# EVALUATION OF THE FIXED POPULATION OF ZANTHOXYLUM ZANTHOXYLOIDES (LAM.) ZEPERNICK & TIMLER ALONG THE CLIMATE VARIATION IN BENIN (WEST AFRICA)


## ABSTRACT

*Z. zanthoxyloïdes is a versatile plant that serves multiple purposes. Consequently, it faces significant user demand in Benin. The present investigation evaluated the abundance of this species and conducted an ecological analysis of the existing habitats that sustain its growth. The inventory of Z. zanthoxyloïdes was carried out in 120 square 50 m x 50 m plots on mega-transets in the Lama, Wari-Maro and N'Dali classified forests and fallows that surround them.The results show that adult individuals are almost absent in fallow land and are found in natural forests (P< 0.05). As for juveniles, they are found in both natural forests and fallow.. The distributions of the diameter classes showed a good fit with the Weibull distribution .The density of Z. zanthoxyloïdes adult trees is greater in the Lama Classified Forest compared to the other two. The study reported that fallows currently contain more young individuals than natural forests. The confirmation of the species' vulnerability aligns with the previous report from the Benin Red List. Consequently, undertaking measures to support its natural rejuvenation becomes imperative in order to preserve the species for both current and future generations.*



***Key words***: *Z. zanthoxyloïdes*, abundance, density, fallow, protected areas


## INTRODUCTION

In several developing countries, Non-Timber Forest Products (NTFPs) refer to the products derived from forests that are not timber such as fruits, nuts, honey , medicinal plants and other forest-based products**[1]**. Products (NTFPs),have traditionally been an important source of income and livelihood for many people living in and around forests, particularly in developing countries**[2]**. However, due to various factors like deforestation, climate change and lack of proper management, NTFPs have often been underutilized and undervalued. **[3]** It was from 1995 that the need to domesticate them to increase the well-being of local populations became a major concern **[4]**. The data concerning non-timber forest resources is most often qualitative and does not bring out the quantitative data necessary to demonstrate economic opportunities or for social development and environmental management**[5]**. Among these NTFPs is *Z. zanthoxyloides*, which is a multi-purpose species. It is a plant on Benin's red list in the category of vulnerable species**[6]**.The roots of this plant are in high demand in Benin and are even exported to other countries **[7]**.

To this end, it deserves special attention for the implementation of conservation and domestication strategies in a context of climate change**[8]**. Numerous efforts have been carried out to contribute to the enhancement of *Z. zanthoxyloides*species in the sub-region. However, most studies on *Z. zanthoxyloides* plant have only focused on its pharmaceutical value**[9]**. Admittedly, a fewauthors, in this case **[6], [10]** and [11]have addressed its ethnobotanical and ecological aspects, but it shouldbe noted that the aspects of abundance and population structure have not been elucidated. This study addressed both aspects in order to have the scientific data to help make conservation decisions to ensure its sustainable use in Benin. Knowledge of the species' population structure is essential because it makes it possible to measure anthropogenic pressures on population dynamics**[12]** and is a crucial step in defining a conservation and sustainable management strategy for a species **[13]**. Those related to *Z. zanthoxyloides* populations in Benin in general are not yet documented. In terms of the abundance of the species, its knowledge is useful in explaining how it is influenced by environmental conditions and anthropogenic pressures**[14]**. Thus, abundance is one of the very first pieces of information in the evaluation of the potential and availability of species (Avocevou-Ayisso, 2011)**[15]**. The present study, which has documented the abundance of *Z.zanthoxyloides* in the different climatic zones, allow us to better appreciate the occurrence, the level of availability, and the challenges they face. Consequently, these findings enabled us to proposeconservation action and sustainable exploitation. By doing so, the species will be conserved for current and future generations.

## MATERIAL AND METHODS

### 1-Description of the species

*Z. zanthoxyloides*, which belongs to the Rutaceae family, is a shrub that can reach a height of 6 to 7 meters**[16]**. The twigs of *Z. zanthoxyloides* are very armed with very curved and sharp prickles, claw-shaped, small or up to 1 meter long**[17]**. The rachis of *Z. zanthoxyloides*and sometimes the midrib bear large curved spines**[18]**. The leaves of *Z. zanthoxyloides***(photo 1)** are alternate, compound and imparipinnate with a petiole of 2 to 5 cm of rachis more or less cylindrical or flattened. The stems are in the form of cylindrical fragments 3 to 5 cm in diameter**[19]**. **(photo 2)**.

