

**Characterisation of the baobab tree (*Adansonia digitata*) population in the commune of Catengue, municipality of Caimbambo, province of Benguela**

*Caracterização do povoamento do imbondeiro (Adansonia digitata), na comuna de Catengue, município de Caimbambo, província de Benguela*

*Caracterización del stock de imbondeiro (Adansonia digitata), en la comuna de catengue, municipio de Caimbambo, provincia de Benguela*

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## ABSTRACT

The general objective of this work was to characterise the baobab tree population in the commune of Catengue, municipality of Caimbambo, province of Benguela. The study comprised a descriptive method, based on the description of the population's behaviour regarding the treatment of the baobab stand, and a quantitative method based on the sampling technique in plots established within a sample area of 30 km<sup>2</sup>, representing 33.3% of the total studied area, which corresponds to approximately 90 km<sup>2</sup>. Ten random sampling plots and 20 systematic sampling plots were installed, totalling 30 plots of 1 ha each. Interviews with the Communal Administrator of Catengue, the Head of the Agrarian Development Stations, the leader of the traditional authorities (regedor), and a bibliographical review served to achieve the objectives. Data were statistically processed using Excel software from the Microsoft Office Student 2013 package, which was used to construct bar and scatter graphs and to calculate the similarity index and phytosociological parameters. The results indicate a population of 226 adult plants and

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12 young plants in the systematic plot "I", 205 adult plants and 145 young plants in the systematic plot "II", and 61 adult plants and 313 young plants in the random plot, reflecting a decrease in baobab plants as altitude increases; the number of adult plants decreases from East to West, while the number of young plants increases in this direction. The increase in the local population, the expansion of urban areas, cultivated areas, and uncontrolled logging contribute to the destruction of the baobab's habitat.

**Keywords:** Baobab; Characterisation; Vulnerability; Sustainable Management; Catengue.

## RESUMO

O presente trabalho teve como objectivo geral de caracterizar o povoamento do imbondeiro na comuna de Catengue, município do Caimbambo, província de Benguela. compreendeu o método descritivo, baseado na descrição do comportamento da população em relação ao tratamento do povoamento do imbondeiro e o método quantitativo baseado na técnica de amostragem em parcelas feitas com base a uma área-amstral de 30 km<sup>2</sup>, representando 33,3% da área total estudada que corresponde aproximadamente 90 km<sup>2</sup>. Foram instaladas 10 parcelas de amostragem aleatória e 20 de amostragem sistematizada, totalizando 30 parcelas de 1ha. A entrevista ao Administrador Comunal de Catengue, ao Chefe da Estações de Desenvolvimento Agrário, ao líder das autoridades tradicionais (regedor) e a revisão bibliográfica, serviram para o alcance dos objectivos. Os dados foram tratados estatisticamente com ajuda do software Excell do pacote Microsoft Office student 2013, que serviram para a construção dos gráficos de barra e de dispersão, cálculo do índice de similaridade e dos parâmetros fitossociológicos. Os resultados apontam uma população de 226 plantas adultas e 12 plantas jovens na plotagem sistemática "I", 205 plantas adultas e 145 plantas jovens na plotagem sistemática "II" e 61 plantas adultas e 313 plantas jovens na plotagem aleatória, espelhando a diminuição de plantas de imbondeiro a medida que a altitude aumenta, o número das plantas adultas diminui de Este para Oeste aumentando neste sentido as plantas jovens. O aumento da população local, a extensão das áreas urbanas, as áreas cultivadas e a exploração florestal descontrolada contribuem na destruição do habitat do imbondeiro.

**Palavras-chave:** Imbondeiro, Caracterização, Vulnerabilidade, Gestão Sustentável e Catengue.

## RESUMEN

El objetivo general de este trabajo fue caracterizar la población del árbol baobab en la comuna de Catengue, municipio de Caimbambo, provincia de Benguela. estuvo comprendido por el método descriptivo, basado en la descripción del comportamiento de la población en relación al tratamiento de la población de baobabs, y el método cuantitativo basado en la técnica de muestreo en parcelas realizadas con base en un área de muestra de 30 km<sup>2</sup>, que representa el 33,3% del área total estudiada, que corresponde a aproximadamente 90 km<sup>2</sup>. Se instalaron 10 parcelas de muestreo aleatorio y 20 parcelas de muestreo sistemático, totalizando 30 parcelas de 1ha. La entrevista con el Administrador Comunal de Catengue, el Jefe de las Estaciones de Desarrollo Agrario, el líder de las autoridades tradicionales (regedor) y la revisión bibliográfica, sirvieron para lograr los objetivos. Los datos fueron tratados estadísticamente con ayuda del software Excell del paquete Microsoft Office Student 2013, el cual se utilizó para construir gráficos de barras y de dispersión, calcular el índice de similitud y parámetros fitosociológicos. Los resultados indican una población de 226 plantas adultas y 12 plantas jóvenes en la parcela sistemática "I", 205 plantas adultas y 145 plantas jóvenes en la parcela sistemática "II" y 61 plantas adultas y 313

