Assessment of plant communities' pattern and diversity along a land use gradient in W Biosphere Reserve, Benin Republic

Laurent Gbenato Houessou[1,2*], Anne Mette Lykke[3], Oscar Semadegbe Teka[2], Aristide Cossi Adomou[2,4], Madjidou Oumorou[5], Brice Sinsin[2]

[1] *Laboratory of Ecology Botany and Plant Biology, Faculty of Agronomy, University of Parakou (Benin)*

[2] *Laboratory of Applied Ecology, Faculty of Agronomic Sciences, University of Abomey-Calavi (Benin)*

[3] *Department of Bioscience, Aarhus University, Vejlsøvej 25, 8660 Silkeborg (Denmark)*

[4] *National Herbarium, Faculty of Sciences and Technics, University of Abomey-Calavi, Abomey-Calavi (Benin)*

[5] *Laboratory of Research in Applied Biology, Polytechnic School of Abomey-Calavi, Department of Environment, University of Abomey-Calavi, (Benin)*

*Corresponding Author: *houessoulaurent@gmail.com*

Abstract

Human disturbance on vegetation is an important concern in biodiversity conservation. In this study we assessed how anthropogenic disturbance affected plant communities pattern, diversity, life form and chorotype composition along a land use gradient. Vegetation relevés were performed along a land use gradient (park-buffer zone-communal land) at W Biosphere Reserve in Benin. Non-metric multidimensional scaling (NMS) was used to assess plant communities patterns. Indicator species were determined for each plant community and land use. Plant community diversity, life forms and chorotypes composition were assessed and compared among land uses using one-way analysis of variance. NMS ordination showed a good separation between relevés of the park and those from the communal land while relevés of buffer zone were mixed within the park and communal land relevés. There was no significant difference between species richness among land uses types ($F = 0.68$; $p = 0.529$, ANOVA test at a level of significance of 5%). The Pielou evenness for the plant communities was higher in the park ($E= 0.69±0.04$) and buffer zone ($E = 0.61±0.13$) than in the communal lands ($E = 0.44±0.02$) while Shannon index showed no clear pattern along land use gradient. Therophytes abundance was significantly higher in the communal land while hemicryptophytes abundance was significantly higher in the park. Wide-distributed species abundance was significantly higher in the communal land whilst Sudanian species showed significantly higher abundance in the park. We concluded that monitoring of the indicator species of the plant communities and their traits are relevant tools for managers to follow-up changes in plant communities.

Introduction

Aside environmental factors, disturbance is considered as a factor affecting plant community structure, distribution, composition and functionality (Biswas and Mallik, 2010; Nacoulma *et al*., 2011). Human disturbance on vegetation is nowadays an important concern in biodiversity conservation and current global change (O'Connor, 2005, Southworth *et al*., 2016). The effects of this disturbance could lead to: (i)- rarity and vulnerability of some species (Adomou *et al*., 2006), (ii)- high occurrence of invasive species (Aboh *et al*., 2008), (iii)- ecosystem loss or habitat fragmentation (Thompson *et al*., 2017). Moreover, human disturbance could completely change the species composition of the original plant communities, which in some cases can become irreversible (Kassi N'Dja and Decocq, 2008; Lindenmayer *et al*., 2017). In tropical region, many anthropogenic factors were targeted as inducing notable changes in vegetation. Flamenco-Sandoval *et al*. (2007) outlined clearing for agriculture, i.e. slash and burn cultivation, grazing and tree logging as important driving forces contributing to land use and land cover change and accordingly vegetation composition. For instance, most studies on vegetation fire underlined meaningful effect of fire on vegetation pattern in savannas and plant communities' structure, composition as well as their traits (van Wilgen *et al*., 2007). Meanwhile grazing systems effects on plant communities' diversity, structure, composition, life form and productivity were evidenced by previous studies (Lezama *et al*., 2014). In that way, Hendricks *et al*. (2005) observed perennial species substitution by annual species near livestock camp in South Africa. Likewise, O'Connor *et al*. (2011) underlined long-term decrease of forbs richness under a high stocking rate.

As disturbance results, patches of vegetation in different stages of succession are distributed across the landscape. Most previous ecological studies have documented the successional vegetation patterns as temporal and spatial change in vegetation composition (Fournier *et al*., 2001; Kassi N'Dja and Decocq, 2008). Following time scale, the vegetation composition goes from, vegetation dominated by pioneer plant species to secondary pseudo-stable vegetation with more competitive species (Kassi N'Dja and Decocq, 2008). Depending on the interaction between anthropogenic disturbance intensity and abiotic factors, plant community traits as well as their composition shift over time and space at each vegetation stage and reflect the ongoing process in the plant community (Bangirinama *et al*., 2010).

Therefore, the knowledge on the change occurring in plant communities' characteristics across land use can enable to understand how far human disturbance affect plant community's composition and diversity and provide reliable tools for phytodiversity monitoring and management. Except for researches already reported on human disturbance on tree species communities or herbaceous communities more often separately (Shackleton, 2000; Nacoulma *et al*., 2011), little is known about how anthropogenic disturbance shapes the whole plant communities' pattern and affects community diversity and floristic composition. Hence, in this study we focused on a gradient going from communal land to core area of a biosphere reserve, where anthropogenic disturbance is considered as absent. Overall, we aim to describe changes in floristic composition along a land use gradient. More specifically, the study aims i)- to assess plant community patterns, ii)- to determine change in indicators species along the land use gradient, iii)- to determine alpha and beta diversity of plant communities, iv)- to investigate the change in plant communities traits (life form and chorotypes) in order to provide managers with simple and reliable tools for monitoring and evaluating the success of ongoing conservation actions with respect to phytodiversity.