**Photo1.** Leafy branch of *Z. zanthoxyloïdes*

**2-Field Tools**

The study has utilized various materials, including of a penta decameter for the delimitation of the squares**[20]**; fluorescent strip for marking square boundaries, cutting tools for opening sills and creating corner stakes**[21]**, pruning shears for collecting samples**[22]**, pi tape for measuring tree diameters**[23]**, GPS for georeferencing **[24]***Z. zanthoxyloïdes* locations, and a map of Benin's protected areas.

**3- Study environment**

The study site consists of the Classified Forests of the Lama, Wari – Maro and N'Dali as shown in Figure1 at the bottom **(Photo1).**

The Classified Forest of the Lama located in Benin in Guinean zone which cover approximately 4000 miles hectares**[25]**. This particular forest is known for its rich biodiversity, housing several endangered species such as the white parrot, the pangolin, and the West African manatee**[26]**. The Classified Forest of the Lama plays a vital role in regulating the country's climate, maintaining water quality, and providing essential ecosystem services to local communities**[27]**. However, like the rest of the Classified Forest of the Lama, this forest also faces significant threats like deforestation, poaching, and encroachment by agricultural activities, emphasizing the need for effective conservation efforts to preserve it for future generations**[28]**.

The Wari-Maro Classified Forest, is located in Zone Soudano – Guinean in Benin. It is a protected area because of its exceptional biodiversity**[29]**. It is home to many plant and animal species, including primates and rare birds, making it a crucial habitat for

conservation**[30]**. This forest also plays an important role in regulating the local climate and protecting the soil. In addition to its ecological values, it is an essential resource for surrounding communities, who depend on its resources for their livelihoods**[31]**.

The N'dali Classified Forest, is located in Soudano zone in Benin, is a protected area that plays a vital role in conservation and is home to a variety of animal and plant species, some of which are threatened, thereby contributing to the balance of local ecosystems**[32]**. In addition to its ecological wealth, this forest is essential to surrounding communities, providing resources such as timber and medicinal plants**[33]**. The preservation of the N'dali Classified Forest is crucial for environmental sustainability and the well-being of local populations**[34]**.

In the future, the coordination of Classified Forests of the Lama, Wari-Maro, and N'dali in Benin could involve the development of a comprehensive management plan that integrates the conservation of biodiversity, sustainable use of forest resources, and the well-being of local communities. This plan could include joint patrols and surveillance activities to prevent deforestation, poaching, and encroachment by agricultural activities, as well as capacity-building initiatives for local communities to promote sustainable livelihoods and forest stewardship.