plantas jóvenes en la parcela aleatoria, reflejando la disminución de plantas de baobab a medida que aumenta la altitud, el número de plantas adultas disminuye de este a oeste, aumentando el número de plantas jóvenes en esta dirección. El aumento de la población local, la extensión de las zonas urbanas, las zonas cultivadas y la explotación forestal descontrolada contribuyen a la destrucción del hábitat del baobab.

**Palabras clave:** Baobab, Caracterización, Vulnerabilidad, Manejo Sostenible y Catengue.

## INTRODUCTION

The baobab is a wild plant of great nutritional and medicinal importance for humans. In central and southern Angola, for example, it is observed that the population frequently uses its fruit for daily self-consumption, consuming it as juice or sucking it after harvest, discarding the seeds. In recent years, its exploitation and consumption have become increasingly pronounced, and its economic value rises according to demand (Mendonça, 2023). However, there has been a considerable reduction in *múcua* (baobab fruit) production in this territorial area due to poor exploitation and/or frequent harvesting of the fruit in immature stages, thus hindering its natural reproduction. Following various research studies on floristic data collection in Angola, *Adansonia digitata* is referred to as vulnerable (Costa et al., 2009).

In 2018, with the publication of the Angola Red List, the baobab was again placed in this category (Executive Decree No. 252/2018). In the commune of Catengue, the baobab grows naturally, taking advantage of the abundant ecological resources in the region, essentially the climate and soil, as well as its pollinating agents. Given its high utility for the local population, from its fruit, leaves, stem, and beyond, it is considered a very important plant.

Given the spontaneous nature of the baobab stands in the Catengue region, municipality of Caimbambo, province of Benguela, and the absence of plant stand programmes oriented towards this species, there is increasing pressure on *Adansonia digitata* stands to obtain the pulp, whose commercial value is widely recognised.

Due to the pressure on *imbondeiro* (baobab tree, *Adansonia digitata*) population in the region, the following question arises: What is the level of vulnerability of *imbondeiro* in the commune of Catengue, municipality of

Caimbambo, province of Benguela, and which elements condition its sustainability?

## **CLASSIFICATION CATEGORIES**

For adequate sustainability, through legal norms, the Angolan Government and its partners established a List of Extinct, Threatened with Extinction, Vulnerable, and Invasive Fauna and Flora Species of Angola, designated the Angola Red List of Species (Ministério do Ambiente, 2018).

**Categories: The List comprises four categories: A, B, C and D.**

**Category A:** Extinct Species (Ex): When the species has a history of natural occurrence in Angola and is considered extinct or has never been seen again in its habitat.

**Category B:** Threatened with Extinction (T Ex): When various factors seriously threaten its existence, hindering its reproduction or natural regeneration, bringing its populations below sustainable levels.

**Category C:** Vulnerable Species (Vul): When human activities threaten its natural existence within the national territory.

**Category D:** Invasive Species (Inv.): When the species does not occur naturally or is introduced to a specific location within the national territory and becomes invasive, competing with or eliminating native species (Ministério do Ambiente, 2018).

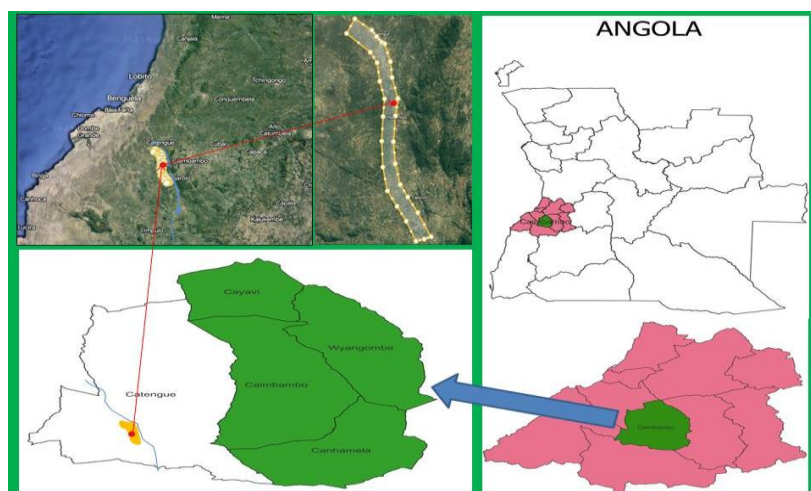
In this sense, the species *Adansonia digitata* appears in “Category C” of the aforementioned red list, being a vulnerable species, i.e., a taxon is considered vulnerable when the best available evidence indicates that the species faces a high risk of extinction in the wild (IUCN, 2002).

