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Influence of Geographic Distance on the Floristic Composition of the Miombo Savannah in Unango, Northern Mozambique

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Abstract: Geographic distance results in population decline, influencing species richness, diversity and distribution. The aim of this research was to evaluate the influence of geography on the floristic composition in the Miombo Savannah in Unango the northern part Mozambique. The studied area was 1.8ha, where 20 sample units of 30m * 30m were established using systematic sampling with a distance of 20m and individuals with DBH ≥ 5 cm were measured. The description of species composition and distribution was evaluated using the Importance Value Index (IVI), diversity by the Shannon Index, and the influence of geographical distance on floristic similarity by the Mantel test. In the floristic survey a total of 999 individuals were sampled, belonging to 34 species distributed in 19 families, the Shannon index was 2.6 and in terms of number of species, the Fabaceae family was the most representative in the study area. The species with the highest importance index values in the study area were *Brachystegia spiciformis, Brachystegia boehmii, Uapaca kirkiana, Uapaca nitida, Julbernardia globiflora* and *Salix mucronata*. The Mantel test was not significant, showing that the geographical distance does not influence the floristic similarity within the forest formation on a local scale, other factors may have an influence on the similarity between areas such as climate, topography and soils.

Keywords: Species Diversity, Spatial Distance, Floristic Similarity, Vegetation

1. Introduction

Miombo is a term used to describe those Central, Southern and Eastern African woodlands dominated by the genera *Brachystegia, Julbernardia* and/or *Isoberlina*, three genera from the legume family (Fabaceae, subfamily Caesalpinioideae) considered most abundant in the region [1]. In Africa, Miombo occurs only in south of the equator, in Tanzania, Zambia, Congo, Malawi, Mozambique and Zimbabwe over an area of approximately 270 million hectares [2]. The dominance of the genera *Brachystegia, Julbernardia* and *Isoberlina* (Fabaceae, subfamily Caesalpinioideae) makes Miombo different floristically from most other forest formations in Africa, as these are rarely found outside of Miombo [3]. Miombo plant species richness can be considered high, although animal richness is low. The Miombo region has about 8.500 species of higher plants, of which more than 54% are endemic [4].

In Mozambique has an estimated 334 tree species and 51 families, and the Miombo areas cover about 2/3 of the national territory and represent an important source of income for formal and informal economies [5]. Miombo's ecological dynamics are largely defined by its woody component, whose composition has been greatly influenced by climatic factors and fires [6]. Differences in the composition, diversity and structure of species in Miombo are more evident on a local scale, and these differences in species composition between different communities are often explained by several factors, in general those linked to soil conditions and climatic [7].

The growth of trees in Miombo is generally determined by edaphic factors, mainly the availability of nutrients and humidity, the position of the landscape, the effects of fire and anthropogenic disturbances [3]. In areas where tropical forests occur, several studies show that in addition to edaphic factors, geographical distance influences the distribution of plants in these regions [8, 9, 10, 11]. These studies demonstrated that species similarity decreases as the geographical distance between plots increases, corroborating with Hubbell's Theory of Neutrality, which predicts that the similarity of species in a community decreases with increasing geographical distance between locations, regardless of environmental differences, this reduction being the result of limiting dispersion of species in space [12].

In Mozambique, specifically in Unango, Northern Mozambique there is a lack of studies on Miombo forests that demonstrate how the floristic composition can be influenced by geographical distance. Studies done in Mozambique focused on the carbon sequestration and biodiversity of re-growing miombo woodlands in Mozambique in anthropized areas after slash and burn agriculture [13]. Other studied the effects of fire and elephants on species composition and structure [5]. These studies were done without assessing other factors such as the influence of geographical distance on the floristic composition, a study should be done to assess whether the geographical distance influences the variation of composition of tree species in Miombo on a local scale.

2. Methodology

2.1. Study Area

The study was carried out in Unango Administrative Post, in the district of Sanga, province of Niassa (Figure 1). This region is 12 km from the Malulu district headquarters, bordering on the north with the Administrative Post of Macaloge, on the South with the District of Lichinga, on the East with the District of Muembe across the Lucheringo River and on the West with the Administrative Post of Lussimbesse.