Material and methods

Study Area

The study was conducted in the W Biosphere Reserve in Benin (WBR) (11°26'-12°26' N; 2°17'-3°05' E, Figure 1). The WBR is composed of the park and its adjacent hunting zones and is under the administration of the National Centre for Wildlife Reserves Management (CENAGREF) that outlines and implements management and conservation actions of the reserve (Clerici *et al*., 2007). The reserve is located in the Sudanian centre of endemism (White, 1983), where climate is characterized by one rainy season (May to October) and a dry season (November to April). The mean annual rainfall experienced ranges from 900 mm to 1100 mm. The mean monthly temperature ranges from 25 to 35°C and values of the relative air humidity range from 81% in August to 26 % in February (ASECNA, Unpubl. data). Overall, soils are tropical ferruginous type and characterized by moderate fertility (Viennot, 1978). Anthropogenic activities (livestock grazing, cropping, uncontrolled fire and logging) are strictly prohibited inside the reserve. At the periphery of the reserve, a 5 km land belt (buffer zone) is set up to stop anthropogenic pressure from the communal lands on the park. In the buffer zone, crop growing, Non-timber Product Forests (NTFPs) harvesting and livestock grazing are allowed but subjected to restrictions. In contrast to the park and buffer zone, there is no restriction with respect to human activities in the communal lands. Thus, this latter is subjected to high anthropogenic disturbance. Cropping based on shifting cultivation and livestock breeding based on extensive use of pastureland represent the most important socio-economic activities of the local populations. The main cultivated crops are cotton, sorghum, corn and millet. Cattle, sheep and goat are the main livestock farmed. Uncontrolled fires are frequently applied by the local populations in order to favour perennial grasses regrowth, for poaching and for land cleaning according to local perception. The population density in the peripheral WBR is about 20.0 inhabitants km^{-2} (INSAE, 2013). Vegetation types occurring in the reserve are composed of a mosaic of savannas (shrub, tree, grass savanna and woodland) and gallery forest (CENAGREF, 2008). In the communal lands, vegetation is dominated by croplands and fallows and degraded savanna. Roughly the area is divided in three land uses (park, buffer zone, communal lands) presenting a gradient of land use from protected to non-protected area. Then we assume that the area is suitable for studying the land use gradient effect on plant communities' pattern and

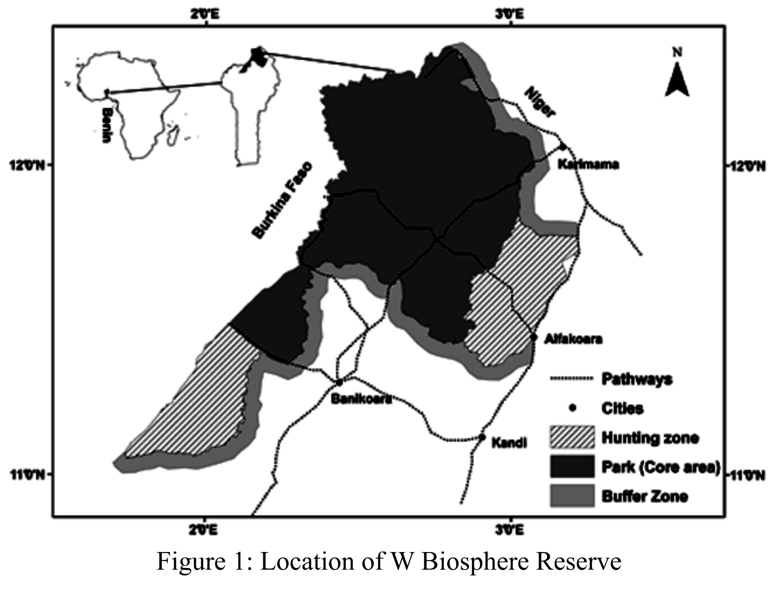

Figure 1: Location of W Biosphere Reserve

diversity.

Data Collection

Landsat 8 OLI/TIRS satellite image of October 2017 (path 192 and row 52) was processed by using normalized difference vegetation index "NDVI" to enhance vegetation contrast. Then we performed the maximum likelihood supervised classification which enable to identify the main patches of vegetation in each land use type (i.e. park, buffer zone and communal lands). Based on the processed image, we set up a total of 120 stratified random plots in five main vegetation types (woodland, gallery forest, shrub/tree savanna, grass savanna and fallow) in the three land uses types. Trees and shrubs sampling was carried out in 30 m x 30 m plots and herbaceous floristic composition was carried out through phytosociological relevés in subplots of 10 m x 10 m (Weber *et al*., 2000). In each plot we recorded directly in the field: (i)- exhaustive species list, species naming conventions were taken from Benin flora (Akoègninou, 2006); (ii)- percentage cover for each species; (iii)- vegetation types; (iv)- soil texture using visual assessment (clayey soil; silty soil; sandy soil, gravely soil); (v)- level of perturbation (grazing disturbance) based on a visual assessment of the level of clipped vegetation and cattle footprint presence.

Data Analysis

Plant Community Ordination, Classification and Indicator Species Determination

A presence absence data matrix of the 120 vegetation relevés was analysed using PC-Ord (McCune and Mefford, 2006). Non-metric multi-dimensional scaling (NMS) based on Sørensen (Bray-Curtis) distance measure was used for the vegetation ordination (Kruskal, 1964). We used NMS autopilot to determine the number of axes which gave the best configuration of the relevés in the ordination space (McCune and Grace, 2002). Cluster analysis was used to classify the plant communities in each land use type (with Sørensen distance measure and flexible beta linkage method). The number of plant communities was determined using indicator species analysis, which implied selecting the number of clusters that had the smallest average p-value and the highest number of indicator species (McCune and Grace, 2002). A cover-abundance data matrix was used for the indicators species determination. For each plant community and land use type, the indicator species were selected numerically following the method of Dufrêne and Legendre (1997). The indicator species determination in each land use type was done by adding to the initial data matrix of relevés an additional variable describing the land use type to which the relevé belong. The same rule was used for the plant communities' indicator species determination. The Indicator Species Analysis Package in PC-Ord was run to determine the indicator value (IV) of each species in each land use type and in each plant community. The indicator value is the combination of the species relative abundance (Ai in %) and relative frequency (Bi in %) in each land use type and in each plant community (IV = Ai x Bi). The Monte Carlos test of permutation was performed on the indicators values to determine the plant species which indicator value was significant. The indicator species were represented by the species which had the highest indicator value and significant Monte Carlos test ($p < 0.05$).