## **MATERIALS AND METHODS**

### **CHARACTERISATION OF THE STUDY AREA**

The present study was carried out in the commune of Catengue, municipality of Caimbambo, province of Benguela. The study area has an average altitude of 558m, with extreme geographical coordinates of 13° 01' 44" South and 13° 44' 13" East. It is located southeast of the municipality of Baía Farta, southwest of the municipal seat of Caimbambo, south of the municipality of Benguela, and

northwest of the municipal seat of Chongoroi. The commune of Catengue is 75 km from the city of Benguela, 30 km from the municipal seat of Caimbambo, and 75 km from the municipal seat of Chongoroi.



**Figure 1.**  
Representation of the study area (Source: Own elaboration).

It has an area of approximately 1,685 km<sup>2</sup> and its population is estimated at 19,480 inhabitants (2014 Census). It comprises 34 villages and 5 settlements.

## **SOCIO-ECONOMIC ASPECTS**

A large part of the population is engaged in agriculture and livestock farming, as the region has favourable edaphoclimatic conditions for agriculture and animal husbandry, and possesses gentle pastures. In recent years, people of **Mumuila** and **Mucubal** origin, coming from Huíla and, have immigrated to this region, taking advantage of the favourable natural conditions for livestock farming in the form of transhumance.

## **AGRICULTURE**

Agricultural activities use a production model based on extensive agriculture, relying on the intensive use of natural and industrial agricultural inputs to ensure production, producing diverse crops in different seasons of the year. Production is essentially aimed at self-consumption, with the surplus directed towards precarious commercialisation. The areas potentially promoting agriculture are the settlements of **Ningi Ningi**, **Mahumbulu**, and **Cábio**, as they are watered by the **Coporolo** and **Halu** rivers.

According to the Communal Administrator of Catengue, the Head of Section of the Agrarian Development Stations (EDA), and the leader of the traditional authorities (*regedor*), in interviews they stated that the main crops produced in this region are:

- Rainy season: Predominance of cereals such *massambala* and *massango* (*Sorghum ap.*), *maize* (*Zea mays*) and *beans* (*Phaseolus vulgaris*).
- Dry season: Predominance of vegetables such as *carrots* (*Daucus carota*), *tomatoes* (*Solanum lycopersicum*), *cabbages* (*Brassica oleracea*), *onions* (*Allium cepa*), *peppers* (*Capsicum annum*), *lettuce* (*Lactuca sativa*), *aubergines* (*Solanum melongena*), *watermelons* (*Citrullus lanatus*), among others.

The crops produced are intended exclusively for human consumption, and they do not produce pasture or fodder due to a lack of technical and financial means. Investment in pasture and fodder production is considered irrelevant as there are no profitable returns because the region's animals are low-yielding and are mostly native breeds, feeding only on natural pastures.

The crop fertilisation system uses cattle, goat, and sheep manure collected from stables and pens, as well as compound mineral fertilisers, mainly NPK 12-24-12, and simple minerals such as ammonium sulphate and urea. Mineral fertilisers are the most frequently used despite the high costs involved.

Crop intercropping is carried out irregularly, only with maize and beans, to make better use of the areas during regular rainfall periods.

## **CLIMATE, SOIL, AND VEGETATION**

The commune of Catengue has a dry steppe climate (BSh') with a maximum temperature ranging between 28 and 30°C and a minimum temperature between 16 and 18°C. It comprises two seasons during the year, dry and rainy, with an annual rainfall ranging between 400 and 600 mm (Diniz, 1998).

The soil is of the “lithosol and rocky terrain” type, poorly developed, on consolidated, slightly weathered rock at less than 15/20 cm depth, often with embedded stony material, distinguishing a more or less expressed A1 horizon, but not humiferous. Lithosols are frequently associated with rocky outcrops, and on the desert-like surface of the south-west, with “rocky terrains”, corresponding to large extensions of generally flattened relief where the rocky substrate is dominated by lithic materials of schistose nature (Diniz, 1998).