Agriculture is the dominant economic activity in the district of Sanga, although it is subsistence, with the practice of slash and burn agriculture and low productivity [14]. This type of agriculture is practiced in small plots of approximately 2.5 ha, designed “farms” [15]. Each household has more than one farm and, normally, different crops, the main crops being corn, peanuts, beans and potatoes.

The region's climate is under the influence of the Intertropical Convergence Zone (IICZ), which gives rise to two well-defined seasons. Average annual rainfall ranges from 1000mm to 1200mm in the far north, along the Rovuma and Lucheringo rivers, reaching peaks of 2000mm in the highest areas of the mountain range [14]. The average temperature values during the hot and humid season are 20°C and 23°C in the plateau area, and in the mountain range of Sanga the temperature values tend to increase to 23°C to 26°C in the North range, in the plains area, along of the Rovuma River [14].

Miombo is the main forest type in Mozambique and covers approximately 2/3 of the total area, mainly north of the Limpopo River. Depending on the topographic and physiographic variations, the Miombo's structure and composition is modified by climate, soil and altitude, distinguishing itself from one region to another. The administrative post of Unango is inserted in the district of Sanga which is in the Zambesíaca region, with the subdivision of dry deciduous Miombo that occupies most of the district, in the North and Northeast zone and along the Rovuma River and late Miombo deciduous late of the plateau zones and mountainous areas of the south of the district dominated by species of the genera Brachystegia (*Brachystegia boehmii*, *B. spiciformis*, commonly known as Messassas) and species of the genera Uapaca (Massuco) in the plateau and mountainous areas [14].

2.2. Sampling and Data Collection

To survey the floristic composition, 20 sample units of 30m x 30m were installed systematically, spaced 20m apart, totaling 1.8ha in the entire study area. The floristic surveys of the tree component in the sample plots were identified and all individuals with diameter at breast height (DBH ≥ 5cm) were counted. In the floristic surveys, the information containing the scientific names; common; the family; the diameter of the individuals, were noted. The botanical identification of individuals was carried out in the field by common name with the help of local guides, and for scientific names the bibliography commonly used to identify plant species in Southern Africa was used (Field guide to trees of Southern Africa). Where taxonomic identification in the field was not possible, this was done through the analysis of photographs or herbarized botanical material collected in the study area. The spelling and validity of the scientific names of the species were checked and updated in taxonomic revisions on the International Plant Names Index (http://www.ipni.org/ipni/plantnamesearcpage.do).

The species nomenclature follows the proposal of the Angiosperm Philogeny Group (APG III).

2.3. Data Analysis

2.3.1. Floristic Composition and Species Diversity

The species composition was listed and the species richness (S) of the tree component was calculated. To assess whether the sampling effort was sufficient to sample most of the biological diversity of the studied area, rarefaction curves were generated [16]. This method has been widely used to indicate sample sufficiency; it is a quantitative concept to inform whether the number of sample plots used are representative of the community under study [17]. Estimated species riches for the area as a whole were also calculated using non-parametric estimators based on species incidence (*Bootstrap, CHAO 2, ICE, Jackknife 1 and Jackknife 2*) available in the EstimateS 9.1.0 software [18].

Species diversity was calculated using the Shannon diversity index. The diversity indices provide more information on the composition of the community than simply species richness, taking into account the relative abundance of different species [19].

To obtain a description of species composition and distribution, the Importance Value Index (IVI) was used. The IVI for a species is the sum of three ecological parameters - relative abundance, relative frequency and relative dominance [20]. The Importance Value Index (IVI) describes the floristic structure and composition of forests and has been used frequently in Miombo woodland [21, 22].

$$IVI = RF + RD + RDo \quad (1)$$

Where:

IVI: is the Importance Value Index; RF: is the relative frequency; RD: is the relative density; and RDo: is the relative dominance.

