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Floristic Composition and Structure of Mangrove forest in Macuze, Central of Mozambique

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Abstract: Despite its importance, mangroves are considered in the current context the most vulnerable and susceptible to degradation, due to anthropic activities, therefore, studies that help in understanding these environments, such as the floristic and structural characterization of vegetation are necessary. Thus, the aim of this study was to describe the floristic and phytosociological characteristics of the Macuze-Sede mangrove in the district of Namacurra in the province of Zambézia, in central Mozambique. Twenty-four plots measuring 20 m x 20 m (400 m²), were installed through systematic sampling, where all arboreal individuals with diameter at breast height (DBH) greater than or equal to 10 cm were quantified. The diameter at breast height of all individuals were grouped into classes, and the phytosociological parameters (absolute and relative density, absolute and relative frequency, absolute and relative dominance, and importance value index) of the species were calculated. In the study area 546 individuals were quantified and seven species identified, distributed among 7 genera and 5 families. The density was 568.75 trees per hectare, the mean diameter was 13.07 cm and the total basal area 7.97 m^2/ha. In the diametric distribution, most individuals fitted into the smallest classes. *Avicennia marina (Forssk.) Vierh. var. marina* presented the largest number of individuals (340) and the highest values in all phytosociological parameters, with an importance value of 52.8%. Thus, it was found that Avicennia marina is the most important species for the study area, and showing that it is the species widely distributed in Mozambique according to other studys.

Keywords: Coastal Areas, Density, Mangrove, Species Richness

1. Introduction

Mangroves are forests that grow in the intertidal area in the tropical and sub-tropical areas [1-3]. The area occupied by the mangrove is approximately 137760 km^2 [4]. The Mangrove occur in coastal areas and places with little influence of tidal energy [5]. Mangroves are made up of a group of very diverse trees, which have a great capacity to live and to adapt in flooded areas with regular flooding caused by the tides [1].

A recent study, reports that Mozambique has a mangrove forest cover that varies between 290000 and 368000 ha, which extend along the 2770 km of coastline [5]. A study by C. Giri *et al.* [4], the Mozambican mangrove ranks third in Africa, after Nigeria and Guinea Bissau. The highest concentrations of mangroves in Mozambique are located in the central region of the country followed by the north coast and finally the south region [6].

Mangroves are among the most productive forests in the tropics [7]. The mangroves are biologically considered the important ecosystems of the world because they provide important ecosystem goods and services for human society and coastal and marine systems [4]. The important ecosystem goods and services that Mangrove provide are fishery production, natural protection against disturbances and

nutrient cycling [8].

The large number of marine species that the mangroves shelter have high commercial value and, when associated with tree plants, constitute ecosystems with great socioeconomic importance for populations living in coastal areas [9].

Among coastal ecosystems, mangroves are considered in the current context the most vulnerable and susceptible to degradation, due to anthropic activities [10]. The decline of mangroves in recent years have been alarming due to the conversion of areas for agriculture, aquaculture, tourism, urban development and over-exploitation [11, 4].

In Mozambique, the causes of mangrove degradation are linked to anthropogenic and natural factors, anthropogenic factors are the main threats to mangroves in the country, and are largely related to the main ways of using mangrove resources [12]. These ways of using the mangrove can be highlighted: the extraction of wood fuel, the cutting of trees for the construction of houses and boats, the construction of saltpans [6, 13, 14].

Allied to this, there is a need for studies that help in understanding these environments, such as the floristic and structural characterization of vegetation, which are useful to evaluate the response of species to inhospitable environmental conditions, and to the processes of altering the natural environment [15].

The Phytosociology aims to explain the phenomena that relate to plant life within ecological units [16]. Phytosociology is currently considered a valuable tool in determining the most important species within a given community and through phytosociological surveys, it is possible to establish degrees of hierarchy among the studied species and to evaluate the need for measures aimed at the preservation and conservation of forest units [16]. The study aimed to describe the composition and structure of the Mangrove in the Administrative Post of Macuze-Sede, Province of Zambézia in Central Mozambique.