The vegetation comprises dense thicket and wooded savanna. Dense forests predominate, especially in the strips in contact with the relief that mark the sub-plateau contour, alongside wooded savanna formations, with the baobab (*Adansonia digitata*) being the notable tree element common to both formations (Diniz, 1998).

## **METHODOLOGICAL ASPECTS**

Initially, a literature review was conducted on the content related to the theme under study, along with appropriate theoretical grounding and consolidation of the defined premises. Through this process, it was possible to understand the ecology of the baobab tree (*Adansonia digitata*) as well as its nutritional value. Subsequently, a survey of information relating to the population’s customary habits and the conduct of their subsistence activities was carried out, using structured interviews with the Communal Administrator of Catengue, the Section Chief of the Agricultural Development Stations (EDA), and the leader of the traditional authorities (*regedor*). Afterwards, plots were installed, which enabled the establishment of sampling units distributed across the study area, thus allowing for a representative sample of the individuals under study (Duringan, 2023).

## **MATERIALS USED**

For data collection and field processing, the following equipment/materials and software were used:

### **ELECTRONIC EQUIPMENT AND SOFTWARE**

- Garmin eTrex GPS, used for surveying geographical coordinates for mapping the locality as well as the points of the demarcated plots;

- QGIS Qt Designer with QGIS 3.22.7 custom widgets and Google Earth Pro software, which enabled the production of the study area location maps;
- Excel from the Microsoft Office 2013 package, which allowed the construction of bar and scatter graphs and the calculation of the similarity index and phytosociological parameters.

### **NON-ELECTRONIC EQUIPMENT**

- 12 cm nails, which facilitated the demarcation of the plots by fixing the ropes when delimiting the area;
- Measuring tape, used to measure the side distances of the demarcated plots as well as the Circumference at Breast Height (CBH);
- Rope, used to better delimit the plots and determine which plants were inside or outside the plots.

Plot marking served as a method for sampling baobab plants, being one of the most used methods in vegetation surveys. The plot method consists of establishing field sampling units distributed throughout the study area, thus enabling a representation of the individuals under study (Duringan, 2023).

### **SAMPLING TECHNIQUES**

Methodology is the application of procedures and techniques aimed at constructing knowledge about a given reality or subject; the method represents the path, the way of approaching the procedures and techniques applied (Prodonov & Freitas, 2013; Kleina & Rodrigues, 2014).

For this study, descriptive, qualitative, and quantitative research and interviews were conducted, as the real situation of the region, the local population, their habits and customs, and the importance of *Adansonia digitata* for the local community were described.

A general observation of the native vegetation was also made, as well as its distribution and variation along the data collection route, and the variation of soil types in different points of the study area to better relate to the data collected through the plots.

Twenty plots were installed, 10 of which were placed at a distance of 100 metres from the EN-105 highway, separated from each other by approximately 3 km, thus fulfilling the systematic probabilistic sampling method (Anabela & Carla, 2019), and another 10 were installed at a distance of 1.5 km from the EN-105, separated from each other by approximately 3 km.

Subsequently, 10 plots were installed randomly further into the forest (3 km), using the random probabilistic sampling method (Anabela & Carla, 2019), making a total of 30 plots of 1 ha each.

### **PLOT MARKING**

For plot marking, a tape measure was used to measure the side distances of the plots, 100 m for each side, forming a square with an area equivalent to 1 ha per plot. After measuring, the area was marked with rope to delimit each plot. Following demarcation, the baobab plants in the plot were counted. Plot marking was carried out to facilitate a detailed visualisation of the baobab's phytosociology.



**Figure 1.**  
Demonstration of plot demarcation (Photo: Euclides Quessongo)

### **PHYTOSOCIOLOGICAL PARAMETERS**

Phytosociology is an area related to methods of recognising and defining plant communities. Phytosociological parameters are the indices or indicators used to characterise the structure of a plant community. This structure refers to the arrangement, organisation, and spatial distribution of individuals within the plant

community, both in terms of height (vertical structure) and density (horizontal structure) (Freitas & Magalhães, 2012).

Data on phytosociology allow the identification of threatened species, as well as decision-making on management actions for conservation purposes, among others (Felfili & Venturoli, 2000). Parameter calculations were performed in MS Excel, including: Frequency (F), Relative Frequency (RF), Absolute Frequency of the species (AF<sub>i</sub>), Absolute Density (AD), Relative Dominance (RDo), and Importance Value Index (IVI).

**Frequency** expresses the spatial distribution of each species in the area, indicating the number of sampling units in which a species occurs relative to the total number of sampling units. It can be: Absolute Frequency (AF): indicates the percentage (or proportion) of occurrence of a species in a given area, calculated by the formula:

$$AF = \frac{p_i}{P} * 100$$

$p_i$  = number of plots (sampling units) with occurrence of species  $i$ ;  $P$  = total number of plots (sampling units) in the sample.