In the specific case of land use indicators species determination, we selected plant species which indicators values probability of Monte Carlos test is <0.01 and had a high IV value in the considered land use type comparing to the other land use.

Intra-community diversity of the Plant Communities

The intra-community diversity (α-diversity) of the plant communities was assessed using the species richness, the Shannon diversity index (Shannon, 1949) and the Pielou evenness (Pielou, 1969).

Plant community species richness

Species richness was determined by counting the number of species recorded in the relevés describing each plant community. We computed the total number of species recorded per plant community and estimated the species richness for woody and herbaceous layers.

Plant community Shannon index - It was estimated as:

$$\mathbf{H' = -\sum_{i=1}^{s} P_i \log_2 P_i} \qquad (1)$$

where pi is the relative abundance of the species i in a given plant community and S the species richness of the community.

Plant community evenness - It was computed as:

$$\mathbf{E = H'/\log_2 S} \qquad (2)$$

where S is the total number of species per plant community and H' is the value of the Shannon index. E values range from 0 (dominance of few species in the community) to 1 (evenly distribution of plant species in the community).

Beta Diversity of the Plant Communities

In contrast to alpha diversity, beta diversity (β-diversity) is considered as the intercommunity diversity i.e. within plant communities (Magurran, 2004). β-diversity describes the change (turn over) in species composition between two plant communities. We used it hereafter to determine floristic change between land use compositions. It was estimated as:

$$\boldsymbol{\beta} - \textbf{diversity} = \mathbf{1} - \textbf{Sørensen similarity index} \qquad (3)$$

where Sørensen similarity index = 2c / (a+b); and a = number of species recorded only in the plant communities of land use A, b = number of species recorded only in a plant communities of land use B and c = number of species shared by both communities of land use A and B. The values of β-diversity range from 0, for a complete similarity, to 1, for an absence of similarity. We assumed that if β-diversity > 0.5, the plant communities in two land use types were floristically different (Mwaura and Kaburu, 2009).

Plant Community Composition in Life Forms

We assigned life forms to species using those defined by Raunkiaer (1934): Therophyte (THERO); Hemicryptophyte (HEMI), Chamaephyte (CHAM), Cryptophyte (CRYP) and Phanerophyte (PHAN). Afterward, the abundance of each life form type (CLFi) was calculated for each plant community according to the formula:

$$\mathbf{C_{LFi} = ni/S \ x\ 100} \qquad (4)$$

where **ni** = number of the species with the life forms **i** in plant community and **S** = total number of species in the community. In addition, we estimated the percentage cover of each life form type according to the formula:

$$\mathbf{C'_{LFi} = ri/R\ x\ 100} \qquad (5)$$

where **ri** = percentage cover of the species with the life i in the plant community and **R** = total percentage cover of all species in the community.

Plant Community Composition in Chorotypes

For chorotypes composition assessment, we used the classification defined by White (1983) and grouped species into three main chorotypes i.e. *Sudanian species (*S*)*; *Wide distribution species* (WD), corresponding to afro-american, pantropical and paleotropical plant species, and *Continental distribution species* (CD) corresponding to afro-malagasy, afro-tropical, pluri-regional African species and sudano-zambesian species. On this basis, the composition in chorotype for each plant community was estimated following the rules described above for life forms. Both percent abundance and percent cover were assessed.

Statistical Analysis

The data were log-transformed to meet the assumptions of normality and homogeneity of variance for each of the estimated parameters (Dagnelie, 2011). One-way analysis of variance (ANOVA) test was performed in Minitab 18.1 to determine if there were significant differences between species richness, life form composition and chorotype composition for the plants communities along the gradient going from communal land to the park.

Results

Plant Communities Pattern and Classification

In the 120 sample plots inventoried, an overall of 338 plant species belonging to 57 plant families were noticed. The NMS ordination diagram shows a good separation between relevés of the park and those from the communal land. Relevés of the buffer zone were mixed within the park and communal

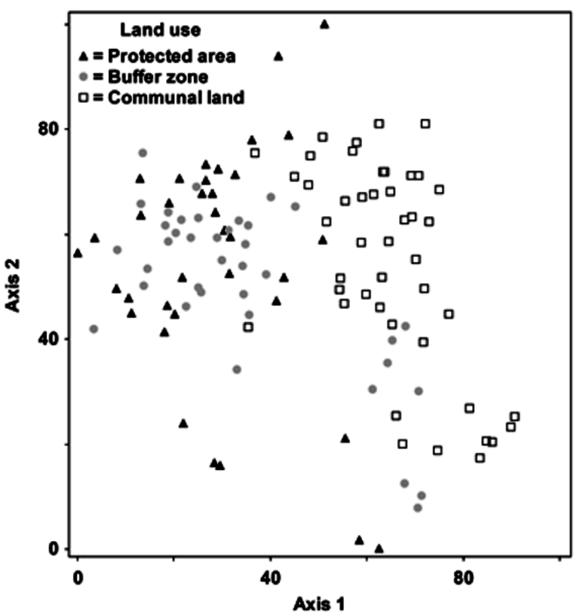

Figure 2: Diagram of the projection of the 120 plots in the first two axes of the non-metric multidimensional scaling (NMS). A two-dimensional solution was obtained by NMS autopilot for a best configuration of the plots. The final stress = 18.14 and final instability = 0.0032 with 200 iterations and 50 runs with randomized data. Legend: Ap = Park; BZ = Buffer zone and CL = Communal land

