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# Distribution and Composition of Herbaceous Plants in Response to Arable Cultivation and Local Topographical Variation in the Nigerian Northern Guinea Savannah

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## ABSTRACT

This study examined the pattern of distribution and composition of herbaceous plant species with respect to cultivation and local topographical variation in the Nigerian northern Guinea Savannah. Data on plant species was collected using quadrats. Soil samples were collected using cores and analyzed for Total Nitrogen (%), Available Phosphorus (mg $kg^{-1}$), Exchangeable Potassium (cmol (+) $kg^{-1}$), pH, Organic Carbon (%) and soil textural class. Arable cultivation practices create uniquely different plant communities on contiguous plots but of different local topography in terms of species composition as shown by the Jaccard's Dissimilarity Index and dominance by the Important Value Index (IVI). Cultivation affects species attributes of plant communities in different ways on different local topography. Species diversity, species richness and their abundances were decreased by cultivation on Flat and Highlands but increased on Lowland, while species evenness was relatively unaffected by the combined impacts of cultivation and local topographical variation. The Lowland topography was the strongest local environmental force of selection of plant community composition and structure in terms of dissimilarity. Studies on the impact of the combined forces of topography and cultivation on plant communities are still very scanty to make global cross-biome comparisons and conclusion. Understanding the impacts of cultivation, topography and other edaphic variables in shaping floristic structure of plant communities will contribute not only to the understanding of the mechanisms determining plant community distribution and composition but also provides information necessary for their future prediction. This is an indispensable tool for environmental planning for biodiversity conservation, especially in the face of the current unprecedented environmental crisis, namely climatic change-induced drought and desertification.

Key Words: Dissimilarity; Evenness; Highland; Nigeria; Phosphorus; Potassium; Organic Carbon; Savanna,; Species Composition

## INTRODUCTION

Every plant species has a different distribution or tolerance range and each species respond differently to different environmental factors to form distinct associations with different species that have a similar environmental requirement and share the ability to tolerate adverse impact like human interferences (Wyant et al. 1991, Youssef and Al-Fredan 2008). Hence, the composition of plant communities varies along environmental gradient as species are successfully replaced as a function of variation in the environment (Casas and Ninot 2003). This spatial heterogeneity may alter species composition in response to change in local environmental conditions. The composition of plant communities and their species diversity, at any given point in time and space, will therefore, reflect the combined effects of their interactions with their biotic and abiotic environment. Thus, assemblage of plants found at any given locality can be interpreted as the product of the filtering effects of climatic conditions, edaphic factors, biotic interactions and disturbance type and regime (Alados et al. 2004, Macdonald and Fenniak 2007).

Within a landscape, the patterns of plant community are also strongly correlated with topographic variables (Zhang et al. 2007, Ruifrok et al. 2014). Topographical variables do not have any direct effect on the vegetation but their importance is based on their correlation with some direct resource gradients consumed by plants such as water availability and soil nutrients (Ali and Malik 2010). For example, the amount of rainfall on the ground surface can be affected by the local topography through redistribution, and bring about surface water drainage; transportation and accumulation of soil nutrients; and also a change in micro-climate. The surface run-off, brought about by the topographic variability, therefore, amplifies productivity at the run-on areas by favoring them with more water and nutrients at the expense of elevated areas (Munn 1991). This is one of the main reasons why plant community composition and species richness varies with micro-topography, resulting in a mosaic of vegetation types (Moran et al. 2009). Since plants only grow in areas where the soil is favorable, then the variation of soil properties across the landscape will influence the distribution and association of the vegetation (Rezaei and Gilkes 2005, Munishi et al. 2007). Soil physical and chemical factors that play key roles in plant distributions are textual class, PH, organic matter and nitrogen, phosphorus and potassium (El-Demerdash et al. 1995, Garnier et al. 2007, Youssef and Al-Fredan 2008).

Plant community assemblage is also an indicator of the form and degree of human interference (Atik et al. 2009). This means that human disturbance can also be correlated with the distribution and diversity of plant species (Jun-feng and Yun-xiang 2006) which may vary in their response to anthropogenic disturbances. This may be due to their physiological variations in the environmental resource requirements and acquisition capacity and strategy, and degree of their tolerance and resilience to stress and disturbance (Fraterrigo et al. 2006). These imply that different management regimes will create different species composition and diversity even in similar environments; or similar management regimes will create different floristic structure of plant communities in different environments. Since habitat differ in their sensitivity to utilization and development (Stalmans and Peel 2010), and plant communities show variation in their dynamics, different plant community types are created due to various anthropogenic disturbances (Kukshal et al. 2009). Arable cultivation, in particular, has been widely reported to have significant effects on the species richness and diversity patterns in grasslands, so that species composition and diversity in grasslands depends on the current management type and intensity (Aavik et al. 2008, Lyaruu 2010).

Although, many studies have been conducted on the impacts of topography and cultivation on plant communities on separate bases, studies on the impact of the combine forces of these two factors are still very scanty to guarantee the global cross-biome comparisons. Therefore, this study was conducted in an effort to, at least, reduce that gap of knowledge. Knowledge of the role played by cultivation, topography and other edaphic variables in shaping floristic structure of plant communities will contribute not only to the understanding of the mechanisms determining plant community distribution and composition but also provides information necessary for their future prediction. This is an indispensable tool for environmental planning and biodiversity conservation, especially in the face of the current unprecedented environmental crisis, namely climatic change-induced drought and desertification. However, such knowledge is almost completely lacking in the Nigerian Savannah, and since environmental factors operate differently across different regions and one cannot adopt results of studies from different regions (Mbue et al. 2009), this study becomes unavoidably necessary.