**Relative Frequency (RF)** is the ratio between the absolute frequency of a given species and the sum of the absolute frequencies of all species.

$$RF = \frac{AF_i}{\sum AF} * 100$$

**AF<sub>i</sub>** = Absolute frequency of species  $i$ ,  **$\sum AF$**  = sum of absolute frequencies of all sampled species.

Frequency provides some information about species dispersal. Species with a high number of individuals may have low frequency values due to their individuals being clustered, while other species may have 100% frequency because their individuals are distributed across all sampled plots.

**Density:** expresses the participation of different species within the plant association. It can be: **Absolute Density (AD):** indicates the number of individuals of a species per unit area, usually per hectare (ha).

$$AD = \frac{n}{Area}$$

**Relative Dominance (RDo):** represents the percentage of the basal area of a given species ( $g_i$ ) in relation to the basal area of all sampled species ( $G$ ), the sum of the individual basal areas, both calculated per unit area ( $G = \sum g_i$ ).

$$RDo = (g_i/G) * 100$$

Dominance can be defined as the projection of the basal area onto the soil surface, thus providing a more effective measure of biomass than simply the number of individuals.

**Importance Value Index (IVI):** is the index that characterises the importance of each species in the community (from a horizontal perspective), bringing together the analysis criteria of the three parameters (RD, RF, RDo). It is the sum of the relative density, relative frequency, and relative dominance of each species in the plant association.

$$IVI = RD + RF + RDo$$

Theoretically, the most important species in terms of IVI is the one that shows the greatest success in exploiting the resources of its habitat. From the calculations and analyses performed for each parameter, it can be understood that adult baobab plants have a greater number of individuals represented in the study area, higher relative density, higher relative dominance, higher absolute frequency, higher relative frequency, and higher importance value index.

To verify the similarity index between Adult and Young plants, the Sorensen-Dice calculation, or data coefficient, was used, which is a statistical test to measure the similarity and diversity of a sample set.

**Table No. 1.**  
Phytosociological parameters

	<b>Total No. of plants</b>	<b>Relative Density</b>	<b>Relative Dominance</b>	<b>Absolute Frequency</b>	<b>Relative Frequency</b>	<b>IVI</b>
<b>AP</b>	505	51.79487	64.16773	93.33333	56	171.9626
<b>YP</b>	470	48.20513	35.83227	73.33333	44	128.0374
<b>Total</b>	975	100	100	166.6667	100	300

## SIMILARITY

The similarity index is a measure that objectively presents the level of similarity between two or more communities (Scolforo et al., 2008).

To estimate the degree of similarity between the two categories (Young and Adult) and in the composition of the sampled individuals, the Sorensen-Dice similarity index (CS) was used, defined by the presence or absence of baobab individuals as well as their abundance in the study area. The Similarity Index ranges from 0 to 100, being maximum when all categories are common and minimum when there are no common species.

$$CS = \frac{2c}{a+b}$$

Figure 3.  
Sorensen-Dice Similarity Coefficient Formula

- **CS**= Sorensen-Dice Similarity Coefficient
- **a**= AP (Adult Plants)
- **b**= YP (Young Plants)
- **c**= AP and YP

**Table No. 2.**  
Sorensen-Dice Similarity Index (CS)

	Occurrence	Total sampled plots
<b>AP</b>	28	30
<b>YP</b>	22	30
<b>AP and YP</b>	20	30
<b>Sorensen-Dice Index</b>	70%	

The result obtained in the similarity calculation between the sampled individuals was 70%. That is, most of the installed plots contain both adult and young individuals. In this sense, the result shows that the level of similarity between

young and adult plants is high, as 30% corresponds to the plots that contain only adult individuals.

## **RESULTS AND DISCUSSION**

It was confirmed that the premature harvesting of baobab fruits and the felling of young plants near inhabited and cultivated areas have become common practices by the population, and the excess of these practices will henceforth contribute to the vulnerability of this species as well as its extinction. However, this is one of the aspects causing its vulnerability.

The results from the plots were obtained based on the number of baobab individuals each plot contained. Along the route, individuals of different statures were identified, and therefore, it was necessary to record and fit each individual into the parameters defined during data collection. However, it was necessary to install sample plots, which are delimited areas within the forest that represent the characteristics of the study area (Joaquim, 2018).