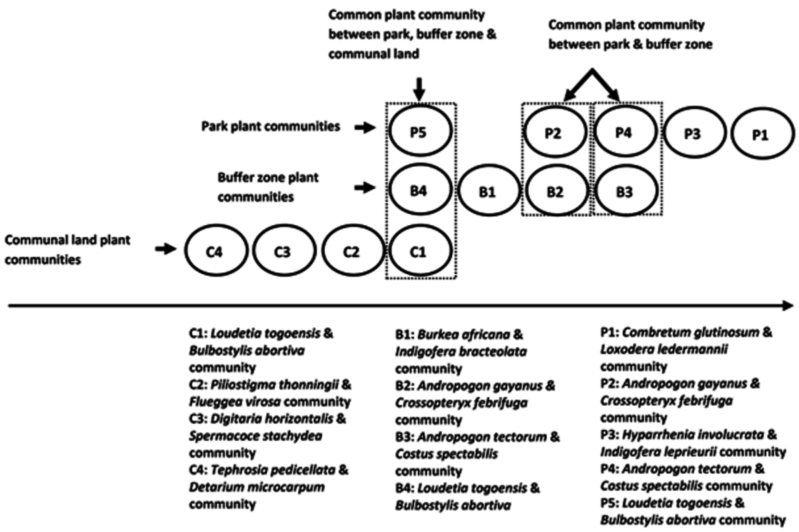

Figure 3: Clustered plants communities per land use based and common plant communities between land uses as revealed by indicator species analysis.
Legend: P1, P2, P3, P4, P5 = Plant communities clustered in the park, C1, C2, C3, C4 = Plant communities clustered in the communal. B1, B2, B3, B4 = Plant communities clustered in the buffer zone

land (Figure 2). NMS ordination on the relevés for each land use followed by cluster analysis allowed classification of the park relevés into 5 main plants communities (P1, P2, P3, P4, P5), buffer zone relevés into 4 communities (B1, B2, B3, B4) and communal land relevés into 4 communities (C1, C2, C3, C4) (Appendix). Based on the indicator species analysis, results showed that the *Loudetia togoensis* & *Bulbostylis abortiva* community was found in park (P5), buffer zone (B4) and communal land (C1). The *Andropogon tectorum* & *Costus spectabilis* community (B3 in the buffer zone; P4 in the park) and the *Crossopteryx febrifuga* & *Andropogon gayanus* community (B2 in the buffer zone; P2 in the park) were both present in the buffer zone and in the park (Figure 3 & Appendix).

Species Richness, Shannon Index and Pielou Evenness of Plant Communities

Overall, the mean (± standard error) species richness recorded per plant community was lower in the park (128.6 ± 45.2) comparatively to the buffer zone (135.1 ± 42.6) and the communal land (143.2 ± 40.9). However, there was no significant difference between species richness among land uses (F = 0.08;

TABLE 1
Mean alpha diversity of the plant communities in each land use

Vegetation Layer	Alpha diversity	Land use			Significance (Anova test at 5% level)
		Park	Buffer Zone	Communal land	
Herbaceous	Species richness	120.6±29.96	117±42.44	132.5±37.04	F=0.68; P =0.529
	Shannon index (bits)	3.27±0.41	3.46±0.28	3.15±0.65	
	Pielou evenness	0.67±0.08	0.59±0.23	0.45±0.01	
Woody	Species richness	21.25±12.03	19.25±6.06	19±7.84	F = 0.42; P = 0.669
	Shannon index (bits)	4.42±0.64	4.13±0.91	2.05±0.37	
	Pielou evenness	0.81±0.22	0.72±0.11	0.44±0.19	
Overall	Species richness	128.6±45.2	135.1±42.6	143.2±40.9	F = 0.08; P = 0.925
	Shannon index (bits)	4.08±0.29	3.94±0.44	3.96±0.61	
	Pielou evenness	0.69±0.04	0.61±0.13	0.44±0.02	

p = 0.925; Table 1). At a significance level of 5%, ANOVA test showed that there was no significant difference between species richness for the herbaceous layer ($F = 0.68$; $p = 0.529$) and the woody layer among the three land use types ($F = 0.42$; $P = 0.669$).

Considering the woody layer, the mean Shannon index value of the plant communities was higher in the park (H' = 4.42 ± 0.64) and buffer zone (H' = 4.13 ± 0.91). In contrast, the woody species diversity was low in the communal land (H' = 2.05 ± 0.37) with an uneven distribution in communal land (Pielou evenness < 0.5). Considering the herbaceous layer, the diversity was intermediate in the three land use types. However, Pielou evenness displayed low value in the communal land showing the dominance of few species in the communal communities

Beta diversity among Land Use Type

β-diversity displayed high floristic similarity between the buffer zone and the park (β = 0.10). Moreover, we found that plant communities in the park and buffer zone were floristically different from those in the communal land (β > 0.5). Park and buffer zone shared 193 species (58 %) while the number of shared species between the buffer zone and communal land was 108 species (32 %). Park and communal

TABLE 2
Indicators value of the plant species in each land use

Land use	Species	Indicator Value			P-value
		Park	Buffer zone	Communal land	
Park	*Androgon gayanus*	55	30	0	0.0002
	Diheteropogon amplectens	30	2	0	0.0004
	Hyparrhenia smithiana	32	11	0	0.0004
	Loudetia arundinacea	24	0	0	0.0004
	Lannea barteri	16	0	0	0.0008
	Loxodera ledermannii	14	0	0	0.002
	Aganope stuhlmannii	35	5	0	0.0024
	Andropogon chinensis	29	15	0	0.0032
	Andropogon tectorum	16	0	0	0.0034
	Tinnea barteri	22	6	0	0.0034
	Indigofera paniculata	15	0	0	0.0042
Buffer Zone	*Aspilia angustifolia*	8	39	1	0.0002
	Chasmopodium caudatum	10	46	1	0.0002
	Indigofera bracteolata	5	50	5	0.0002
	Polygala arenaria	13	42	8	0.0002
	Hyparrhenia smithiana	5	34	1	0.0004
	Sorghastrum bipennatum	1	41	0	0.0004
	Ximenia americana	4	34	0	0.0004
	Andropogon schirensis	12	34	0	0.0006
	Andropogon pseudapricus	6	28	3	0.0014
	Commelina erecta	13	35	4	0.003
Communal Land	*Flueggea virosa*	0	1	51	0.0002
	Pennisetum polystachion	1	2	70	0.0002
	Senna obtusifolia	0	0	36	0.0002
	Setaria pumila	0	1	76	0.0002
	Sida acuta	0	1	31	0.0002

TABLE 2 *continued*
Indicators value of the plant species in each land use

Land use	Species	Indicator Value			P-value
		Park	Buffer zone	Communal land	
Communal Land (continue)	*Vitellaria paradoxa*	0	1	52	0.0002
	Tephrosia pedicellata	0	1	81	0.0002
	Triumfetta rhomboidea	0	0	64	0.0002
	Sida cordifolia	0	0	16	0.0008
	Desmodium hirtum	0	0	19	0.0012
	Euphorbia hyssopifolia	0	0	16	0.0016
	Euphorbia convolvuloides	3	1	24	0.0028
	Wissadula amplissima	0	0	17	0.0044
	Paspalum scrobiculatum	0	0	13	0.005
	Dichrostachys cinerea	1	1	43	0.0066

lands shared 30 % of the species (106 species).