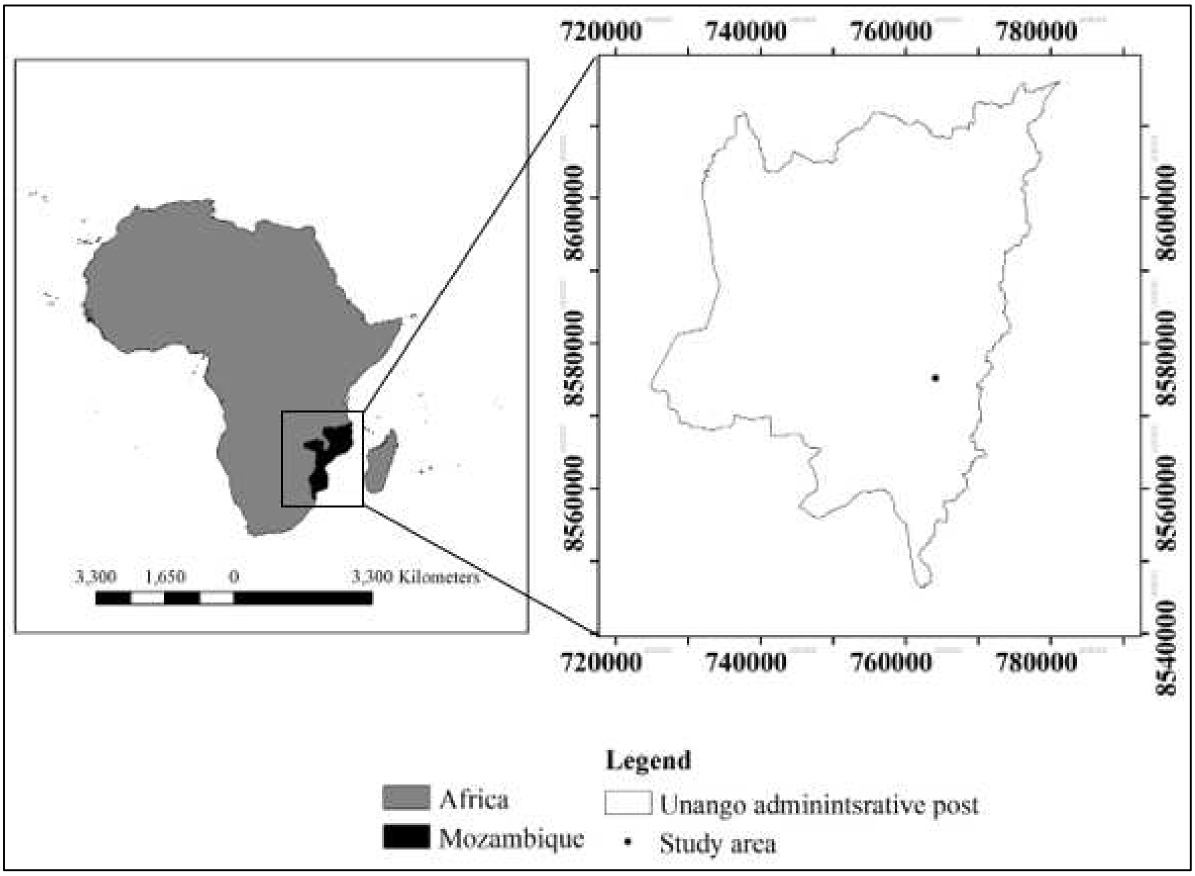

Figure 1. *Location of study area.*

2.3.2. Spatial Autocorrelation Analysis

For spatial autocorrelation analysis, two matrices were used, one of geographic distances and the other of presence and absence of species. The geographical distance was calculated by a Global Positioning System (GPS), from the supply of the geographical coordinates of each sample plot. To assess the relation between floristic similarity and geographical distance, the Mantel test was calculated using Euclidean distance and jaccard index. The purpose of the analysis was to test whether the distance between sample plots influences the composition of species [23]. This analyze was done using R core Team Development program version 3.6.1.