2. Methodology

2.1. Study Area

The phytosociological survey was conducted in a mangrove area in the district of Namacurra, at the administrative post of Macuze-Sede, province of Zambézia.

The mangrove is of the riverside type, bordering rivers and canals, the area occupied by mangroves in Namacurra is about 41 km^2 (2% of the district area), distributed essentially by the Macuze river estuary and the Licungo river delta.

The mangrove forest patches occur inland, beyond the mouth of the rivers, along its innumerable channels. These are usually composed of the species *Avicennia marina* [17].

2.2. Sampling and Data Collection

The mangroves of the Macuze-Sede Administrative Post were divided into 2 areas according to their location (Figure 1). In each study area, an area of 1 hectare was defined, where units or plots of fixed and quadratic areas of 20 m x 20 m (400 m^2) were established according to [18].

The samples were systematically selected at a distance of 20 m from each other, where the tree vegetation was surveyed.

Thus, 12 plots were sampled in each 1 ha area, totalling 24 plots across the study area.

Quadratic plots of fixed area are commonly used for phytosociological surveys in mangrove areas, as these are easy to install and use, as well as allowing the determination of a wide range of estimates, given the difficult conditions of accessibility in mangrove forests.

Within each sampled plot, scientific names, common names, family names of all trees with DBH (diameter at breast height) equal to or greater than 10 cm were identified, the data datas were recorded in data collection sheets for further analysis.

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 from Southern Africa (Field guide to trees of Southern Africa). Where taxonomic identification in the field was not possible and this was done through analysis of photographs or herbalized botanical material, collected on site. The species nomenclature follows the proposal of the Angiosperm Phylogeny Group (APG III).

2.3. Data Analysis

Floristic Composition and Structure

The species composition was listed and the species richness (S) of the tree component was calculated. To verify how the number of species increased with the number of plots sampled, rarefaction curves were built, based on the presence or absence of the species, in the plots of the study area [19]. The rarefaction curves were built using the statistical program EstimateS 9.1.0 [20]. The stabilization of the curve was considered when it assumed an asymptote. The same program was used to carry out the specific richness estimates for the total sample, through 100 random resamplings of the data and with non-parametric estimators: *Chao 2, Jackknife 1* and *Bootstrap* that use data of presence or absence of species.

The following phytosociological parameters were analyzed based on diameter measurements: number of individuals (Ni), absolute and relative density (AbsDe and RelDe), absolute and relative frequency (AbsFr and RelFr), basal area (BA), dominance absolute and relative (AbsDo and RelDo) and importance value index (IVI) which represents the sum of relative density, relative dominance and relative frequency [21]. In addition, the datas used in the results of the present study were: Number of individuals, Relative frequency, relative density, relative dominance and importance value index. These analyzes were made using the FITOPAC 2.1 program [22].

The Importance Value Index (IVI) describes the floristic structure and composition of forests and has been used frequently in Miombo woodland [10].