Indicator Species Change among Land Use

Floristic analysis based on the indicator value of the plant species in each land use type revealed that *Androgon gayanus, Diheteropogon amplectens, Hyparrhenia smithiana, Loudetia arundinacea, Loxodera ledermannii, Andropogon chinensis* and *Andropogon tectorum* yielded high indicator value in the park (Table 2). Postcultural or ruderal species such as *Senna obtusifolia, Tephrosia pedicellata, Triumfetta rhomboidea, Sida cordifolia, Desmodium hirtum, Euphorbia hyssopifolia, Dichrostachys cinerea, Euphorbia convolvuloides* presented high indicator value in the communal land. Buffer zone displayed a pioneer species as well as perennial Poaceae with high indicator value: *Andropogon schirensis, Hyparrhenia smithiana, Andropogon pseudapricus, Commelina erecta* and *Indigofera bracteolata, Ximenia americana*.

Life Forms Composition of Plant Communities

Life forms composition of the plant communities showed that the percent abundance as well

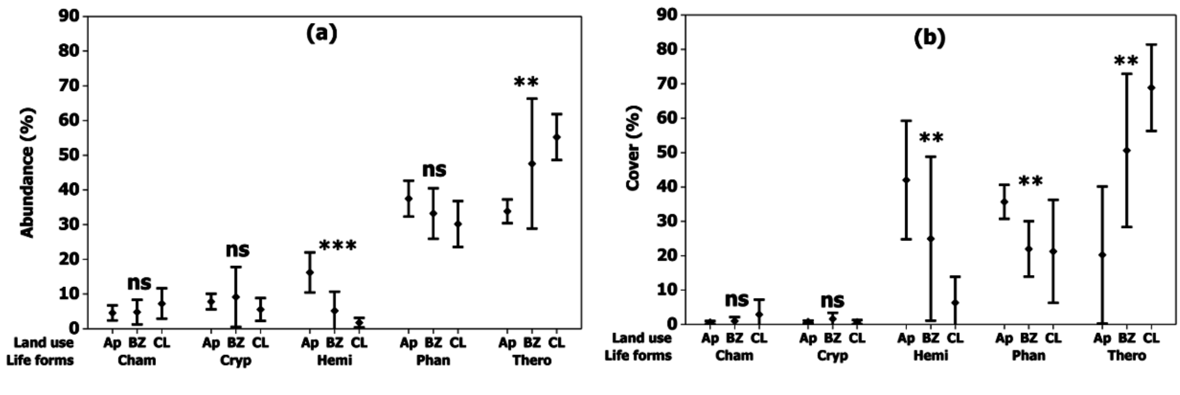

Figure 4: Life forms composition of the plant communities: (a) – Percentage of abundance of the life forms in the plant communities; (b) – Percentage cover of the life forms in the plant communities
Legend: **P < 0.01, ***P < 0.001, ns for P>0.05; Ap = Park; BZ = Buffer zone; CL = Communal land; THERO= Therophyte; HEMI= Hemicryptophyte, CHAM = Chamaephyte, CRYP = Cryptophyte and PHAN = Phanerophyte

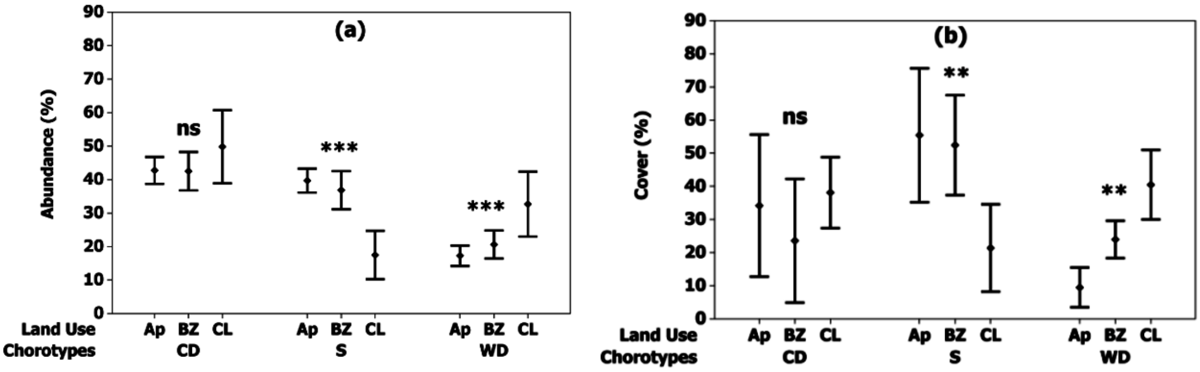

Figure 5: Chorotypes composition of the plant communities: (a)- Percent abundance of the chorotypes in the plant communities; (b)- Percent cover of the chorotypes in the plant communities.
Legend: **P < 0.01, ***P < 0.001, ns for P>0.05; Ap = Park; BZ = Buffer zone; CL = Communal land; WD = Wide distribution species; S = Sudanian species; CD = Continental distribution species

as the percent cover of hemicryptophytes and therophytes were significantly different among the three land uses at a significance level of 1% ($p < 0.01$, Figure 4a & 4b). Park presented higher percent abundance (16.24 ± 4.64 %) and higher percent cover (42.00 ± 13.89 %) in hemicryptophytes compared to the buffer zone and communal land. Therophytes yielded high percent abundance (55.20 ± 4.16 %) and high percent cover (68.86 ± 7.90 %) in the communal land. At a significance level of 5%, ANOVA test showed that land use type had no significant effect on the phanerophyte percent abundance ($F = 3.31$; $p = 0.079$; Figure 4a). However, the cover of the phanerophytes was significantly different among the land use types at a significance level of 1% ($F = 7.76$; $p = 0.009$, Figure 4b). Results showed no significant difference between the land use types with regard to cryptophytes and chamaephytes.