**Photo2.** Stem of *Z. zanthoxyloides*

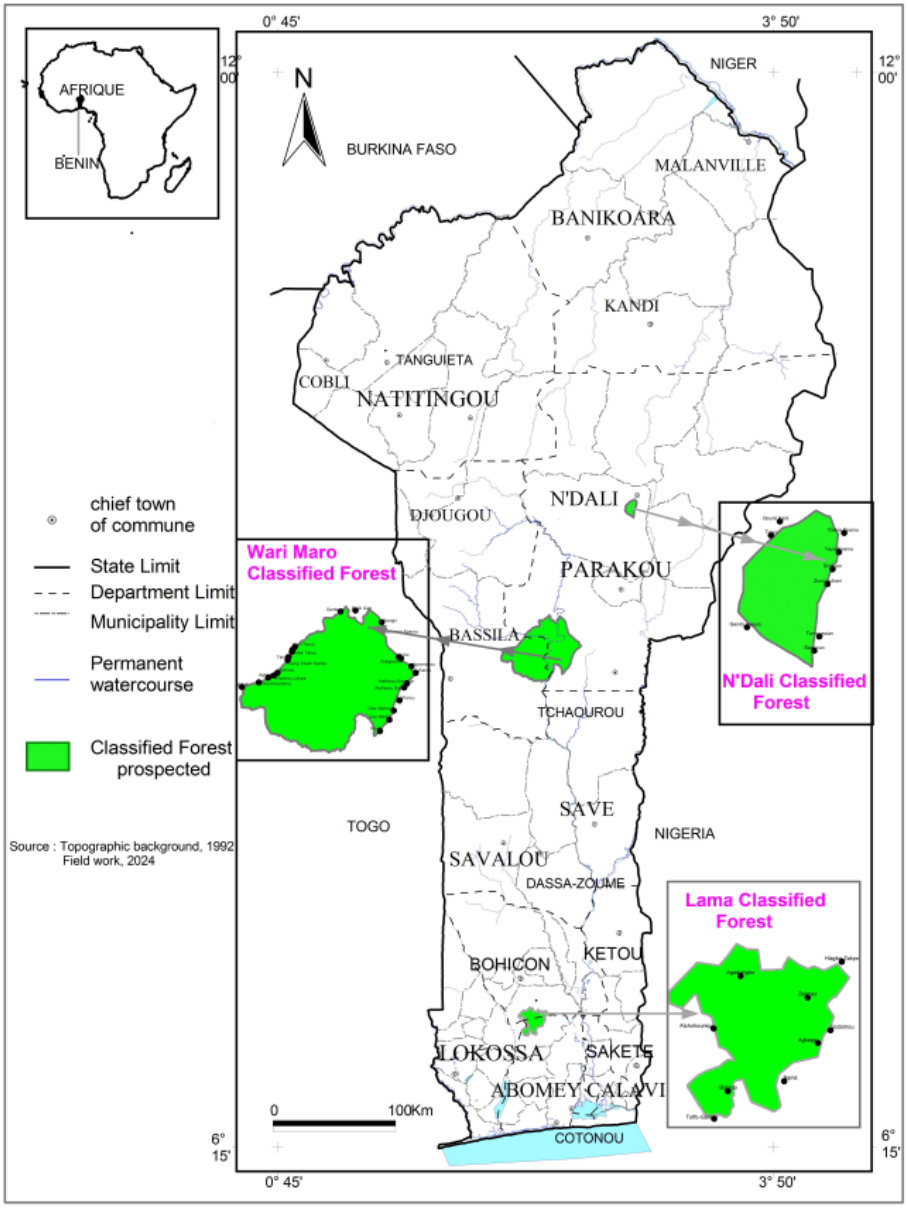



**Figure 1** : A map displaying the three classified forests within Benin's protected areas.

**3-Sampling data collection**

The selection of its habitats was made in a reasoned way, taking into account the forests classified in each climatic zone**[35]**. The Lama Classified Forest in the Guinean zone, the Wari-Maro Forest in the Sudano-Guinean transition zone and the N'Dali Classified Forest in the Sudanian zone were chosen for the the study of the *Z. zanthoxyloides* because they are known to be areas with high biodiversity and endemism in Benin**[36]**. These forests are home to a variety of plant species, including the *Z. zanthoxyloides,* which is used for medcinal purposes by local communities.**[37]**

The sub-equatorial zone in Benin, has four seasons and extends from the coast to the latitude of Dan north of Abomey**[38]**. It experiences 250 days of rain divided into two parts: the first, the longest from March until the end of July and the second from September to mid-November**[39]**.

The Sudano-Guinean zone in Benin experiences two distinct seasons, a rainy season and a dry season. , and is located in the center of the country with 200 days of rain concentrated in the period between April and October**[40]**. It extends from the latitude of Dan to that of Savè. On the other hand, the Sudanian-type zone, located from the latitude of Parakou to the entire northern region of the country, also has two seasons, a rainy season and a dry season. However, it receives around 145 days of rainfall**[41]**.

At the level of each habitat, the prospecting effort was determined through the number of plots to be installed by means of the formula of (Dagnelie, 1998)**[42]** :

$$N = \frac{U^2_{1-\alpha/2}(CV^2)}{d^2}$$

*N*, Sample size was determined by vegetation,

$U^2_{1-\alpha/2}$=1.96 ;

*CV* = coefficient of variation.

The coefficient of variation was therefore calculated by Classified Forest and d is the margin of error (*d*=10 pour cent).

Thus, the number of places is as shown in Table1 below.

These plots were also installed randomly by following mega-transects oriented from south to north. These are the 50 m x 50 m (2500 $m^2$) plots indicated for structural analysis in dense forest (Salako et al. 2013). In tropical formations, it is more practical to utilize square or rectangular plots, as suggested by (Van Laar&Akça, 2007)**[43]**. In each plot, all

*Z.zanthoxyloides* individuals were counted and the diametric measurement was made at the level of individuals with a dbh ≥10 cm. Table1 shows the distribution of plots by forest and climate zone.

**Table 1:** Distribution of plots by Classified Forest and by climatic zone

| **Climatic Zones** | **Natural Formations** | **Fallow** | **Total** |
|---|---|---|---|
| Guinean zone (Classified Lama Forest) | 60 | 19 | 79 |
| Sudano-Guinean zone (Classified Forest of Wari - Maro) | 20 | 7 | 27 |
| Sudanian Zone (N'Dalie Classified Forest) | 10 | 4 | 14 |
| **Total** | **90** | **30** | **120** |

To focus on anthropogenic pressures and destruction of *Z. zanthoxyloides* populations, we based on the literature review.