3. Results and Discussion

3.1. Floristic Composition and Species Diversity

Altogether in the floristic survey in the study area, 999 individuals were sampled, with DBH greater than or equal to 5 cm. In this study 34 species were registered, distributed in 27 genera of 19 families (Table 1), the Shannon diversity index was 2.6, this value is low when compared to other studies in Miombo woodland [7, 24]. Shannon's diversity index value was high when compared to another study [25]. These low values are expected in different areas, especially when the areas are subjected to anthropic disturbances, this affects the composition and structure of the forest, leading to alteration of ecosystem functions [26].

Regarding to the number of species, 110 species in the Bereku Forest Reserve, in Tanzania were registered, and the high number of species found in the study can be attributed to the presence of riverine forests, which contribute to the growth of many species of Miombo [7]. Other study found 86 species around the village of Ihombwa in Tanzania [1]. In Mozambique 79 species were registered in Niassa National Reserve [5]. Other study, 69 species in N'hambita Community within the Buffer zone of Gorongosa National Park [13]. The low species richness found in this study can be explained by the location of the area, which is close to small family communities that live and depend on natural resources and whose human activities, such as firewood extraction, collection of non-wood forest products and hunting affect forest biodiversity. These activities may have a more important influence on the ability of forests to maintain their original biodiversity, causing even theoretically preserved areas to have less diversity and species richness. Reference [3] pointed out that the growth of trees in Miombo is generally determined by edaphic factors, mainly the availability of nutrients and humidity, the position of the landscape, the effects of fire and anthropogenic disturbances. In addition, the difference in species richness between areas may be the result of different types of land use, or because of the difference in the number of individuals found in the areas [16].

Table 1. *List of families and tree species recorded in the study area.*

Família	Espécies
Anacardiaceae	*Rhus natalensis* Bernh
Annonaceae	*Annona senegalensis* Pers
Araliaceae	*Cussonia arborea* Hochst
	Cussonia natalensis Sond
Celastraceae	*Gymnosporia nemorosa* Szyszy
Chrysobalanaceae	*Parinari curatellifolia* Planch
Combretaceae	*Terminalia spinosa* Northr
Erythroxylaceae	*Erythroxylum pictum* E. Mey
Euphorbiaceae	*Uapaca kirkiana* Mull. Arg
	Uapaca nitida Mull. Arg
	Uapaca sansibarica Pax
Fabaceae	*Acacia abyssinica* Hochst
	Brachystegia boehmii Taub
	Brachystegia bussei Harms
	Brachystegia spiciformis Benth
	Brachystegia utilis Hutch
	Burkea africana Hook
	Dalbergia melanoxylon Guill & Perr
	Dichrostachys cinerea Wight & Arn
	Julbernardia globiflora Benth
	Pericopsis angolensis Baker
	Pterocarpus angolensis DC
	Swartzia madagascariensis Desv
Flacourtiaceae	*Flacourtia indica* (Burm. f) Merr
Loganiaceae	*Strychnos spinosa* Lam
Moraceae	*Ficus natalensis* Hochst
	Ficus sp
Myrtaceae	*Syzygium guineense* Guill & Perr
Polygalaceae	*Securidaca longepedunculata* Fresen
Proteaceae	*Protea caffra* Lotter
Rubiaceae	*Catunaregam spinosa* Taylorii (S. Moore) Verdc
Salicaceae	*Salix mucronata* Archer & Jordaan
Sapotaceae	*Mimusops zeyheri* Sond
Verbenaceae	*Vitex doniana* Sweet

The families with the highest number of species were Fabaceae, which corresponds (12 ssp), Euphorbiaceae (3 ssp), Araliaceae and Moraceae (2 ssp), respectively. All other families were represented by one specie, the families Fabaceae, Euphorbiaceae and Araliaceae contributed with 55.88% of the species registered in the present study (Figure 2). The highlight for the Fabaceae family is expected, it is often registered among the most important in the areas where Miombo occurs [27, 24, 28, 29, 22]. This family constitutes about 35.29% of all trees measured in the study area.