## THE STUDY AREA

The study area was the Yelwa campus of Abubakar Tafawa Balewa University, Bauchi. Bauchi is located at latitude 10° 74' N and longitude 9° 47' E and at 690.3 m above mean sea level in the northern Guinea Savanna ecological zone of Nigeria (Figure 1). The soils are generally classified as Altisols (Amba et al. 2011). The climate is characterized by rainy season that starts in April and ends in October, with 1300 mm rainfall per annum (Hassan 2010).

The study sites were categorized into three different types of lands based on their local topographical differences. These were High Land, Flat Land and Low Land. The High Land is a slope of a mountain base. The Low Land is a marshy land that is typical for rice cultivation. The Flat Land, which was relatively uniformly flat, lies in between the mountain slope (High Land) and the marshy land (Low Land). In each of these lands categories, there were uncultivated lands and lands that were currently under cultivation. These conditions have been there for at least seven years. All the lands were contiguous. Rice was exclusively cultivated on the Low Land, while maize and cowpea were cultivated on the Flat Land. The High Land was cultivated for sorghum (guinea corn) and cowpea (beans).

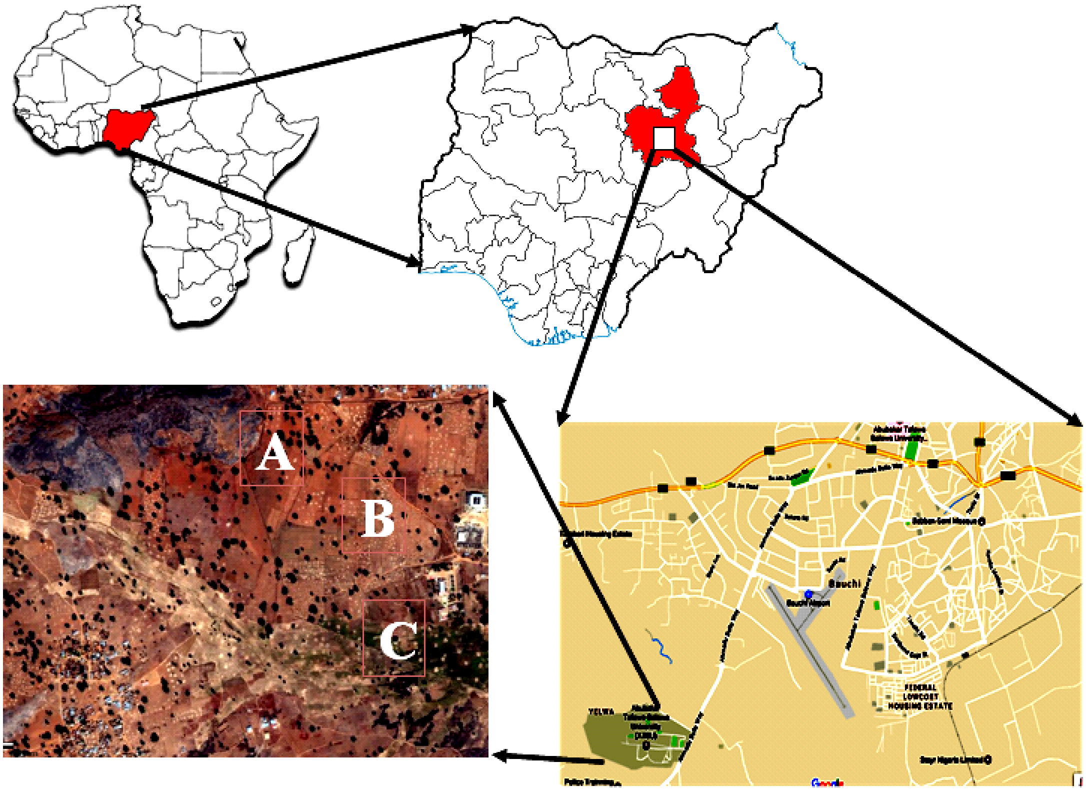


Figure 1. A = High Land; B= Flat Land; C= Low Land; ULL = uncultivated low land; CLL = cultivated low land; UCFL= uncultivated flat land; CFL = cultivated flat land; UCHL = uncultivated high land; CHL = cultivated high land.

METHODOLOGY

**Floristic Data and Soil Sample Collection**

Floristic data and soil samples were collected in both the cultivated and uncultivated lands of each of the three sites. The data were collected towards the end of the rainy season when the annual herbaceous plants of the uncultivated lands and the arable weeds were well established after the cessation of weeding, and the applied fertilizer might have been exhausted. Floristic data were collected by using 50x50cm quadrats, which are the most suitable for sampling short grasses (Kent and Coker 1992). The quadrat was randomly thrown twice at each of the cardinal points and at the center, making a total of 10 samples in each of the cultivated and the adjoining uncultivated lands of the three sites with different topographical features. Number of plant species in each quadrat was counted and recorded. Specimens of all the plant species were taken and identified in the herbarium of the Abubakar Tafawa Balewa University and using Flora of West Tropical Africa (Hutchinson and Dalziel 1972).