**C-Data processing**

The data collectedwere entered into the Excel spreadsheet and several ecological and dendrometric parameters were calculated:

- **Scarcity index (***species rarity weight richness index***)**

The rare status of the species was determined by the rarefaction index calculated according to the following equation: Ri = (1- ni/N) with Ri: rarefaction index of species i, ni: number of places where species i is found and N: total number of places in the formation.**[44]**

Taking into account this relationship, if the scarcity index is less than 80%, the species is considered preferential, very frequent and abundant in the areas studied. Although the rarefaction index is more than 80%, the species is rare**[45]**. A 100% rarefaction index means that the presence of the species has not been observed anywhere in the areas studied. Thus, the latter is highly threatened with extinction in the region**[44]**.

**- Stand density**

N is the average number of mature trees (dbh ≥ 10 cm) per hectare. It is given by the formula:

$$N = \frac{n}{s}$$

*n*is the total number of trees per plot and s is the area of the plot in ha. In the case of the density of Z. zanthoxyloides plants, the area considered is equal to 1 ha.**[46]**.

**- Structural characterization** of *Z. zanthoxyloides*

*Z. zanthoxyloides* individuals were categorized into groups based on a 5 cm diameter. Thus, the densities of trees by diameter classes were determined. The densities of adults (dbh ≥ 15) and juveniles (10≤ dbh<15) are compared between the three Forests Classified within natural formations and fallow with the nonparametric Mann Whitney test because the data do not follow a normal distribution. The R software was utilized to perform this statistical analysis. The diameter distribution classes were fitted to the theoretical 3-parameter Weibull distribution (a, b and c) using the density function (f) expressed as a function of the diameter (x) according to the formula :

$$f(x) = \frac{c}{b}\left(\frac{a-b}{b}\right)^{c-1} exp\left[-\left(\frac{x-a}{b}\right)^{c}\right]$$

where: b= scale or size parameter; a=position parameter; c= shape parameter. The threshold of the parameter a was considered with a=10cm to adjust the class size of the species. The analysis was done in R using the packages (Mass, Survival and Fitdistrplus) to test the observed distribution compared to that of Weibull.