$$IVI = \frac{RelDe+RelFr+RelDo}{3} \quad (1)$$

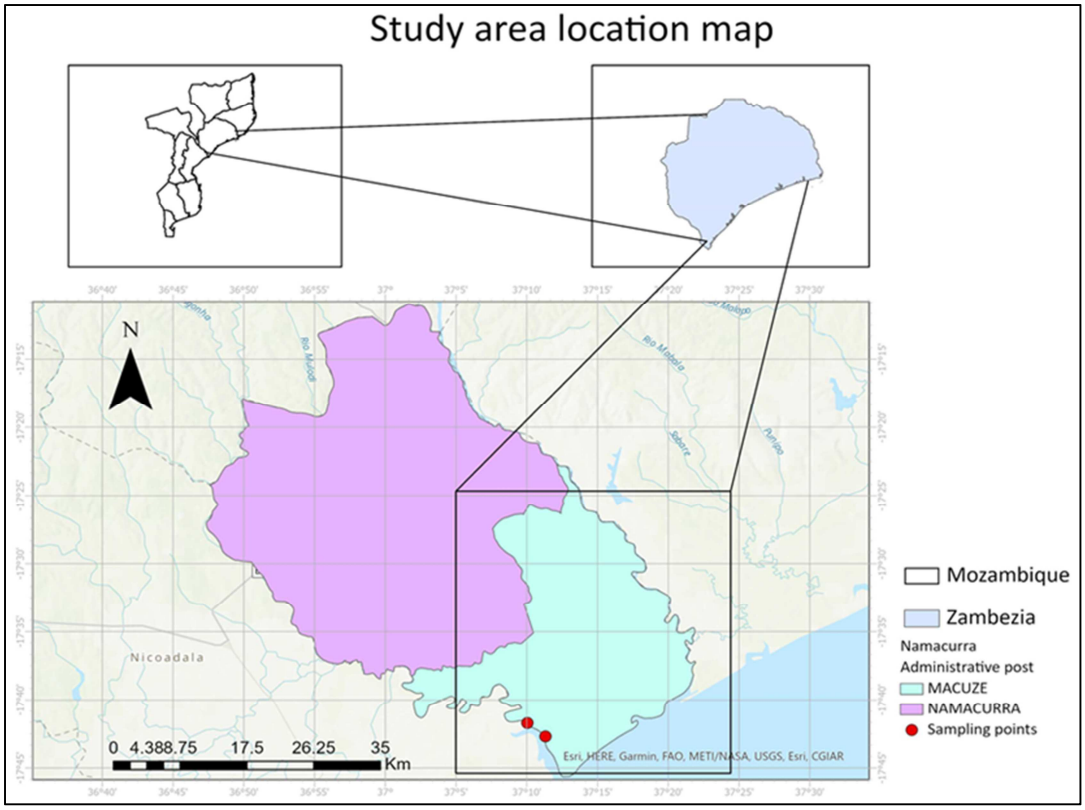

Figure 1. *Location of study area.*

3. Results and Discussion

3.1. Floristic Composition and Species Richness

The results indicate that in the study area, seven species were identified, distributed in seven generas and five families (Table 1). All families had a single species, except for Rhizophoraceae, three species were observed.

Table 1. *Macuze-Sede mangrove floristic composition.*

Species	Botanical families
Avicennia marina (Forssk.) Vierh. var. marina	Acanthaceae
Ceriops tagal (Perr.) C. B. Rob.	Rhizophoraceae
Xylocarpus granatum J. König	Meliaceae
Rhizophora mucronata Lam.	Rhizophoraceae
Sonneratia alba Sm.	Lythraceae
Heritiera littoralis Aiton	Malvaceae
Bruguiera gymnorrhiza (L.) Lam.	Rhizophoraceae

There are eight mangrove species in Mozambique, *Avicennia marina* (Forssk.) Vierh., *Bruguiera gymnorhiza* (L.) Lam., *Ceriops tagal* (Per.) CB Robinson, *Rhizophora mucronata* Lam., *Sonneratia alba* Smith, *Heritiera littoralis* Aiton, *Lumnitzera racemosa* Willd. and *Xylocarpus granatum* Koenig [6], but the number of species in each forest can vary [5].

D. K. Nicolau registered six species of Mangrove in the Quirimbas National Park in Cabo Delgado [23]. The same number of species were registered in Sofala Bay [24].

In the southern part of Mozambique in the provinces of Inhambane, Gaza and Maputo, seven species of mangrove occur in these areas, *Avicennia marina, Ceriops tagal, Rhizophora mucronata* and *Bruguiera gymnorrhiza* are the most common, *and Sonneratia alba* is frequent in the city of Inhambane and surroundings (Maxixe to Morrumbene). *Lumnitzera racemosa* and *Xylocarpus granatum* also occur.

Many woody mangrove species were observed in the Incomáti River estuary (Ilha pequena da Xefina and Muntanhana), but in terms of provinces, Inhambane has a higher number of species, with all seven woody species identified in the study area [25].

S. O. Bandeira in his study registered a richness of 5 species, in a study carried out in Pemba city, in the province of Cabo Delgado, namely *Avicennia marina, Ceriops tagal, Rhizophora mucronata, Xylocarpus granatum* and *Bruguiera Gymnorrhiza* [14]. The difference found in the floristic composition can be explained by the fact that these areas are located in different phytogeographic regions and have different edaphic and climatic conditions, despite all of them being located in the coastal zone [26].

