana*	10	4	0	0	14
12.	*Diospyros mespiliform*	5	0	0	0	5
13.	*Avicenia* spp.	0	0	0	8	8
14.	*Febrifuga* spp.	1	0	0	0	1
15.	*Tectona grandis*	9	0	0	0	9
16.	*Anogeissus leocarpus*	6	0	0	0	6
17.	*Gardenia aqualla*	4	4	0	0	8
18.	*Prosopis africana*	3	0	6	3	12
19.	*Vitex doniana*	0	0	1	2	3
20.	*Entada africana*	0	0	9	12	21
21.	*Khaya senegalensis*	0	0	45	20	65
22.	*Bombax costatum*	0	0	4	8	12
23.	*Citrus medica*	0	0	4	6	10
24.	*Gmelina arborea*	0	0	1	2	3
25.	*Pauliostis macrossopteryx*	3	0	0	0	3
26.	*Ficus trichopoda*	0	0	3	4	7
	Total	**126**	**174**	**152**	**173**	**660**
	***Grassess**					
1.	*Eragrotis* sp.	10	12	0	21	43
2.	*Pennisetum nordeides*	5	10	12	14	41
3.	*Sporobolus pyramidalis*	11	14	14	3	42
4.	*Occimum bacilicum*	13	12	13	9	47
5.	*Paspalum orbiculare*	14	4	3	7	28
6.	*Cynodon dactylon*	7	5	10	5	27
7.	*Stylosarithes arrecta*	3	11	11	13	28
8.	*Sataria pallid fuxa*	9	10	12	12	43
9.	*Eragrotis tramula*	3	11	0	14	28
10.	*Digitaria debilis*	13	13	8	8	42
11.	*Paspalidium germnatum*	2	14	7	9	32
	Total	**90**	**105**	**90**	**115**	**400**
	***Sedges**					
1.	*Cissus* spp	3	8	11	8	30
2.	*Dioscorea maxima*	0	3	7	5	15
3.	*Cucurbita maxima*	2	0	12	6	20
4.	*Kyllinga squanmulata*	1	9	0	7	17
	Total	**6**	**20**	**30**	**26**	**82**

Table 2 reveals the percentage spread of the flora species identified in the laid plots. In herbs growth form, *Isoberlinia doka* has high percentage spread (32.7%) than all others in the growth form. *Eragotis tramulais* has higher percentage

spread (13.3%) in grasses growth form while in sedges growth form *cissus spp*. Is higher with 44.6% percentage spread. 41 different species were encountered increasing in the following order: shrubs>grasses>sedges. These species had fallen into 24 families of which poaceae was the most dominant with 9 species belonging to the family including: *Eragrotis* species*, Paspalun orbiculae, Penisetum hordeides, Eragrotis tranula* in which the later had the highest percentage spread (13.3%) of them all. Other families include Fabaceae, Combetaceae, Sapotaceae, Rutaceae, Moraceae and so on.