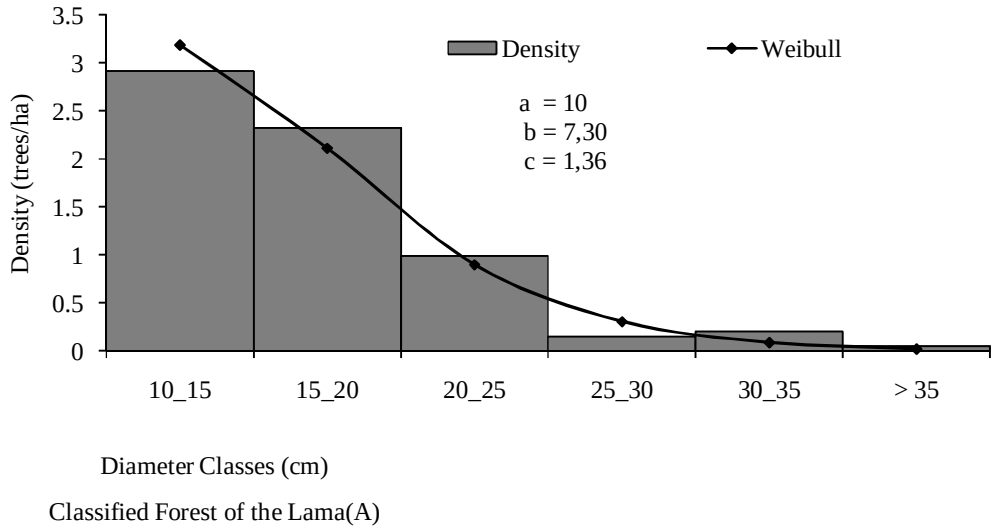
## RESULTS

**Abundance** of *Z. zanthoxyloides*

**Table 2**: Densities and Indices of *Z. zanthoxyloides* scarcity by climatic zone and by forest studied.

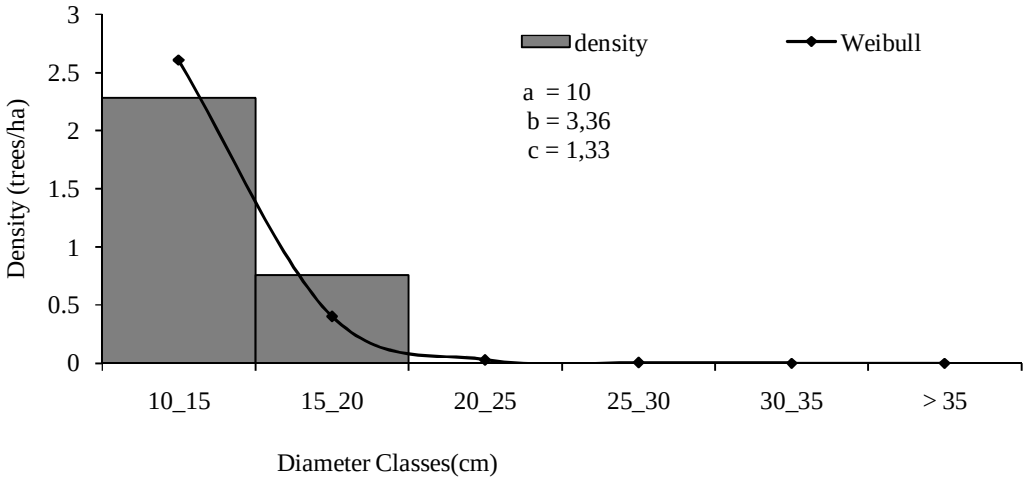
| (Climate Zone) | (Densities :pieds/ha) | (Rarefaction Indices) |
|---|---|---|
| Guinean (Classified Lama Forest) | 1,2 | RI<80% |
| Sudano-Guinean (Wari-Maro Classified Forest) | 0,24 | RI>80% |
| **Sudanian (N'Dali Classified Forest)** | **0,1** | **RI>80%** |

The density of *Z. zanthoxyloides* subjects decreases from the Guinean zone (FC de la Lama) to the Sudanian zone (FC de N'dali) and the scarcity index also shows that the species is abundant in the Guinean zone and increasingly rare as we evolve towards the Sudanian zone. The findings align closely with the research conducted by (Romain Glèlè Kakaï et al, 2011) **[47]**.who worked on the ecological adaptation of Vitellaria paradoxa along aclimatic gradient in Benin.It appears from tables 2 and 3 that adult individuals are almost absent in fallow land and are found in natural forests ($P< 0.05$). As for juveniles, they are found in both natural forests and fallow. The diameter structures of *Z. zanthoxyloides* in the two different plant formations of the Central Core of the Classified Lama Forest are shown in **Figure 2 and 3.**




Classified Forest of the Lama(A)

**Figure2** : Structure in diameter of *Z.zanthoxyloides* in the classified forest of the Lama (A)




Surrounding Fallow Lama(B)

**Figure 3** : Structure in diameter of *Z.zanthoxyloides* in the Surrounding Fallow Lama(B)

**Tableau 2 : Classified Forest of the Lama Data**

| Classes | x | ni | Frequencies | F(x ) | Densities observed | Weibull |
|---|---|---|---|---|---|---|
| 10_15 | 12,5 | 59 | 44,02985075 | 0,100378 | 2,913580247 | 3,18965511 |
| 15_20 | 17,5 | 47 | 35,07462687 | 0,066468 | 2,320987654 | 2,112116159 |
| 20_25 | 22,5 | 20 | 14,92537313 | 0,028287 | 0,987654321 | 0,89886005 |
| 25_30 | 27,5 | 3 | 2,23880597 | 0,009617 | 0,148148148 | 0,305593987 |
| 30_35 | 32,5 | 4 | 2,985074627 | 0,002785 | 0,197530864 | 0,088497375 |
| > 35 | 37,5 | 1 | 0,746268657 | 0,00071 | 0,049382716 | 0,02256127 |
| Total | | 134 | 100 | 0,208245 | | |

**Tableau 3 : Surrounding Fallow Land Data**

| Classes | X | ni | Frequencies | F(x ) | Densities observed | Weibull |
|---|---|---|---|---|---|---|
| 10_15 | 12,5 | 6 | 75 | 0,182658 | 2,279202279 | 2,608168362 |
| 15_20 | 17,5 | 2 | 25 | 0,028103 | 0,759734093 | 0,401281934 |
| 20_25 | 22,5 | 0 | 0 | 0,001975 | 0 | 0,028200969 |
| 25_30 | 27,5 | 0 | 0 | 0,000087 | 0 | 0,001242271 |
| 30_35 | 32,5 | 0 | 0 | 0,000003 | 0 | 4,28369E-05 |
| > 35 | 37,5 | 0 | 0 | 0 | 0 | 0 |
| Total | | 8 | 100 | 0,212826 | | |