In addition, at the center of each of the quadrats, a soil sample was collected to a depth of 15 cm, using soil corer. The ten soil samples of each site were pooled together into a composite sample. All samples were immediately sun-dried and transported to soil laboratory of Abubakar Tafawa Balewa University for physico-chemical analyses following a standard procedure (Page 1982). The samples were analyzed for total nitrogen, available phosphorus, exchangeable potassium, organic carbon, pH and percentages of sand, clay and silt for the soil textural class. These some of the most important soil characteristics are also the most common limiting factors that affect plants' distribution and performance (Tilman 2001, Lesoli 2008, Sheikh and Kumar 2010). The soil textural class was described by USDA soil textural triangle (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_054167).

**Data Analysis**

The Importance Value Indices (IVI) of all plant species were calculated using Microsoft Office Excel 2007. All other plant species parameters for describing plant community were calculated using the software Community Ecology Parameter Calculator (ComEcoPaC) Version 1.0 (Drozd 2010). The formulae used by this software were as follows:

*Dominance*

$$Di\,(\%) = (n_i / N) \times 100$$

where $n_i$ = abundance of species $i$, and
$N$ = total abundance in sample

*Shannon-Wiener Diversity Index* - H'

$$\sum_{i-1}^{s} Pi \,.\, log_2\, Pi$$

where $s$ = species richness (number of species), $p_i$ = proportion of species $i$, $n_i$ = abundance of species $i$, $N$ = total abundance.

*Evenness (E) and Corrected Eveness* (E')

$$E = H' / H'_{max} \text{ and } E' = (H' - H'_{min})/(H'_{max} - H'_{min})$$

where $H'_{max} = \log_2 S$; and

$$H'_{\min} = -\frac{N-S+1}{N}\log_2\frac{N-S+1}{N} + \frac{S-1}{N}\log_2 N$$

*Simpson's Index* - D

$$D = \sum_{i-1}^{s} P_i^2$$

where $S$ = species richness, $p_i$ = proportion of species $i$

The Simpson index is a dominance index because it gives more weight to common or dominant species. In this case, a few rare species with only a few individuals do not affect the diversity.

*Jaccard's Similarity Index* - Ja

$$Ja = \frac{S_{12}}{S_1 + S_2 - S_{12}}$$

where $S_{12}$ = number of species present in both samples (joint occurrences)
$S_1$ ($S_2$) = number of species in sample 1 (sample 2).

*Jaccard's Dissimilarity Index*
= 1- Similarity Index (Kent and Coker 1992).

*Sörensen's Similarity Index* (So)

$$So = \frac{2S_{12}}{S_1 + S_2}$$

where,
$S_{12}$ = number of species present in both samples (joint occurrences)
$S_1$ ($S_2$) = number of species in sample 1 (sample 2).

*Sörensen's Dissimilarity index =*

1- similarity index (Kent and Coker 1992).

*Importance Value Index*

This index is used to determine the overall importance of each species in a community structure, which affect the survival and abundance of many other species in the community. The elimination or addition of such species, results in a significant shift in the composition and structure of the community (Rathod 2014). The IVI was determined as the average of the sum of relative density (RD), relative frequency (RF), and relative dominance (Rdo), each expressed as a percentage of the total density, frequency and dominance of all species in the sample. IVI = sum of (RF+RD+RDo)/3 (Ahmed 2012). Frequency, density and dominance are computed following Kent and Coker (1992).

## RESULTS

### Soil Physicochemical Properties

The result show that the mean values of soil Total Nitrogen (%), Available Phosphorus (mg $kg^{-1}$), pH and Organic Carbon (%) were all higher in all the three uncultivated lands than in the adjacent cultivated lands (Table 1). Exchangeable Potassium (cmol (+) $kg^{-1}$) was slightly higher in the uncultivated lands of Low and High Lands than in their cultivated lands, but the reverse is the case in Flat Land. The soil Textural Class were Sandy Loam in both the uncultivated and cultivated Low Land and Flat Land; while it was Loamy sand in both the uncultivated and cultivated High Land.

### Species Composition And Dominance

The Important Value Indices (IVI) presented in the Appendix 1 show that all the cultivated and uncultivated lands were dominated by different plant species. Three

Table 1. Soil physicochemical properties of the cultivated and uncultivated lands with different local topography. UCLL = uncultivated low land; CLL = cultivated low land; UCFL= uncultivated flat land; CFL = cultivated flat land; UCHL = uncultivated high land; CHL = cultivated high land.

| Soil physicochemical parameters | UCLL | CLL | UCFL | CFL | UCHL | CHL |
|---|---|---|---|---|---|---|
| Total Nitrogen (%) | 0.12 | 0.07 | 0.09 | 0.03 | 0.11 | 0.07 |
| Available Phosphorus (mg $kg^{-1}$) | 18.82 | 7.29 | 10.88 | 3.13 | 12.98 | 8.17 |
| Exchangeable Potassium (cmol (+) $kg^{-1}$) | 0.21 | 0.14 | 0.19 | 0.24 | 0.21 | 0.16 |
| pH | 6.02 | 5.93 | 6.23 | 6.08 | 6.58 | 6.13 |
| Organic Carbon (%) | 1.33 | 0.98 | 1.15 | 0.11 | 1.64 | 0.93 |
| Soil textural class | sandy Loam | sandy Loam | sandy Loam | sandy Loam | Loamy sand | Loamy sand |