Table 2: Percentage Spread of Herbaceous Species in Old Afaka Forest Reserve

S/N	Herbaceous species	Family	Local Name (Hausa)	Species frequency	Percentage (%) Spread
	***Shrubs**				
1.	*Isoberlinia doka*	Fabaceae	Bakardookaaa	54.3	32.7
2.	*Monotes kersstingii*	Dipterocarpaceae	Hantso	10.5	6.3
3.	*Terminalia senegal*	Combretaceae	Baushe	10	6
4.	*Annona senegal*	Annonaceae	Gwandardaji	17	10
5.	*Acacial seyal*	Fabaceae	Dumshe	0.3	0.3
6.	*Parkia biglobosa*	Mimosaceae	Dorowa	1.0	0.6
7.	*Lannea barteris*	Anacardiaceae	Faru	9.5	5.7
8.	*Vitellaria paradoxa*	Sapotaceae	Kandaya	7.5	4.5
9.	*Terminalia glaucescenes*	Fabaceae	Baushe	5.0	3.0
10.	*Uapaca togoensis*	Euphorbiaceae	Kafafago	3.6	2.2
11.	*Ximenia americana*	Olacaeae	Tsada	3.5	2.1
12.	*Diospyros mespiliform*	Ebenaceae	Kalwa	1.3	0.8
13.	*Avicenia* spp.	Acanthaceae	Kadora	2.0	1.2
14.	*Febrifuga* spp.	Hydrangeaceae	Shafta	0.3	0.3
15.	*Tectona grandis*	Laminiaceae	Teak	2.3	1.4
16.	*Anogeissus leocarpus*	Combretaceae	Marike	1.5	0.9
17.	*Gardenia aqualla*	Rubiaceae	Gaudee	2.0	1.2
18.	*Prosopis africana*	Fabaceae	Kiriya	3.0	1.8
19.	*Vitex doniana*	Verbenaceae	Dinya	0.8	0.4
20.	*Entada africana*	Fabaceae	Tawatsa	5.6	3.4
21.	*Khaya senegalensis*	Meliaceae	Madaacii	16.3	9.8
22.	*Bombax costatum*	Bombaceae	Kurya	3.0	1.8
23.	*Citrus medica*	Rutaceae	Leemun Masar	2.5	1.5
24.	*Gmelina arborea*	Verbenaceae	Kumneti	0.8	0.4
25.	*Pauliostisma crossopteryx*	Moraceae	Kalgo	0.8	0.4
26.	*Ficus trichopoda*	Moraceae	Cediya	1.8	1.0
	Total			**166.2**	**100**
	***Grassess**				
1.	*Eragrotis* sp.	Poaceae	Buburwa	10.8	13.3
2.	*Pennisetum nordeides*	Poaceae	Kysuwa	9.2	11.3
3.	*Sporobolus pyramidalis*	Poaceae	Nakaselye	9.9	12.2
4.	*Occimum bacilicum*	Lamiaceae	Gwander/daji	9.8	12.0
5.	*Paspalum orbiculare*	Poaceae	Tanbamtsuntsu	3.9	4.8
6.	*Cynodon dactylon*	Poaceae	Laki	3.0	3.7
7.	*Stylosarithes arrecta*	Papilionaceae	Goa	8.9	10.8
8.	*Sataria pallid fuxa*	Poaceae	Malagasy	8.7	10.6
9.	*Eragrotis tramula*	Poaceae	Tsintsiya	6.4	7.9
10.	*Digitaria debilis*	Poaceae	Harkiya	6.9	8.5

11.	*Paspalidium germnatum*	Poaceae	Tumbinkusu	4.0	4.9
	Total			**81.5**	**100**
	***Sedges**				
1.	*Cissus* spp	Vitaceae	Daji	3.3	44.6
2.	*Dioscorea maxima*	Dceaeioslorea	Tamil	0.4	5.4
3.	*Cucurbita maxima*	Cucurbitaceae	Geza	3.2	43.2
4.	*Kyllinga squanmulata*	Cyperaceae	Turare	0.5	6.8
	Total			**7.4**	**100**

Table 3 shows the abundance indices and total percentage spread (%) of the growth forms of herbaceous flora species identified in Old Afaka forest reserve. Shrubs are higher (57.8%) than all other growth forms in the reserve, followed closely by grasses (35%) while sedges were the least with 7.2%.

Table 3: Abundance Indices and Total Percentage Spread of Herbaceous Species Identified in Old Afaka forest reserve

S/N	Herbaceous species Form	Abundance	Total of Spread
1.	Shrubs	660	57.8
2.	Grasses	400	35.0
3.	Sedges	82	7.2
	Total	1142	100

Table 4 revealed the various biodiversity indices values for the growth forms of herbaceous species in the study area. Shannon – Weiner index was found to be higher in grasses (0.37), lower in sedges (0.20) while, Simpson diversity index was higher in sedges (1.00) but lower in shrubs (0.67). Margalef's richness was higher in shrubs (85.1) but lower in sedges (11.5) and lastly the Pielous's evenness shows higher index in grasses (0.061) but lower in sedges (0.043)

Table 4: Biodiversity Index Values of Herbaceous Species Growth Forms in Old Afaka Forest Reserve

S/N	Herbaceous growth form	Shannon-Weiner's Diversity Index (H)	Simpson's Diversity Index (D)	Margalef's Richness index (R)	Pielous's Species Evenness index (E)
	Shrubs	0.3169	0.6660	85.07	0.0488
	Grasses	0.3674	0.8773	56.67	0.0613
	Sedges	0.1894	0.9948	11.50	0.0430