3.2. Sampling Sufficiency

Sample sufficiency is a quantitative concept used in phytosociological studies to inform whether the sample used is representative of the plant community [30]. The rarefaction curve showed a tendency to stabilize as indicated by the rarefaction curve and the respective confidence intervals (Figure 3). The non-parametric richness estimators used (*ICE, Chao 2, Jacknife 1, Jacknife 2 and Bootstrap*) showed that with increased sampling effort, more species would be sampled in the study area, that is, the proportion between the number of species observed in relation to the obtained by the estimators varied from 85% to 91.5% demonstrating that the number of plots used in this study managed to cover more than 50% of the estimated richness (Table 2).

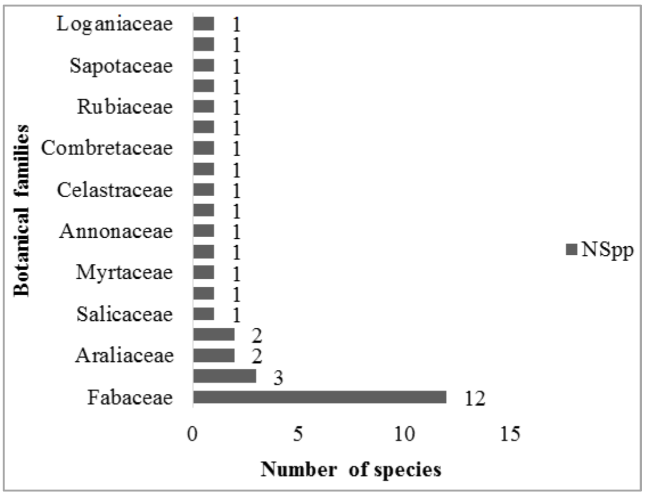

Figure 2. *Number of species (NSpp) per family in the study area.*

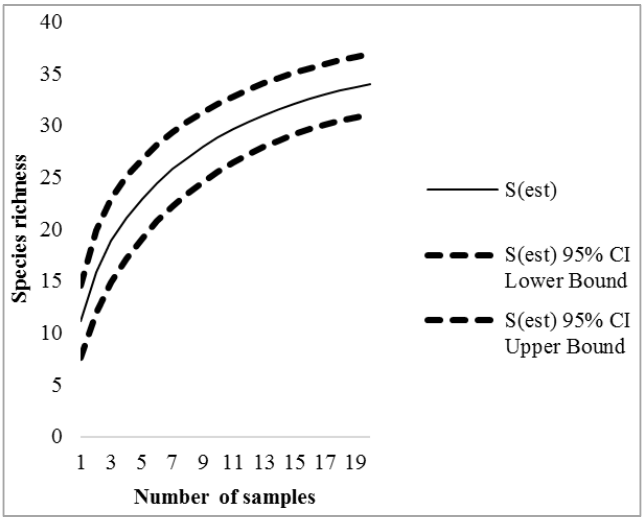

Figure 3. *Rarefaction curve for the study area (continuous line-estimated richness, and discontinuous lines-confidence intervals).*

Table 2. *Estimated richness of tree species by five non-parametric estimators (ICE, Chao 2, Jacknife 1, Jacknife 2 and Bootstrap), in the study area.*

Study area	Estimators					
	S (Obs)	***ICE***	***Chao 2***	***Jacknife 1***	***Jacknife 2***	***Bootstrap***
Miombo	34	38	36	40	39	37
% of species		89.5	94	85	87.1	91.9

Table 3. *Estimates of phytosociological parameters of the species sampled in the study area, in decreasing order of importance (VI%). NInd - number of individuals, AbsDe-absolute density, RelDe - relative density%, AbsFr - absolute frequency, RelFr - relative frequency%, AbsDo - absolute dominance and RelDo - relative dominance%.*