Table 2. The value of Jaccard's and Sörensen's indices of the cultivated and uncultivated lands with different local topography (dissimilarity index values in parentheses). Abbreviations as in Table 1.

| | CLL | UCFL | CFL | UCHL | CHL |
|---|---|---|---|---|---|
| **Jaccard's index** | | | | | |
| UCLL | 0.24 (0.76) | 0.07(0.93) | 0.05 (0.95) | 0.07 (0.93) | 0.09 (0.91) |
| **CLL** | | 0.00 (1.00) | 0.00 (1.00) | 0.00 (1.00) | 0.00 (1.00) |
| **UCFL** | | | 0.20 (0.80) | 0.86 (0.14) | 0.14 (0.86) |
| **CFL** | | | | 0.21 (0.79) | 0.11 (0.89) |
| **UCHL** | | | | | 0.10 (0.90) |
| **Sörensen's index** | | | | | |
| **UCLL** | 0.39 (0.61) | 0.12 (0.88) | 0.10 (0.90) | 0.13 (0.87) | 0.17 (0.83) |
| **CLL** | | 0.00 (1.00) | 0.00 (1.00) | 0.00 (1.00) | 0.00 (1.00) |
| **UCFL** | | | 0.33 (0.67) | 0.93 (0.07) | 0.24 (0.76) |
| **CFL** | | | | 0.35 (0.65) | 0.19 (0.81) |
| **UCHL** | | | | | 0.19 (0.81) |

species with the highest IVI value in the uncultivated Low Land are *Aeschynomene americana* (10.42), *Sorgum halepense* (9.08) and *Ageratum conyzoides* (8.77). Cultivated Low Land was dominated by *Ageratum conyzoides* (19.01), *Sphaeranthus angustifolius* (8.6) and *Ammania auriculata* (5.24). In the uncultivated Flat Land, the dominants were *Borreria chaetocephala* (19.8), *Zornia glochidiata* (19.21) and *Brachiaria distichophylla* (8.2). The cultivated Flat Land was dominated by *Leucas martinicensis* (19.77), *Spermacoce stachydea* (12.10) and *Cyanotis angusta* (5.71). The dominant species in the uncultivated High Land were *Dactyloctaenium aegyptiacum* (14.23), *Zornia glochidiata* (13.16) and *Aristida mutabilis* (96.59); while in the cultivated High Land the dominant species were *Polycarpaea linearifolia* (7.67), *Oldenlandia corymbosa* (7.67) and *Mollugo nudicaulis* (7.23). Only one species (*Ageratum conyzoides*) with high IVI was found to occupy both cultivated and uncultivated lands, even so, only on Low Land and no other local topography.

**Plant Community Similarity and dissimilarities**

The values of dis(similarity) Index (Jaccard's index) indicate that all the six sampling plots (the three cultivated and their three adjoining uncultivated lands with different local topography) are distinctively different with dissimilarity values that range from 0.76 to 1.00, except between the uncultivated High And Flat Lands, which are very similar with 0.14 (Table 2). Highest dissimilarities occurred between the uncultivated and cultivated low land compared with uncultivated and cultivated Flat And High Lands with the range of dissimilarities from 0.91 to 1.00. The dendrogram resulted from the Hierarchical Cluster Analysis of Variables also revealed that all the six land categories are not 100% similar (Figure 2). At 45% similarity, the cultivated Flat Land and cultivated High Land forms distinct plant communities that different from all others. The uncultivated and cultivated low land are similar but only at 69%, while the uncultivated Flat Land and uncultivated High Land were similar but at 85%.

### Species Richness, Species Diversity, Abundance and Evenness

In terms of species richness, uncultivated Flat and High Lands had higher number of species (21 and 20 respectively) than their corresponding cultivated lands (9 and 12 respectively), but the reverse was the case for the Low Land where more species were found in the cultivated than uncultivated land (19 and 12 respectively' Table 3). The same result was obtained for the Species Abundance, i.e. the total number of individuals of all the species present. The Shannon-Wiener diversity index (H') revealed that all the six plots have relatively high species diversity, but here also the values were slightly higher in the uncultivated Flat and High Lands (2.86 and 3.39 respectively) than their corresponding cultivated lands (2.08 and 3.05 respectively). However, in the Low Land, there was higher species diversity in the cultivated (3.19) than uncultivated (2.44) plot. The Index of Evenness showed that the distribution of species in all the sampling plots were relatively even with their values ranges from 0.60 – 0.81.