When counting the number of baobab individuals in each plot, two categories of baobab plants were defined: “Adult Plants or AP”, which are those whose diameter at breast height (DBH) was greater than 15 cm, and “Young Plants or YP”, which are those whose diameter at breast height (DBH) was equal to or less than 15 cm. These categories were defined due to the partial distribution of baobabs with different statures. Plants with a DBH of less than 15 cm did not have the capacity for reproduction, whereas plants with a DBH greater than 15 cm already showed reproductive signs, i.e., capsules, flowers, and/or fruits, meaning they had sufficient stature and the capacity to produce fruit and consequently the capacity for reproduction. Regarding the reproductive age of the baobab, trees typically begin to flower when they are 8 to 23 years old (Amin, 1990; Sidibé & Williams, 2002; Bosch et al., 2004; Sacande et al., 2006).



**Figure 4.**  
Measuring the circumference of the baobab (Photo: Euclides Quessongo)

To calculate the DBH of the plants, it was necessary to first measure their circumference, and then this value was divided by 3.14, the value of “Pi”, according to the formula below:

$$DAP = \frac{CAP}{\pi}$$

The main growth stages observed during the training period were:

- **Regeneration phase or seedlings:** Plants with a diameter of less than 10 cm.
- **Young Plants:** Plants with a diameter between 10 and 15 cm.
- **Adult Plants:** Plants with a DBH greater than 15 cm.

In these classes, during data collection, plants in the regeneration phase or seedlings were recorded as young plants.

**Table 3.**

Number of individuals recorded in each plot

Systematic Plot I			Systematic Plot II			Random Plot III		
Plot No.	AP	YP	Plot No.	AP	YP	Plot No.	AP	YP
I-1	32	9	II-1	36	12	III-1	6	38
I-2	28	3	II-2	58	17	III-2	8	41
I-3	17		II-3	18	15	III-3	3	22

<b>I-4</b>	13	<b>II-4</b>	14	20	<b>III-4</b>	7	26
<b>I-5</b>	54	<b>II-5</b>	26	7	<b>III-5</b>		32
<b>I-6</b>	46	<b>II-6</b>	8	14	<b>III-6</b>		28
<b>I-7</b>	16	<b>II-7</b>	12	18	<b>III-7</b>	4	32
<b>I-8</b>	10	<b>II-8</b>	13	10	<b>III-8</b>	8	29
<b>I-9</b>	13	<b>II-9</b>	9	15	<b>III-9</b>	8	36
<b>I-10</b>	10	<b>II-10</b>	11	17	<b>III-10</b>	17	29

### Table Legend

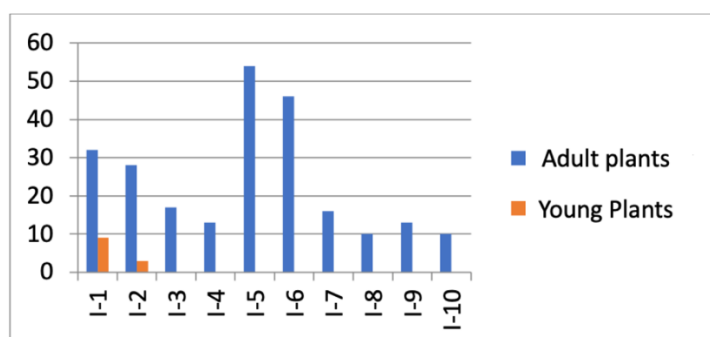
- **AP:** Adult Plants
- **YP:** Young Plants
- **Plot No.:** Plot Number

### ANALYSIS AND DISCUSSION

The results were analysed based on the number of individuals per 1-hectare area as well as their distribution throughout the study area.

It was necessary to observe factors such as human pressure on native vegetation, such as deforestation for agricultural production purposes, charcoal and firewood production, human settlement, and the expansion of their housing areas (Niza & Ana, 2019). However, the expansion of occupation areas for agricultural production and human habitation purposes constitute the main factors that most degrade baobab habitats in the commune of Catengue.

Thus, the data obtained from the plots and their distribution are presented in the following graphs:



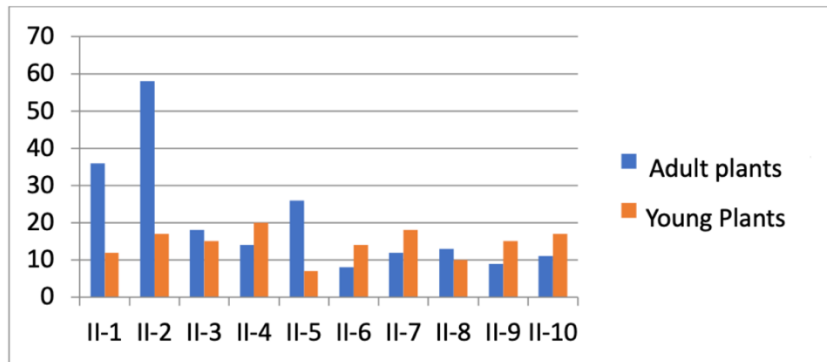
**Graph 1.**

Distribution of the baobab population in the 10 plots of systematic plot "I"