Differences in species composition and structure are most notable at the local level, and the origin of these differences is uncertain and can be attributed to edaphic factors, soil nutrients, fauna, past and present use that the land has suffered or suffers and others anthropic disorders [23].

Therefore, the differences in terms of species richness between mangrove areas are due to some factors (natural and anthropic) that vary between regions and between mangrove areas, determining their composition.

Sample sufficiency is a quantitative concept used in phytosociological studies to inform whether the sample used is representative of the plant community. The rarefaction curve showed a tendency to stabilize as indicated by the rarefaction curve and the respective confidence intervals (Figure 2).

The non-parametric richness estimators used (*Chao 1, Jackknife 1,* and *Bootstrap*) showed that with increased sampling effort, only one specie would be sampled in the study area based on *Jackknife 1,* and *Bootstrap* estimators. The proportion between the numbers of species observed in relation to the obtained by the estimators varied from 87.5% to 100% demonstrating that the number of plots used in this study managed to cover more than 50% of the estimated richness (Table 2). These generated richness estimates do not provide accurate predictions of the actual number of species in a community, but point out the minimum values expected [27].

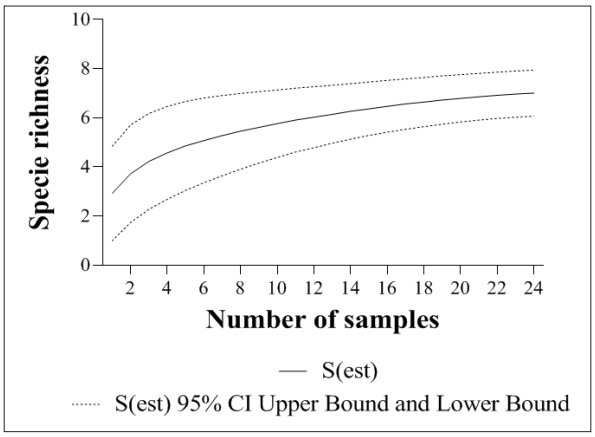

Figure 2. *Rarefaction curve for the study area (continuous line-estimated richness, and discontinuous lines-confidence intervals).*

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

Study area	Estimators			
	S (Obs)	Chao 1	Jackknife 1	Bootstrap
Mangrove	7	7	8	8
% of species		100	87.5	87.5

3.2. Structural Parameters

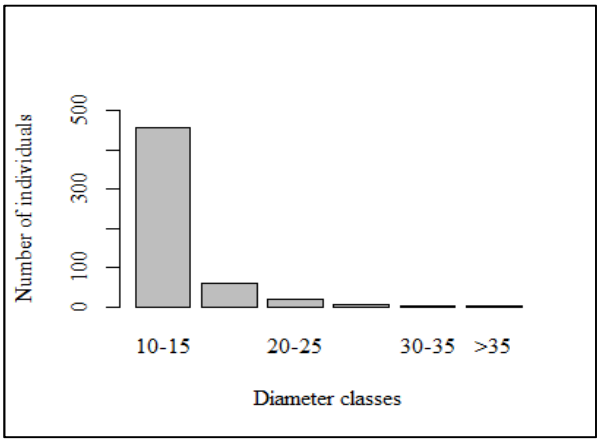

Figure 3. *Diameter distribution of inventoried individuals in the Macuze mangrove.*

In the study area, 546 individuals were sampled, with a density of 568.75 trees per hectare and the total basal area was 7.97 m^2/ha. The trees present in the investigated area presented DBH between 10 to 37 cm (average 13.07 cm). Analyzing the diametric distribution, it was observed that most individuals fit into the smallest classes (Figure 3). A. L. Gonçalves investigating floristic and phytosociological composition of the Mangrove of São Luís Port, Maranhão, also reported the largest number of individuals in the smallest diameter classes [18].

The results of phytosociological analyses are shown in the following (Table 3).