Chorotypes Composition of Plant Communities

Regarding the chorotypes' composition of the plant communities, we found no significant difference for the species with continental distribution among the land use types (ANOVA test at a significance level of 5 %). Sudanian species percent abundance ($F = 46.49$, $p < 0.001$, Figure 5a) and wide distribution species percent abundance ($F = 17.99$, $p < 0.001$, Figure 5a) were significantly different among the land use types based on ANOVA test at a significance level of 1 %. Plant communities in the park, sheltered a high percent abundance of Sudanian species (39.7 ± 2.86 %) and those in communal land exhibited low percent abundance (17.49 ± 4.53 %) in Sudanian species. Plant communities in the communal land yielded higher percent abundance (32.69 ± 6.09 %) of wide-distribution species than those in the park. Plant communities in the buffer zone presented an intermediate situation. The same tendency was observed for percent cover of the different chorotypes' composition in the plant community (Figure 5b).

Discussion

Plant Communities Pattern and Floristic Change

In this study, we focused on potential

floristic change of plant communities along a gradient of land use (park-buffer zone-communal land). Results showed a clear difference between communal land relevés, where anthropogenic disturbance occurred, and park relevés where the vegetation was undisturbed. Buffer zone relevés were mixed within park relevés and communal land relevés. These results highlight the human disturbance influence on plant communities' distribution and composition (Koulibaly *et al*., 2006; Liu *et al*., 2009). Plant communities pattern and indicator species analysis showed that, although there were plant communities exclusive to each land use yet some of them were shared between the land uses. The *Loudetia togoensis* & *Bulbostylis abortiva* community was found to be common to the three land uses suggesting that this community may be less affected by disturbance. Indeed, this plant community thrives on shallow and poor soil which is named "bowe" (Padonou *et al*., 2014). This type of soil is not suitable for agriculture purpose and is hence set apart during land clearing for cultivation. However, the herbage on "bowe" is grazed by cattle in the communal lands.

Plant communities in the communal lands derived from secondary successional pattern as evidenced by the indicators' species of the plant communities in this land use type. For instance, *Tephrosia pedicellata* and *Triumfetta rhomboidea* were described as indicating overgrazed sites near to hamlets (Fournier *et al*., 2001) while *Spermacoce stachydea*, *Digitaria horizontalis* and *Schizachyrium* exile are generally associated with young fallow (1-3 years) on poor soils (Sinsin, 1993). Plant species such as *Dichrostachys cinerea*, *Piliostigma thonningii* and *Flueggea virosa* are indicators of old fallow (5-10 years) on soil which is recovering its fertility.

In the park, indicator species analysis revealed that perennial Poaceae such as *Andropogon gayanus*, *Andropogon schirensis, Andropogon tectorum* and *Loxodera ledermannii* were the main indicator species in the park. Although variation can occur depending on the soil, these species are often described as characterising the ultimate stage of succession, which is maintained by the annual cyclic fire in savanna (Fournier *et al*., 2001).

Indicators species in the buffer were both represented by perennial grasses and ruderal species. This highlights the dynamics of indicator species in the buffer area from perennial Poaceae species to postcultural and ruderal species characteristic of disturbed area. We deduced that indicator species for plant communities shift along the gradient of disturbance depending on the level of disturbance affecting the communities.

β-diversity highlighted similarities between plant community composition in the buffer zone and the park. In contrast, plant communities in the communal lands differed floristically from those in the buffer zone and park. These results suggest that human disturbance influence the composition and distribution of plant species and communities as demonstrated by earlier studies (Kassi N'Dja and Decocq, 2008; Biswas and Mallik, 2010). In fact, in the communal lands adjacent to the park, agriculture and cattle breeding emerged as the main activities practiced in the area (Clerici *et al*., 2007). It is well known that extensive vegetation clearing for agriculture as it is practised around the park leads to fallow and semi-natural vegetation changing the original composition of the plant communities (Kassi N'Dja and Decocq, 2008). In addition, high intensity grazing modifies both the structure and composition of the plant communities by selective grazing of species and trampling as highlighted by Haarmeyer *et al*. (2010).

Plant Communities Species Richness, Shannon Diversity Index and Pielou Evenness

Our findings showed that there was no significant difference in plant communities species richness between the different land uses. However, species richness of the plant communities in the communal lands was numerically higher comparing to the park and to the buffer zone. This suggests that although disturbance affects plant community composition along the gradient of land use, the pattern of species richness in the plant communities did not follow the gradient going from communal land to the park. This result could be supported by the intermediate disturbance hypothesis which predicts that during the course of vegetation succession, the species richness was higher at the intermediate stage than at the final stage (Wilkinson, 1999; Biswas and Mallik, 2010). In our case, plant communities in the communal lands were at earlier stage and intermediate stage of succession while plant communities in the park were at the final stage and more stable. Therefore, it is not surprising to find high species richness in the plant communities in the communal land comparing to the park. However, our findings were contrary to those of Nacoulma *et al*. (2011) who in a related study found that the species richness of the plant communities in the protected area was significantly higher than in the communal land. Nonetheless, our results were corroborated by Shackleton (2000) who found higher species richness for plant communities in communal lands comparing to conservation areas.