The plots of systematic plot “I” were marked at a distance of 100 metres from National Highway No. 105, separated from each other by approximately 3 km from East to West. The graph above demonstrates that along this route, adult plants are distributed more frequently, whereas young plants appear less frequently. This difference was due to the fact that young plants are frequently felled because they are more tender and easier to cut down, precisely to make way for agricultural land, mostly rain-fed agriculture. The felling rate of adult plants is lower as it is more laborious; therefore, deforestation around them, fires, and other activities gradually alter the micro-habitats, slowly deteriorating them and thus reducing their useful lifespan. These results were also confirmed by studies carried out in other regions of Angola where the process of constantly felling baobabs to make way for human habitations, agriculture, and industrial parks was verified (Bonifácio & Henkes, 2012).

The young plants recorded in plots I-1 and I-2 persist because they are located in an area uninhabited by the human population and in a zone with sandy, poorly developed soils where agriculture is unfavourable. For these reasons, they grow without disturbance, and there are indications that if there is no anthropogenic action interfering with the natural state of this micro-region, the number of baobabs could increase, thus ensuring natural wealth or biodiversity. Birhane et al. (2020) confirm this result, considering that the increasing rate and intensification of land use by humans lead to the vulnerability of trees in forests, whereas the absence of any forest disturbance stimulates tree development and the sustainability of native forests.

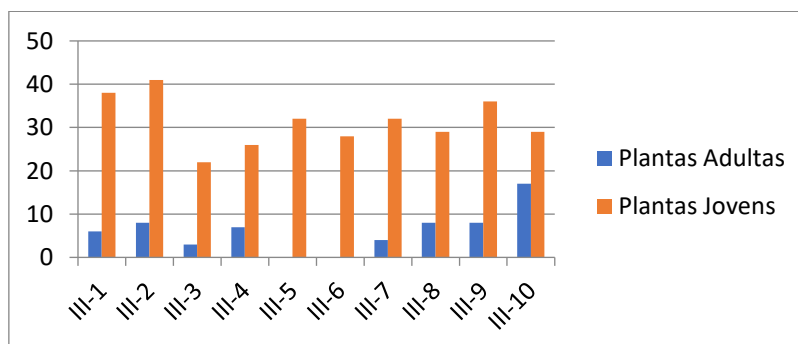
The graph also demonstrates that the number of baobabs decreases with altitude, despite some fluctuation with the records from plots I-5 and I-6. These plots are located in a micro-region where the microclimate differs from the other plots. This is a micro-region with a certain degree of depression where the air temperature is cooler and air pressure is higher. The geological formation consists of granites, soils with a reddish colour, sandy texture, and low compactness. These characteristics significantly favour the good development of the baobab.



**Graph 2.**

Distribution of the baobab population in the plots of systematic plot "II"

The plots of systematic plot "II" were marked at a distance of 1.5 km from the EN-105 highway, separated from each other by approximately 3 km from East to West. Unlike systematic plot "I", the plots of systematic plot "II" show an almost equitable distribution between young and adult plants, although there is a slight difference in plots II-1 and II-2 as they have a high number of adult plants. As in type "I" plots, in general, the number of the adult plant population decreases with altitude. In this regard, the number of young plants increased significantly. Several elements may be involved, including the microclimate transition zone in which they are installed, the more open vegetation compared to plot "I" which is at a higher altitude, where air pressure and temperature are lower compared to the micro-regions of plot "II", more grasses, and fewer prickly pears (*Opuntia stricta*) and shrubs. In this micro-region, there is constant renewal of the baobab. These are also referenced by Birhane *et al.* (2020), who confirm that the impacts of climate change entail the vulnerability or diffusion of valuable trees that provide non-timber forest products, favouring the emergence of other vegetation.