In both habitats, the Weibull shape parameter (c) is between 1.33 and1.36. Hence, the distribution of individuals based on their diameter class generally exhibits a non-Gaussian pattern throughout and displays a leftward asymmetry (1.33 <c < 3.6)**[48]**.This asymmetry is characteristic of stands where young or small diameter individuals are relatively dominant**[49]**. Irrespective of the habitat type, the most abundant individuals are those with diameters ranging from 10 to 15 cm. In the natural formation, there are nearly 3 plants per hectare, whereas in fallow areas, the count exceeds 2 plants per hectare. In fallow land, the diameter of these plants rarely exceeds 20 cm, whereas in the forest, it can reach up to 35 cm. Furthermore, within the additional forests (Wari-Maro and N'dali), no *Z. zanthoxyloides* plants have been found. However, the investigations made it possible to find two isolated plants in a fallow land located in the district of Manigri, a locality not far from the classified forest of Wari-Maro.

## DISCUSSION

### Abundance of Z. zanthoxyloides

The findings of this research indicatedthat the density of *Z. zanthoxyloides*becomes rarer as the distance from the coast increases. This result is similar to that of Yaoitcha (2016)**[50]**, who showed that the species is less abundant in the most arid climates. A previous study had already mentioned that this species is threatened with extinction already at the height of Glazoué-Savè-Ouèssè, in the Sudano-Guinean zone**[51]**.It is therefore not surprising to report the information we have in this study on this species in the two climatic zones of Central and Northern Benin. The scarcity of adult plants in fallow land in the prospected areas could be explained by the anthropogenic pressure exerted on the species. Indeed, apart from its medicinal values**[52]** (Queiroz et al., 2006), the species is used for other purposes such as carbonization, wood energy and sculpture**[53].**.Bossokpi (2003)**[54]** had reported that Z. zanthoxyloides is a species of pre-forest savannahs and coastal thickets. Adesina (2005)**[55]** also reported in southwestern Nigeria that the species is more abundant in savannah and dry forest, so it would not have been otherwise at our study sites if adult plants were not regularly collected. The proof of this is that juvenile and young plants are fairly well represented in fallows, a sign that natural regeneration is occurring relatively well. Seedlings can establish and develop more effectively in fallow land where they have direct access to light.This means that fallow land and open plant formations therefore have a high conservation potential if specific management actions are carried out on this young population of the species **[56]**.

**Population structural characteristic of *Z. zanthoxyloides***

According to**figure 2 and 3**, the diameter distributions by plant formation at the Lama FC level generally show a non-normal distribution, indicating a deviation from a Gaussian appearance. This suggests that the regularity of the *Z. zanthoxyloides* structure is not guaranteed.This left asymmetry had been reported on different tropical species by various studies such as Cassou et al. (1997)**[57]** had reported on the African population of palm trees in Burkina Faso, Kperkouma et al. (2005)**[58]** on the Shea butter trees of Donfelgou in Togo, Bonouet al. (2009)**[59]** on the populations of Afzelia africana in Benin. Some authors have also noted that species with a bell-shaped distribution in small patches may might exhibit an inverted J-shape when the patches are larger **[60]** (Pulido *et al.*,200). The scale of a classified forest could therefore have played a role in the adjustment obtained with the Weibull distribution. The density function (f) of the diameter (x) required for the dendrometric study of the species is justified by its efficiency. According to (Bonou, 2009)**[59]**, the use of the Weibull distribution probability density function is becoming increasingly universal to model the diameter distributions of homogeneous and uneven-aged forest stands. In the case of the N'Dali Classified Forest, the absence of the species has been previously documented (Djagoun et al., 2010)**[62]** , mirroring observations in the Wari-Maro FC.

**CONCLUSION**

The distribution of *Z. zanthoxyloïdes* is limited to the Guinean zone of Benin and enjoys better protection in the Classified Lama Forest. The reduction in mature trees in fallow and anthropogenic areas highlights the need for development efforts to secure its present and future presence. Moreover, the successful propagation of cuttings by the authors suggests a promising approach. Nevertheless, additional research is necessary to create maps showing the historical and current distribution of this species for conservation planning.

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