We found that plant communities in the park and buffer zone displayed high diversity for the woody layer while the diversity was lower in the communal lands. In fact, the lower diversity of the woody species in the communal lands might be linked to the selective exploitation of woody species. During the land clearing for cultivation, woody species in the farmland are cut down. Only a few species with high economic value mainly *Vitellaria paradoxa, Parkia biglobosa, Adansonia digitata, Bombax costatum, Tamarindus indica* or fodder species such as *Pterocarpus erinaceus, Afzelia africana, Khaya senegalensis* and *Stereospermum kunthianum* are set aside by the farmers in the communal lands (Bonou, 2008) for household needs. Therefore, woody species are less diversified in the communal lands comparatively to the park and buffer zone. Regarding the herbaceous layer, results showed that diversity was intermediate within the three land uses. Nonetheless, communal land plant communities presented an uneven species distribution in contrast to the park and buffer zone. This suggests that evenness distribution of plant species communities is more sensitive to disturbance as showed by the significant correlation between plant communities evenness land use type, vegetation type and pastoral pressure. This might be explained by the fact that disturbance results in the emergence of new plant species after land abandonment. Communal lands plant communities are dominated by few pioneer species which behave like invasive species at the first stage of succession. In addition to land cultivation which results in invasion of pioneer species, grazing eliminates most of the preferred grazed species and favours the dominance of some invasive species such as *Hyptis suaveolens* (Aboh *et al*., 2008).

Life Form of Plant Communities

The study highlighted that there was a floristic change in plant community's life forms along the disturbance gradient going from communal lands to the park. Overall, the percent abundance as well as the cover of the hemicryptophytes and therophytes changed significantly between the communal lands, buffer zone and park. Hemicryptophytes abundance as well as their cover were significantly higher in plant communities in the park compared to the buffer zone and communal lands. Conversely, therophytes abundance and cover decreased significantly from the park to the communal lands suggesting that disturbance may favour the occurrence of therophytes in detriment of hemicryptophytes. Considering the phanerophytes percent abundance, our results showed no significant difference among the three lands uses suggesting that disturbance did not affect phanerophytes abundance. This result was similar to those obtained by Banda *et al*. (2006) who found lower density of tree stands in national park in Tanzania comparatively to the open area where human disturbance occurred. Our findings did not show any difference between plant community composition in chamaephytes and cryptophytes composition along the gradient from the park to communal lands. Ultimately, we concluded that the life form composition of plant communities can be used as indicator for phytodiversity monitoring of mainly hemicrytophytes, therophytes and phanerophyes in our study area.

Chorotypes of Plant Communities

The chorotypes are regarded in plant ecological studies as important traits of vegetation, which described the phytogeographical affinity of the plant communities (White, 1983; Adomou *et al*., 2006). Our study revealed that the Sudanian species proportion decreased significantly from the plant communities in the park to the communal lands, while the proportion of wide distribution species increased along the gradient. Previous studies also found an important proportion of wide distribution species in secondary vegetation (Adomou *et al*., 2006; Bangirinama *et al*., 2010). Species with continental distribution showed no significant difference between the land uses. Chorotypes composition of a plant community can be used as an indicator of disturbance. High occurrence of wide distribution species indicates a high level of degradation in the community while high occurrence of the Sudanian species indicates a relatively undisturbed community in the Sudanian region.

Conclusion

This study illustrates change in diversity and species compositions of plant communities along a land use gradient. Our results support intermediate disturbance hypothesis and highlight the relevant indicators of plant community attributes to monitor change occurring in plant communities due to human disturbance at species or habitat level. At species level we found that floristic composition change as expressed by indicators species of the plant communities could be monitored at local scale to detect early change in vegetation. At habitat level, species richness and Shannon diversity index are not relevant at least at local scale, for phytodiversity monitoring, although Pielou evenness could be successfully used. The study also documents life forms and chorotypes composition of the plant communities as relevant indicators to be monitored by managers for phytodiversity conservation.

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APPENDIX

Description of clustered plant community in each land use

Plant communities	Frequent species	Soil texture	Significant indicators species	Plant communities' description
P1 = *Combretum glutinosum & Loxodera ledermannii* community	*Cochlospermum tinctorium(61%)* *Tephrosia bracteolata(58%)* *Burkea africana(53%)* *Annona senegalensis(38%)* *Pteleospsis suberosa(37%)* *Detarium microcarpum(36%)* *Isoberlinia doka (36%)* *Andropogon gayanus(30%)*	Silty-gravelly soil	*Detarium microcarpum* (IV= 64.1; P= 0.0082) *Combretum glutinosum* (IV=40.4; P=0.024) *Loxodera ledermannii* (IV=49.6; P=0.0166)	Communities weakly met in the park on silty soil with sometimes presence of gravel. The vegetation was under tree savanna or woodland dominated by *Isoberlinia doka* and *Burkea africana*
P2 = *Andropogon gayanus & Crossopteryx febrifuga* community	*Andropogon gayanus(100%)* *Indigofera dendroides(80%)* *Ampelocissus leonensis(80%)* *Combretum molle(80%)* *Siphonochilus aethiopicus(80%)* *Grewia cissoides(80%)* *Chamaecrista mimosoides(80%)*	Silty soil	Andropogon gayanus (IV = 62; P = 0.0002) Crossopteryx febrifuga (IV = 48.3; P = 0.0064) Andropogon schirensis (IV = 54.8; P = 0.0066)	Communities under tree savanna vegetation with Vitellaria paradoxa, *Isoberlinia doka* and *Aganope stuhlmannii*
P3= *Hyparrhenia involucrata & Indigofera leprieurii* community	*Hyparrhenia involucrata(73%)* *Siphonochilus aethiopicus(73%)* *Combretum glutinosum(67%)* *Chasmopodium caudatum(58%)* *Combretum collinum(58%)* *Indigofera dendroides(58%)* *Polygala arenaria(51%)*	Sandy-silty soil	*Hyparrhenia involucrata* (IV=65.9; P=0.0002) *Indigofera leprieurii* (IV=41.5; p=0.0272) *Pennisetum polystachion* (IV=38.6; p=0.0431)	Communities met on different type of soil. The vegetation was represented by shrub/tree savanna dominated by *Combretum* spp, on silt-sand soil and *Acacia hockii* on clay-silt soil
P4 = *Andropogon tectorum and Costus spectabilis* community	*Pandiaka heudelotii (79%)* *Combretum molle (76%)* *Gardenia ternifolia (69%)* *Lannea acida (68%)* *Strychnos spinosa (64%)* *Pterocarpus erinaceus (60%)* *Isoberlinia doka (60%)* *Daniellia oliveri(60%)* *Stereospermum kunthianum(60%)*	Soil with silt and clay	*Andropogon tectorum* (IV= 99.5; P =0.0002) *Vigna gracilis* (IV = 77.7; P = 0.0008) *Costus spectabilis* (IV=62.3; P =0.0044) *Lannea acida* (IV=56.7; P=0.0028)	Vegetation on deep soil on upland represented by woodland forest dominated by *Isoberlinia doka*, *Pterocarpus erinaceus* and in the herbaceous layer by *Andropogon tectorum*, *Beckeropsis uniseta*. The community was also met under gallery forest with *Lannea acida* and *Daniellia oliveri* on the tree layer and *Andropogon tectorum, Rottboellia cochinchinensis* at herbaceous layer.
P5 = *Loudetia togoensis & Bulbostylis abortiva* community	*Loudetia togoensis(100%)* *Lannea microcarpa(75%)* *Spermacoce filifolia(50%)* *Andropogon pseudapricus(50%)* *Ophioglossum costatum(42%)* *Ipomoea eriocarpa(45%)* *Polygala arenaria(45%)* *Combretum spp(45%)*	Silty soil on crust	*Loudetia togoensis* (IV = 100; P = 0.0002) *Bulbostylis abortiva* (IV = 97.8; P = 0.0002) *Sporobolus festivus* (IV = 65.1; P = 0.0034) *Spermacoce filifolia* (IV = 65.2; P = 0.0038)	Plant communities on crust lateritic soil (less deep soil) dominated on herbaceous layer by *Loudetia togoensis* and scattered by woody species such *Lannea microcarpa* and *combretim* spp