Table 3. *Phytosociological analysis of vegetation in the Macuze-Sede mangrove.*

Species	Ni	RelDe (%)	RelFr (%)	RelDo (%)	IV (%)
A. marina	340	62.3	34.3	61.8	52.8
C. tagal	93	17.0	30.0	12.6	19.9
X. granatum	68	12.5	17.1	10.8	13.5
R. mucronata	14	2.6	11.4	1.9	5.3
H. littoralis	12	2.2	2.9	8.9	4.6
B. gymnorrhiza	9	1.6	2.9	1.8	2.1
S. alba	10	1.8	1.4	2.2	1.8
Total	546	100	100	100	100

Ni = Number of individuals; RelFr = relative frequency (%); RelDe = relative density (%); RelDo = dominance (%); and IV = importance value

Regarding the density of species, *Avicennia marina, Ceriops tagal* and *Xylocarpus granatum* were the species that had the largest number of individuals distributed in the area and the greatest abundance, with relative density of 62.3%, 17.0% and 12.5% respectively.

In terms of frequency, *Avicennia marina, Ceriops tagal, Xylocarpus granatum* were the most prominent species, with *Avicennia marina* and *Ceriops tagal* being the most frequent with 34.3% and 30.0% respectively, a fact that greater spatial distribution, indicating that these species are distributed regularly throughout the mangrove areas of Macuze-Sede Administrative Post.

S. O. Bandeira observed in their study in the Mangrove area in Cabo Delgado where the most frequent species were A. *Marina*, B. *gymnorhiza*, C. *tagal*, R. *mucronata* and S. *alba* [14].

The three most dominant species in the study area were *Avicennia marina*, *Ceriops tagal* and *Heritiera littoralis*, with 61.8%, 12.6% and 10.8% respectively.

Regarding the importance value index, which is a parameter that indicates the ecological importance of each species. In the study community, it was observed that *Avicennia marina, Ceriops tagal* and *Xylocarpus granatum* constitute the species with the greatest ecological importance in the study area, with around 52.8%, 19.9% and 13.5% of VI, respectively. These species were the most prominent in terms of abundance, frequency and dominance in relation to the other species occurring in the study area, which also indicates that the conditions of the site are favorable for their development.

D. K. Nicolau studying the mangrove forests of Quirimbas

park, found that *Rhizophora mucronata*, *Ceriops tagal, Sonneratia alba and Avicennia marina* were the species that presented the highest importance value index, standing out more *Rhizophora mucronata* with about 36% VI [23]. Slightly similar results were found in the present study, as *Avicennia marina* was the most important specie, indicating the existence of a small similarity of the communities under study in terms of composition, structure, site and dominance.

Studies carried out in the mangrove forests of East and West Africa, and in Mozambique showed greater prominence in relation to the importance value index for *Rhizophora mucronata, Avicennia Marina* and *Sonneratia alba*, being the *Bruguiera gymnorrhiza* the least important [14]. However, this small variation in relation to the present study, in the order of the most important species, is due, on the one hand, to the variation of conditions that determine the occurrence, composition and structure of mangroves and, on the other hand, to the existence of different levels of disturbance and use of species [13].

Avicennia marina and *Ceriops tagal* are species that have a high tolerance capacity to environments with high salinity levels, different flooding regimes, compacted and compound soils, being species widely distributed throughout mangroves throughout the country [28]. Possibly, for this reason they were the species with the highest frequency, abundance, dominance and consequently greater ecological importance in the mangrove forests of the administrative post of Macuze.

4. Conclusions

The floristic composition of the study area were seven species, namely Avicennia marina, Ceriops tagal, Rhizophora mucronata, Xylocarpus granatum, Heritiera littoralis, Sonneratia alba and Bruguiera gymnorrhiza.

Avicennia marina, Ceriops tagal, Xylocarpus granatum and Rhizophora mucronata are the species that stood out the most for having higher values of abundance, frequency, dominance and consequently higher values of index importance, which means that these species are able to coexist in the area of study.

The vegetation physiognomy and diameter measurements are within the expected pattern for this ecosystem.

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