## DISCUSSION

In this study, the assemblage of plant communities in terms floristic composition and distribution are strongly filtered along local topographical gradient. Each of the three sampling plots with different topography, namely Low Land, Flat Land and High Land, are composed of different species considering their dominance based on Importance Value Index (IVI). This agrees with the results of many plant community studies documented in time and space that floristic structures of plant communities reflect their local topography. In addition, the corresponding cultivated lands in all the three plots with varying topography were also dominated by uniquely

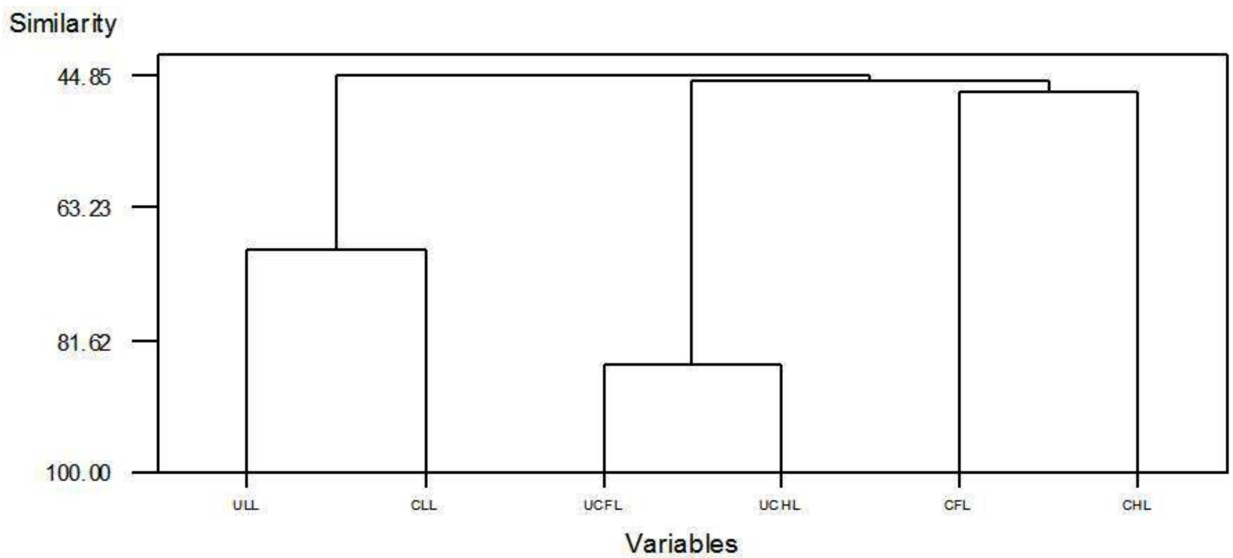


Figure 2. Hierarchical Cluster Analysis of Variables on the different land categories with respect to the floristic data, done by Correlation Coefficient Distance and the Average Linkage method.

Table 3. Plant species richness, diversity, evenness, abundance and other floristic parameters of the cultivated and uncultivated lands with different local topography. Abbreviations as in Table 1.

| Plant Species Parameters | UCLL | CLL | UCFL | CFL | UCHL | CHL |
|---|---|---|---|---|---|---|
| Species Richness | 12 | 19 | 21 | 9 | 20 | 12 |
| Species Abundance | 120 | 659 | 957 | 285 | 759 | 134 |
| *****Eudominant Species 10 % ≤ $D_i$ ≤ 100 % | 4 | 2 | 3 | 3 | 3 | 4 |
| Dominant Species 5 % ≤ $D_i$ < 10 % | 0 | 4 | 2 | 0 | 3 | 2 |
| Subdominant Species 2 % ≤ $D_i$ < 5 % | 0 | 4 | 1 | 4 | 5 | 3 |
| Recedent Species, 1 % ≤ $D_i$ < 2 % | 2 | 4 | 4 | 0 | 5 | 2 |
| Subrecedent Species 0 % < $D_i$ < 1 % | 6 | 5 | 11 | 2 | 4 | 1 |
| Abundance of Eudominant Species | 110 | 328 | 688 | 249 | 439 | 93 |
| Abundance of Dominant Species | 0 | 195 | 133 | 0 | 146 | 22 |
| Abundance of Subdominant Species | 0 | 83 | 31 | 33 | 100 | 14 |
| Abundance of Recedent Species | 4 | 38 | 52 | 0 | 61 | 4 |
| Abundance of Subrecedent Species | 6 | 15 | 53 | 3 | 13 | 1 |
| Singletons (species with 1 individuals) | 6 | 2 | 1 | 1 | 1 | 1 |
| Doubletons (species with 2 individuals) | 2 | 1 | 0 | 1 | 1 | 2 |
| Tripletons (species with 3 individuals) | 0 | 0 | 1 | 0 | 1 | 0 |
| H' (Shannon-Wiener diversity index) | 2.44 | 3.19 | 2.86 | 2.08 | 3.39 | 3.05 |
| E (Evenness) | 0.594 | 0.731 | 0.632 | 0.625 | 0.769 | 0.816 |
| **E' (**corrected evenness) | 0.227 | 0.170 | 0.204 | 0.312 | 0.139 | 0.145 |

*Tischler's scale for species dominance

different species. Although, some of the species overlap among the different sampling plots, many species are found only on a particular land with defined topography whether cultivated or uncultivated. This is in line with many other studies that the assemblage of plants found at any given locality is a product of the filtering effects of edaphic factors and disturbance type and regime (Casas and Ninot 2003, Alados et al. 2004).