Discussion

Herbaceous plants are an important component of forest ecosystems, playing important roles in species diversity and forest dynamics in forests. However, the current understanding of the biodiversity of forest communities is mostly from woody plants, and knowledge of community structure and species diversity for herbaceous plants remains scarce. Tropical ecosystem has been one of the ecosystems adjudged to be the richest single ecosystem of the world, due to its species richness and diversity (Akindele,

2006). Species in the ecosystem are of paramount importance in climatic amelioration and regulation, enrichment of soil fertility and other direct and indirect benefits that are too many to mention. The herbaceous species encountered in the study area are of typical northern guinea savannah ecosystem that showed tolerance to all agents of exploitation in the reserve area. Exploitation activities noticeable during the course of research includes firewood collection; poaching; bush burning; illegal farming; illegal timber exploitation and grazing. These findings are in accordance with the work of Fries and Hermans (1990) where they found that some species are tolerance to agents of exploitation in a natural forest found in semi-arid ecological zones of Africa. *Isoberlinia doka* been the dominant species with high percentage spread indicate that the reserve is a secondary forest and the presence of *Eragrotis tranmula* in the reserve indicates the presence of herdsmen that practice excessive uncontrolled grazing thereby, making the area susceptible to various anthropogenic activities such as sheets and gully erosion, reduction of biomass and desert encroachment.

The diversity indices are produced to bring the diversity and abundance different growth forms of herbaceous studied to similar scale for comparison and the higher the value, the greater the species/growth form richness (IIRS, 2002). Shannon diversity index is an indicator of the high species diversity and reflect dominance of the grass growth form which further expatiate the pressure of herdsmen that practicing uncontrolled grazing in the reserve. The above results are in line with the works of Fries and Hermans (1990), Bello (2005), Sodimu (2016). On the other hand, Simpson's diversity index which measures the relative abundance of the herbaceous growth form studied with higher index in sedges indicating high dominance with low diversity. These results are in accordance with the work of (Isichei, 1995). also, with Eilu *et al*. (2004) in tropical forests where density and species diversity are of ultimate aim in tropical forest of Albertine rift, Western Uganda.

Furthermore, the higher Margalef's index obtained in shrub's growth form further confirmed that the reserve is rich in shrubs herbaceous growth form while, the higher index in Pielous's species evenness index in grasses growth form indicate evenness among grasses growth form in the reserve. This is in line with the work of (Sodimu,2016). This is also, in agreement with the work of Rahman *et al*. (2011) in assessing regeneration status and diversity of trees species. Generally, anthropogenic activities are one of the major environmental degradations in the northern guinea savanna eco-zone. The dependence on forest for major and minor products all contribute to reduction in the size, quality and quantity of forest products if various conservation methods are not employed. Forest conservation does not say don't use but rational use of the resources in a sustainable etiquette for maintaining ecological conditions for optimum benefits and services from the forest estate

Conclusion

Based on the study quite number of herbaceous flora were recorded, identified with their families. However, the herbaceous species come across in the study area are of typical Northern Guinea Savannah ecosystem that showed

tolerance to all agents of exploitation such as poaching; bush burning; illegal farming; illegal timber exploitation and grazing. *Isoberlinia doka* been dominant species, indicate that the reserve is a secondary forest and the presence of *Eragrotis tranmula* in the reserve indicates the presence of herdsmen that practice excessive uncontrolled grazing thereby, making the area susceptible to various anthropogenic activities such as erosion, reduction of biomass and desert encroachment. The diversity indices showed the diversity and abundance of different growth forms of herbaceous studied to similar scale for comparison and the higher the value, the greater the species/growth form richness. There is need for further studies in the reserve to promote the regeneration potentials of the diverse species of herbaceous plants, economic significance of herbaceous plants in biomedicine, protective and regulative services, socio-cultural services, energy production and so on, Federal government should revise forestry laws and edicts through relevance agencies against uncontrolled herds grazing; farming; bush burning and indiscriminate exploitation so as to encourage high regeneration potentials in this reserve and lastly, the relevance authority should sensitize the local populace on the economic importance of herbaceous plants and needs to conserve them through awareness campaigns and extension services.

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