APPENDIX *continued*

Description of clustered plant community in each land use

C1 = *Loudetia togoensis & Bulbostylis abortiva* community	*Combretum glutinosum (78%)* *Lannea microcarpa (50%)* *Spermacoce filifolia (45%)* *Ophioglossum costatum(42%)* *Loudetia togonensis (39%)* *Ipomoea eriocarpa (37%)* *Polygala arenaria (35%)* *Andropogon pseudapricus (25%)*	Silty soil on crust	*Bulbostylis abortiva* (IV = 68.7; P = 0.002) *Loudetia togoensis* (IV = 75.7; P = 0.002) *Lannea microcarpa* (IV = 42.2; P = 0.0078) *Ophioglossum costatum* (IV = 33.3; P =0.0084)	Vegetation on less deep soil (bowé in French). Tree layer was almost absent. The herbaceous strata height was about 30 cm. Due to soil condition, that plant communities was not used for cultivation. Nonetheless it was used pasture for cattle grazing
C2 = *Piliostigma thonningii & Flueggea virosa* community	*Setaria pumila(72%)* *Annona senegalensis(69%)* *Piliostigma thoningii(57%)* *Vitellaria paradoxa(53%)* *Hibiscus asper(50%)* *Pennisetum polystachion(48%)* *Flueggea virosa(46%)* *Dichrostachys cinerea(43%)*	Silty soil sometimes with relative dominance of clay	*Dichrostachys cinerea* (IV = 83.4; P= 0.0002) *Flueggea virosa* (IV = 75.9; P= 0.0002) *Piliostigma thonningii* (IV = 95.1; P= 0.0002)	Rare vegetation in communal land, represented by old fallow (5 to 10 years). The tree layer was almost absent and the shrub layer was about 5 m and dominated by *Piliostigma thoningii* and *Dichrostachys cinerea*
C3 = *Digitaria horizontalis & Spermacoce stachydea* community	*Setaria pumila(78%)* *Commelina benghalensis(76%)* *Indigofera hirsuta(69%)* *Detarium microcrapum(47%)* *Ageratum conyzoides(45%)* *Leucas martinicensis(35%)* *Crotalaria retusa(34%)* *Mitracarpus hirtus(25%)* *Celosia trigyna(25%)*	Sandy soil sometimes silty-sandy soil	*Digitaria horizontalis* (IV = 69.7; P =0.0064) *Schizachirium exile* (IV = 49.1 ; P = 0.0204) *Spermacoce stachydea* (IV = 35.4; P = 0.0342)	Young fallow within farmland. The herbaceous layer was dominated by *Setaria pumila, Digitaria horizontalis*. The tree layer resulted from those set apart by farmers and the shrub layer after three years was abundant and grew from coppices
C4 = *Tephrosia pedicellata & Detarium microcarpum* community	*Tephrosia pedicellata(90%)* *Spermacoce stachydea(85%)* *Pandiaka heudelotii(85%)* *Hackelochloa granulari (70%)* *Detarium microcarpum(72%)* *Hyparrhenia involucrata(65%)* *Brachiraria deflexa(60%)* *Digitaria horizontalis(50%)*	Silty soil and sometimes gravel	*Tephrosia pedicellata* (IV = 38.1; P = 0.0077) *Detarium microcarpum* (IV = 64.5; P = 0.001) *Triumfetta rhomboidea* (IV = 76.1; P= 0.0024) *Brachiaria deflexa* (IV = 62; P= 0.068)	Common vegetation in communal lands derived from overgrazing. Tree layer was about 5 à 8 m dominated by *Combretum spp., Terminalia spp.* and *Detarium microcarpum*
B1 = *Burkea africana & Indigofera bracteolata* community	*Aspilia kotschyi(80%)* *Prosopis africana(85%)* *Burkea africana(75%)* *Pennisetum polystachion(70%)* *Combretum nigricans(70%)* *Crossopteryx febrifuga(60%)* *Microchloa indica(50%)* *Bombax costatum(50%)* *Cissus populnea(40%)*	Gravelly with silts. Often, presence of block of stone	*Burkea africana* (IV = 63.8; P= 0.0066) *Combretum glutinosum* (IV = 50.9; P= 0.009) *Indigofera bracteolata* (IV =71.4; P= 0.0108)	Common vegetation on soil with outcrop stone. The tree layer was dominated by species such *Prosopis africana, Burkea africana*. The herbaceous layer was limited in cover

Legend: Note that based on indicator species analysis B2 = P2; B3 = P4 and B4 = P5

P1, P2, P3, P4, P5 = Plant communities clustered in the park, C1, C2, C3, C4 = Plant communities clustered in the communal. B1, B2, B3, B4 = Plant communities clustered in the buffer zone