In the uncultivated Low Land, three dominant species in decreasing order of their IVI value are *Aeschynomene americana*, *Sorghum halepense* and *Ageratum conyzoides*. The adjoining cultivated Low Land was dominated by *Ageratum conyzoides*, *Sphaeranthus angustifolius* and *Ammania auriculata*. In the uncultivated Flat Land, the dominants were *Borreria chaetocephala*, *Zornia glochidiata* and *Brachiaria distichophylla*. While the cultivated Flat Land was dominated by *Leucas martinicensis*, *Spermacoce stachydea* and *Cyanotis angusta*. The dominant species in the uncultivated High Land were *Dactylotaenium aegypiacum*, *Zornia glochidiata* and *Aristida mutabilis*; while in the cultivated High Land the dominant species were *Polycarpaea linearifolia*, *Oldenlandia corymbosa* and *Mollugo nudicaulis*. These suggest that arable cultivation practices create different plant communities on different lands with different local topography. It is also interesting to note that only one species (*Ageratum conyzoides*) out of the 56 species in the checklist was found to occupy both cultivated and uncultivated of these contiguous plots, even so, only on Low Land and no other local topography. This emphasizes the magnitude of arable cultivation as a very powerful filter of floristic composition in plant communities. Although, the fact that arable cultivation practices lead to alteration of plant community structure has been known for long (Aavik et al. 2008, Lyaruu 2010), this study revealed the pattern and magnitude of these impacts.

The Low Land topography was the strongest local environmental force of selection of plant community composition and structure. Here the cultivated Low Land did not share any of its entire species with any of the Flat and High Lands, cultivated or uncultivated, and share only 4 out of 17 of it species with the corresponding contagious but uncultivated Low Land. The uncultivated Low Land share only one species (*Ipomea eriocarpa*) with all the cultivated and uncultivated Flat and High Lands. It is also interesting to note that *Ipomea eriocarpa* is the only species that was found to occupy five of the sampling sites (cultivated and uncultivated Flat and High Lands, and the uncultivated Low Land).

Among the rest in the species checklist, only *Euphorbia hirta* was found on four plots, i.e. uncultivated Low, Flat and High Lands and cultivated High Land. The implication here is that *Ipomea eriocarpa* and *Euphorbia hirta* have highest degree of adaptations to the combined forces of both the local variation in topography and crop cultivation practices. Jaccard's similarity index also showed similar result. Very high dissimilarity values were obtained among all the sampling plots except between uncultivated Flat and High Lands, which are very similar. These result emphasized that topography is one of the most powerful selection forces that affects floristic composition of plant communities.

Cultivation affects species richness and their abundances in different ways on different local topography. Both species richness and their abundances were decreased by cultivation in the Flat and High Lands but were increased in the Low Land. In addition, the species diversity was higher in uncultivated Flat and High Lands than in their corresponding cultivated land. However, in the Low Land, higher species diversity was found on the cultivated than uncultivated plot. As it is also known, crop cultivation entails tillage that causes the rapid elimination of some plant species and re-colonization by the opportunistic ones due to the creation of new soil conditions and relaxation competition (Du, et al. 2014). The result of this study suggests that tillage can only leads to change in species composition for certain, while other floristic attributes, such as species diversity, species richness and the abundance of individuals may be increased or decreased depending on the local environmental heterogeneity. However, the intensity of the tillage (frequency and degree of soil disturbance) should be taken into consideration.

## CONCLUSION

This study was carried out with the aim of finding the pattern of distribution and composition of herbaceous plant species with respect to cultivation and local topographical variations in the Nigerian northern Guinea Savannah. It was found that arable cultivation practices create unique plant communities on contagious plots but of different local topography in terms of composition and dominance. Cultivation also affects species attributes in different ways on different local topography. Species diversity, species richness and their abundance were all decreased by cultivation on Flat and High Lands but increased on Low Land. The Low Land topography was the strongest local environmental force of selection of plant community composition and structure in term dissimilarity index. *Ipomea eriocarpa* and *Euphorbia hirta* have highest degree of adaptations due to the combined forces of both the local variation in topography and crop cultivation practices, as they happened to appear on five and four plots respectively, with different topography that was cultivated and uncultivated.

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Appendix 1. Plant species composition and dominance based on Important Value Index (IVI) of the cultivated and uncultivated lands with different topography. RF = relative frequency; RD = relative density; RDo = relative dominance. ULL = uncultivated low land; CLL = cultivated low land; UCFL= uncultivated flat land; CFL = cultivated flat land; UCHL = uncultivated high land; CHL = cultivated high land.