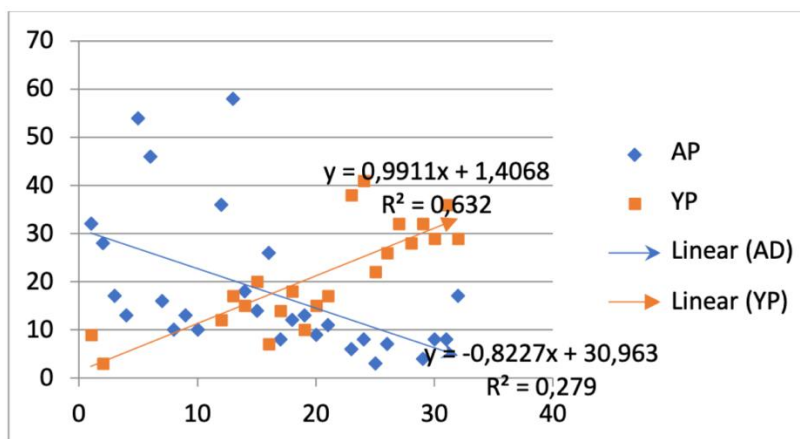


**Graph 3.** Distribution of the baobab population in the plots of random plot

The random pilot sampling plots 'III' were randomly marked slightly further into the forest interior (3 km from EN-105), using the random probabilistic sampling method (Anabela & Carla, 2019). These plots were separated from one another from East to West. The results of the present graph demonstrate the inverse of the results from plots 'I', and the records show, in their majority, young plants. During observation, these results were attributed to several reasons, among which we highlight the following:

As this is a climatic transition zone from West to East, the air temperature is higher, the vegetation is less dense, in May the soil moisture is lower, the soils are more sandy-clayey with fewer smaller rocks, the felling rate of young plants is reduced, and there is no pressure from human settlements for residential purposes or agricultural production, despite being a natural grazing area for cattle, goats, and sheep. In conclusion, this is a zone where constant baobab tree regeneration is recorded. This result is corroborated by the studies of Birhane et al. (2020) and Bonifácio and Henkes (2012), confirming that human disturbances and climate changes influence the reduction or dissemination of the baobab tree.

The intensive harvesting of baobab tree leaves, branches, and bark, combined with the lack of conservation practices indicated by local communities, together with the risk of local extinction under climate change, constitute serious threats to this species in the commune of Catengue. This is corroborated by the study conducted by Birhane et al. (2020), which, after a climate change simulation using the Maximum Entropy Algorithm (Maxent), revealed that increased temperature and anthropogenic actions would lead to the destruction of the baobab tree habitat as well as its significant reduction in forests.



**Graph 4.**  
Correlation analysis between the plots

The graph above presents the correlation between baobab plants in the study area. It shows that the correlation is linear for both categories, Young and Adult, although there is a significant difference in their distribution. This is proven by the “p” value, which is less than 0.05.

Although the value of  $r^2$  (coefficient of determination) is not close to or equal to 1, the correlation trend line shows an increase in the number of young plants from West to East. However, the value of  $r^2 = 0.632$  is justified for assessing the distribution of young plants in the study area.

Similarly, the correlation trend line for adult plants shows an increase or even clustering of adult plants from North to South, and they decrease from East to West and also decrease with increasing altitude. The value of  $r^2 = 0.279$  is justified for assessing the distribution levels of adult plants in the study area.

The graph also shows that in plot II there is a higher incidence of young plants compared to the other plots, although in plot III there is a considerable separation of young and adult plants, isolated from each other. Being a climate transition zone from West to East, the temperature tends to increase as the vegetation becomes scarcer, and the soils are sandy-clayey with few rocks.

## CONCLUSIONS

This study aimed to characterise the baobab stand and assess the level of vulnerability of the baobab in the commune of Catengue, municipality of

**Caimbambo**, province of Benguela. Based on the results obtained, we are led to conclude that:

The number of baobab individuals decreases with increasing altitude, and the similarity index demonstrated that adult plants predominate in the baobab stand at the study area level, having higher occurrences in the installed plots, in addition to presenting a larger basal area and a higher number of individuals. Young plants decrease mainly from West to East, influenced by climatic conditions and the expansion of human settlements, having a lower occurrence compared to adult plants in the installed plots.

The study evidenced that the increase in the local population, the encouragement to expand inhabited areas, the need to carry out their economic activities, such as the expansion of cultivation areas and uncontrolled logging, contribute to the destruction of the baobab's habitat, gradually worsening its level of vulnerability and conditioning its sustainability.

Therefore, the baobab in the commune of **Catengue** is in a vulnerable state, precisely because it is in conditions of extreme insecurity, including anthropogenic actions.

Although the baobab constitutes an important element in the Angolan flora and has socio-cultural and economic importance, a great scarcity of scientific information about its development and uses in the country is observed. This fact suggests the need to develop further studies on the ecology of the species in the ecosystems where it is found, especially in the coastal and south-central region of Angola.

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