Espécies	NInd	AbsDe	RelDe	AbsFr	RelFr	AbsDo	RelDo	IVI
Brachystegia spiciformis	235	130.6	23.52	95	9.36	1.7	27.08	59.96
Brachystegia boehmii	94	52.2	9.41	85	8.37	0.67	10.66	28.44
Uapaca kirkiana	77	42.8	7.71	70	6.9	0.68	10.75	25.35
Uapaca nitida	77	42.8	7.71	70	6.9	0.53	8.41	23.01
Julbernardia globiflora	78	43.3	7.81	75	7.39	0.33	5.33	20.52
Salix mucronata	73	40.6	7.31	70	6.9	0.33	5.23	19.43
Pericopsis angolensis	73	40.6	7.31	55	5.42	0.34	5.37	18.09
Parinari curatellifolia	65	36.1	6.51	65	6.4	0.32	5.05	17.96
Uapaca sansibarica	50	27.8	5.01	45	4.43	0.5	8.03	17.47
Brachystegia utilis	65	36.1	6.51	55	5.42	0.19	3.03	14.95
Cussonia arborea	19	10.6	1.9	40	3.94	0.1	1.59	7.43
Brachystegia bussei	10	5.6	1	30	2.96	0.14	2.22	6.17
Syzygium guineense	15	8.3	1.5	30	2.96	0.07	1.04	5.5
Rhus natalensis	6	3.3	0.6	25	2.46	0.07	1.15	4.21
Annona senegalensis	11	6.1	1.1	20	1.97	0.04	0.58	3.65
Burkea africana	5	2.8	0.5	20	1.97	0.07	1.05	3.52
Flacourtia indica	7	3.9	0.7	15	1.48	0.06	1.03	3.21
Swartzia madagascariensis	5	2.8	0.5	15	1.48	0.02	0.26	2.24
Gymnosporia nemorosa	3	1.7	0.3	15	1.48	0.01	0.08	1.86
Vitex doniana	3	1.7	0.3	15	1.48	0	0.06	1.84
Terminalia sp	5	2.8	0.5	10	0.99	0.01	0.16	1.65
Pterocarpus angolensis	2	1.1	0.2	10	0.99	0.02	0.39	1.58
Cussonia natalensis	2	1.1	0.2	10	0.99	0.02	0.34	1.52
Protea caffra	4	2.2	0.4	10	0.99	0.01	0.12	1.51
Catunaregam spinosa	2	1.1	0.2	10	0.99	0.01	0.1	1.28
Securidaca longepedunculata	2	1.1	0.2	10	0.99	0.01	0.09	1.27
Dalbergia melanoxylon	2	1.1	0.2	10	0.99	0	0.06	1.25
Ficus natalensis	1	0.6	0.1	5	0.49	0.01	0.2	0.79
Ficus sp	2	1.1	0.2	5	0.49	0.01	0.09	0.79
Mimusops zeyheri	2	1.1	0.2	5	0.49	0	0.08	0.77
Erythroxylum pictum	1	0.6	0.1	5	0.49	0.01	0.14	0.73
Strychnos spinosa	1	0.6	0.1	5	0.49	0.01	0.09	0.69
Dichrostachys cinerea	1	0.6	0.1	5	0.49	0.01	0.08	0.68
Acacia abyssinica	1	0.6	0.1	5	0.49	0.01	0.08	0.68
Total	999	555.4	100	1015	100	6.31	100	300

3.3. Community Structure Under Study

The species that showed the highest density in the study area were: *Brachystegia spiciformis* (23.52%), *Brachystegia boehmii* (9.41%), *Julbernardia globiflora* (7.81%) and *Uapaca kirkiana* (7.1% each) (Table 3), and the most frequent species in the plots were *Brachystegia spiciformis (*95%), *B. boehmii* (85%), *Julbernardia globiflora* (75%). For the values of relative dominance, the species that presented relevant values were: *Brachystegia spiciformis* (27.08%), *Brachystegia boehmii* (10.66%), and *Uapaca kirkiana* (10.75%). The ten species with the highest IVI, in decreasing order, in the study area were: *Brachystegia spiciformis*, *Brachystegia boehmii*, *Uapaca kirkiana*, *Uapaca nitida*, *Julbernardia globiflora*, *Salix mucronata Pericopsis angolensis*, *Parinari curatellifolia* and *Uapaca sansibarica*, which represented 24.5% of the total IVI.