| | UCLL | | | | CLL | | | | UCFL | | | | CFL | | | | UCHL | | | | CHL | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plant Species | RF | RD | RDo | IVI | RF | RD | RDo | IVI | RF | RD | RDo | IVI | RF | RD | RDo | IVI | RF | RD | RDo | IVI | RF | RD | RDo | IVI |
| *Acalypha segetalis* Müll.Arg. | | | | | | | | | | | | | 0.02 | 0.6 | 2.1 | 0.91 | | | | | | | | |
| *Acanthospermum hispidum* DC. | 0.04 | 0.1 | 0.83 | 0.32 | | | | | | | | | | | | | | | | | | | | |
| *Aeschynomene americana* L. | 0.17 | 3.7 | 30.8 | 10.42 | | | | | | | | | | | | | | | | | | | | |
| *Ageratum conyzoides* L. | 0.22 | 2.8 | 23.3 | 8.77 | 0.13 | 22.6 | 34.3 | 19 | | | | | | | | | | | | | | | | |
| *Alysicarpus rugosus* (Willd.) DC. | | | | | | | | | 0 | 0.5 | 0.5 | 0.34 | | | | | | | | | | | | |
| *Ammania auriculata* Willd. | | | | | 0.11 | 6.2 | 9.4 | 5.24 | | | | | | | | | | | | | | | | |
| *Aristida mutabilis* Trin.& Rupr. | | | | | | | | | 0.1 | 3.1 | 3.2 | 2.13 | | | | | 0.1 | 8.5 | 11.2 | 6.59 | | | | |
| *Borreria chaetocephala* (DC.) Hepper | | | | | | | | | 0.7 | 29 | 30 | 19.8 | | | | | 0.1 | 6.3 | 8.3 | 4.9 | | | | |
| *Borreria ocymoides* (Burm. f.) DC. | | | | | | | | | | | | | | | | | | | | | 0.07 | 1.2 | 9 | 3.42 |
| *Borreria radiata* DC. | | | | | | | | | | | | | | | | | | | | | 0.13 | 1 | 7.5 | 2.88 |
| *Brachiaria distichophylla* (Trin.) Stapf | | | | | | | | | 0.1 | 12 | 12.5 | 8.2 | 0.04 | 0.2 | 0.7 | 0.31 | 0.1 | 4.3 | 5.6 | 3.33 | | | | |
| *Cassia tora* L. | | | | | | | | | 0 | 0.3 | 0.3 | 0.21 | | | | | 0.1 | 2 | 2.6 | 1.55 | | | | |
| *Chrysanthellum indicum* DC. | | | | | | | | | 0.1 | 0.7 | 0.7 | 0.49 | | | | | 0 | 1.1 | 1.4 | 0.84 | 0.07 | 0.5 | 3.7 | 1.42 |
| *Cirsium arvense* (L.) Scop. | | | | | 0.1 | 1.4 | 2.1 | 0.2 | | | | | | | | | | | | | | | | |
| *Cloris robusta* Stapf. | | | | | | | | | | | | | | | | | 0 | 1.4 | 1.8 | 1.08 | | | | |
| *Commelina diffusa* Burm.f. | | | | | | | | | 0 | 0.1 | 0.1 | 0.07 | 0.04 | 0.8 | 2.8 | 1.21 | 0 | 1.3 | 1.7 | 1 | | | | |
| *Corchorus fascicularis* Lam. | | | | | 0.01 | 0.1 | 0.2 | 0.1 | | | | | | | | | | | | | | | | |
| *Crotalaria glauca* Willd. | | | | | | | | | 0 | 0.4 | 0.4 | 0.28 | | | | | 0 | 0.2 | 0.3 | 0.18 | | | | |
| *Crotalaria ononoides* Benth. | | | | | | | | | 0.1 | 5.7 | 6 | 3.94 | | | | | 0 | 1.4 | 1.8 | 1.08 | | | | |
| *Cyanotis angusta* C.B.Clarke | | | | | | | | | | | | | 0.02 | 3.8 | 13.3 | 5.71 | | | | | | | | |
| *Cynodon dactylon* L.) Pers. | | | | | | | | | 0 | 1.3 | 1.4 | 0.9 | | | | | 0 | 0.7 | 0.9 | 0.53 | | | | |
| *Cyperus indet* Herb Smith | | | | | 0.03 | 1 | 1.5 | 0.84 | | | | | | | | | | | | | | | | |
| *Cyperus lanceolatus* Poir. | | | | | 0.01 | 0.2 | 0.3 | 0.17 | | | | | | | | | | | | | | | | |
| *Cyperus pustulatus* Vahl | | | | | 0.1 | 1.5 | 2.3 | 3.3 | | | | | | | | | | | | | | | | |
| *Dactylotaenium aegypiacum* (L.) Willd. | | | | | | | | 0.7 | 7.6 | 8 | 0.43 | 0.11 | 0.7 | 2.5 | 1.1 | 0.1 | 18.4 | 24.2 | 14.23 | | | | | |
| *Digitaria longiflora* (Retz.) Pers. | | | | | | | | | 0 | 1.4 | 1.5 | 0.98 | 0.13 | 1.2 | 4.2 | 5.53 | 0.1 | 2.2 | 2.9 | 0.72 | | | | |
| *Euphorbia hetrophylla* L. | | | | | | | | | | | | | | | | | | | | | 0.02 | 0.2 | 1.5 | 0.57 |
| *Euphorbia hirta* L. | 0.04 | 0.1 | 0.83 | 0.32 | | | | | 0 | 0.6 | 0.6 | 0.4 | | | | | 0.1 | 1.9 | 2.5 | 1.48 | 0.11 | 1.4 | 10.4 | 3.97 |
| *Evolvulus alsinoides* L. | | | | | | | | | 0.1 | 0.6 | 0.6 | 0.42 | | | | | | | | | | | | |
| *Fuirena umbellata* Rottb. | | | | | 0.04 | 1 | 1.5 | 0.85 | | | | | | | | | | | | | | | | |
| *Hyptis spicigera* Lam. | | | | | 0.01 | 0.1 | 0.2 | 0.1 | | | | | | | | | | | | | | | | |
| *Ipomea eriocarpa* R.Br. | 0.04 | 0.2 | 1.7 | 0.65 | | | | | 0 | 0.5 | 0.5 | 0.34 | 0.04 | 0.1 | 0.4 | 0.18 | 0 | 0.1 | 1.1 | 0.4 | 0.02 | 0.4 | 3 | 1.14 |
| *Ipomea aquatica* Forssk. | 0.04 | 0.1 | 0.83 | 0.32 | 0.03 | 1.1 | 1.7 | 0.94 | | | | | | | | | | | | | | | | |