For species of greater density and dominance, the IVI varied according to the three phytosociological indices together (Table 3). Among the registered species, *Brachystegia spiciformis* stood out from the others due to its high dominance and density and, consequently, represents the most important phytosociologically species, presenting the highest importance value (5.99%) (Table 3). Other species also deserve to highlight representative values of importance, being the following *Brachystegia boehmii* (VI = 2.84%) and *Julbernardia globiflora* (VI = 4,7%). The importance value index provides knowledge about important species in a plant community. The most important species observed in the present study are those commonly found in the Miombo areas in Mozambique [5, 21]. These species are commonly found in other areas of Miombo occurrence in southern Africa [19, 31]. The mentioned species occur in order of different importance, and the genera Brachystegia, Julbernardia are generally associated with species such as Diplorhynchus condylocarpon, Parinari curatellifolia and Pseudolachnostylis maprouneifolia. The species Brachystegia spiciformis was the sociologically important species in the study area, and follows the typical pattern for these forest formations. [32].

The number of trees per hectare was 555.4 found in the present study is within the expected values in the Miombo Savannahs in Africa. In Mozambique, a density of 548 individuals per hectare was recorded [5]. While another study recorded a density of 574 individuals per hectare [13]. A study conducted in Tanzania states that the number of individuals per hectare can vary from 74 to 1041 individuals per hectare [33]. Differences in composition and structure in Miombo are not clear, but may be linked to geomorphological evolution, edaphic factors (mainly soil moisture and nutrients), the effects of fire, the impact of wildlife, the use of land in the past and at present, and other anthropogenic disturbances [2].

The basal area found in the present study was 6.3 m^2/ha not in the range of values found in Miombo. In Miombo, the basal area is a very modifiable attribute depending on the climate and the forest type, with values ranging from 7.0 to 30.0 m^2/ha [1]. While in his study of the diversity and structure of Miombo woodlands in Mozambique using different sample sizes in Zambezia province, Mocuba district were observed that the average basal area was 26.1m^2/ha [21]. In Tanzania, observed values ranging from 15.04-15.63m^2/ha [33]. The results of the present study show a low dominance which suggests that the area corresponds to the area of open Miombo with the presence of trees of smaller diameters in succession stage.

3.4. Spatial Autocorrelation Analysis

There was no significant correlation between species similarity and geographic distance between plots based on the Mantel test ($r = 0.0636$, $p = 0.25275$. The present study did not corroborate with Hubbell's Neutral Theory, which predicts that the similarity of species in a community decreases with the increase in geographical distance between locations, regardless of environmental differences [12]. Acording to Hubbell's Neutral Theory, if more distant the plots are, the more distinct they are in terms of floristic composition, and this is the result of limitations in dispersion [9]. The result of this study can be explained by the fact that species are equally likely to occur anywhere, there is no geographic barrier, its occurrence in a given location would depend on the ecological conditions existing in the place and, thus, if distant places had similar conditions, the flora would be similar [34]. In addition to the geographic distance, other factors such as climate, topography, altitude and soils can influence the similarity between the plots or areas [35, 10].

4. Conclusions

The Fabaceae, Euphorbiaceae families showed the highest specific riches, following the pattern found by other floristic studies carried out in areas where Miombo occurs.

The Shannon-Wiener diversity index of 2.6, considered low in the context of similar studies in the regions of Miombo occurrence.

The species *Brachystegia spiciformis* showed higher values of dominance, frequency and abundance, consequently representing the most sociologically important species, a pattern commonly found in other studies.

The floristic similarity and geographical distance through the Mantel test did not show any significant correlation, the spatial distance does not influence the floristic composition, other factors may influence the floristic similarity between the plots.

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