Appendix 1. Continued

| Plant Species | UCLL | | | | CLL | | | | UCFL | | | | CFL | | | | UCHL | | | | CHL | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RF | RD | RDo | IVI | RF | RD | RDo | IVI | RF | RD | RDo | IVI | RF | RD | RDo | IVI | RF | RD | RDo | IVI | RF | RD | RDo | IVI |
| *Leucas martinicensis* (Jacq.) R.Br. | | | | | | | | | | | | | 0.21 | 13.1 | 46 | 19.8 | | | | | 0.04 | 0.2 | 1.5 | 0.58 |
| *Leucas chinensis* (Retzius) R. Brown, | | | | | 0.1 | 0.5 | 0.8 | 0.47 | | | | | | | | | | | | | | | | |
| *Ludwigia hyssopifolia* (G. Don) Exell. | 0.04 | 0.1 | 0.83 | 0.32 | | | | | | | | | | | | | | | | | | | | |
| *Ludwigia octovalvis* (Jacq.)P.H.Raven. | 0.04 | 0.2 | 1.7 | 0.65 | 0.03 | 0.6 | 0.9 | 0.51 | | | | | | | | | | | | | | | | |
| *Mollugo nudicaulis* Lam. | | | | | | | | | | | | | | | | | | | | | 0.2 | 2.5 | 19 | 7.23 |
| *Nelsonia canescens* (Lam.) Spreng. | 0.13 | 1.6 | 13.3 | 5.01 | 0.11 | 2.3 | 3.5 | 1.97 | | | | | | | | | | | | | | | | |
| *Nemum spadiceum* (Lam.) Desv. ex Ham. | | | | | | 0.1 | 3.6 | 5.5 | 3.07 | | | | | | | | | | | | | | | |
| *Oldenlandia corymbosa* L. | | | | | | | | | | | | | | | | | | | | | 0.2 | 2.7 | 20.1 | 7.67 |
| *Oryza barthii* A. Chev. | 0.04 | 0.1 | 0.83 | 0.32 | | | | | | | | | | | | | | | | | | | | |
| *Pennisetum pedicellum* Trin. | | | | | | | | | 0 | 1.3 | 1.4 | 0.91 | | | | | 0 | 0.3 | 0.4 | 0.24 | | | | |
| *Polycarpaea linearifolia* (DC.) DC. | | | | | | | | | | | | | | | | | | | | | 0.2 | 2.7 | 20.1 | 7.67 |
| *Setaria pumila* (Poir.) Roem. & Schult. | | | | | | | | | | | | | | | | | 0 | 1.9 | 2.5 | 1.48 | | | | |
| *Sorgum halepense* (L.) Pers. | 0.13 | 2.9 | 24.2 | 9.08 | | | | | | | | | | | | | | | | | | | | |
| *Spermacoce stachydea* DC. | | | | | | | | | | | | | 0.19 | 8 | 28.1 | 12.1 | | | | | | | | |
| *Sphaeranthus angustifolius* DC. | | | | | 0.1 | 10.2 | 15.5 | 8.6 | | | | | | | | | | | | | | | | |
| *Sphaeranthus flexuosus* O. Hoffm. | | | | | 0.13 | 5.7 | 8.6 | 4.81 | | | | | | | | | | | | | | | | |
| *Tephrosia pedicellata* Baker. | | | | | | | | | 0 | 0.7 | 0.7 | 0.47 | | | | | 0 | 2 | 2.6 | 1.55 | | | | |
| *Tridax procumbens* L. | | | | | | | | | 0 | 1.2 | 1.3 | 0.84 | | | | | 0.1 | 0.9 | 1.2 | 0.72 | | | | |
| *Vernonia ambigua* Kotschy and Peyr. | | | | | | | | | | | | | | | | | | | | | | | | |
| *Vernonia cinerea* (L.) Less. | 0.04 | 0.1 | 0.83 | 0.32 | 0.1 | 3.1 | 4.7 | 2.63 | | | | | | | | | | | | | | | | |
| *Vicoa leptoclada* (Webb) Dandy. | | | | | | | | | | | | | | | | | | | | | 0.07 | 0.5 | 3.7 | 1.42 |
| *Walteria indica* L. | | | | | | | | | 0 | 0.4 | 0.4 | 0.27 | | | | | 0.1 | 4 | 5.3 | 3.12 | | | | |
| *Zornia glochidiata* Reichb. ex DC. | | | | | | | | | 0.1 | 28 | 29.4 | 19.2 | | | | | 0.1 | 17 | 22 | 13.2 | | | | |