



Research Article

Assessing *Adansonia*'s Species Abundance in Southern Yobe State, Nigeria: A Quadrat-Based Study Using Semi-Quantitative Abundance Ratings and Species-Area Curve Analysis

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This study investigated the abundance and distribution of *Adansonia* species in Yobe State, Northeastern Nigeria. A purposive sampling methodology was employed, dividing the study area into 20 quadrats of varying sizes (100x100m to 500x500m), determined by species-area relationships and graph plotting. Species identification and enumeration were conducted within each quadrat, yielding 791 trees. The results show that *Adansonia digitata* (775 individuals) and *Adansonia kilima* (16 individuals) are the only two species in the study quadrats area, consistent with previous studies suggesting their exclusive presence in sub-Saharan Africa. Frequency analysis revealed that *Adansonia digitata* exhibited a 100% presence in all 20, while *Adansonia kilima* had a 30% presence in 6 quadrats. The species-area curve demonstrated a positive relationship between quadrat size and tree abundance, indicating that larger areas support more species. This finding has important implications for conservation efforts, highlighting the need to protect larger areas to maintain biodiversity. The study's results contributed significantly to understanding *Adansonia* species diversity and abundance in Northeastern Nigeria. The findings provided valuable insights for conservation and management efforts, emphasizing the importance of protecting the remaining *Adansonia* species and their habitats. Furthermore, this study highlighted the need for continued research into the ecological and environmental factors that influence the abundance of *Adansonia* species. The study's methodology and findings have implications for developing effective conservation strategies for *Adansonia* species in Northeastern Nigeria. The results also contributed to the broader understanding of the diversity and abundance of *Adansonia* species in sub-Saharan Africa.

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INTRODUCTION

Species abundance, defined as the number of individuals of a species in a defined area or sample (Gotelli *et al.*, 2019), is a fundamental concept in ecology. It provides valuable insights into the frequency or rarity of a species compared to other species in a specific area or population (Magurran, 2013). Relative abundance, which refers to the percentage composition of an organism of a specific type about the total number of organisms in the region (Angelo *et al.*, 2016), is also a crucial aspect of species abundance. Various sampling techniques are employed to quantify species abundance, including plant cover, which is a prevalent method for evaluating the abundance of plant species in plant communities (Damgaard, 2009). However, species distributions are often skewed, with a small number of species comprising most of those collected (Verberk, 2011).

The African baobab (*Adansonia digitata*) is a tree species of great importance in the African savanna (Josephine *et al.*, 2022). However, there is a lack of information regarding its geographic distribution and abundance (Sithabile *et al.*, 2019). Plant ecology, a field of ecology that investigates the distribution and abundance of plants, is crucial in understanding the ecological viability of plant species (Wood *et al.*, 2012). The Species Abundance Distribution (SAD) is a primary application of species abundance measurement, quantifying a species' frequency or scarcity within a given environment (Baldrige *et al.*, 2016). Species evenness, which refers to the relative abundance of species or the similarity in species relative abundance within a community (Krebs, 1999), is another essential aspect of species abundance.

The distribution and abundance of plant species are typically modelled as functions of soil, relief, climate, humans, and animals (Gadiga, 2012). Clayton *et al.* (2013) conducted a study on the nutritional value of baobab fruit pulp, revealing its richness in vitamins, minerals, and antioxidants. The authors suggested that the fruit pulp could be a valuable supplement for addressing micronutrient deficiencies in developing countries. Other studies have highlighted the need for sustainable harvesting practices to ensure the long-term survival of

baobab trees. For instance, a study by Venter and Witkowski (2013) found that over-harvesting of baobab seeds and fruits can lead to reduced tree populations and decreased genetic diversity. Researchers have also explored the potential medicinal properties of *Adansonia digitata*. A study by Nour *et al.* (2018) investigated baobab extracts' antimicrobial and anti-inflammatory activities, revealing promising results. However, further studies are needed to understand the baobab tree's therapeutic potential fully. *Adansonia* is associated with tropical savannas and is not found in regions with dense sand but in arid climates susceptible to water logging and frost (Kempe *et al.*, 2018). Previous studies have investigated the structure and abundance of *Adansonia digitata* in various soil types (Clayton *et al.*, 2013). However, there is a lack of research on the abundance and distribution of *Adansonia* species in the study region. Furthermore, most research on baobab trees in Africa has focused on the plant's nutritional and therapeutic advantages rather than its distribution pattern and species abundance.

This study aims to address these research gaps by investigating the abundance and distribution of *Adansonia* species in Yobe State, Northeastern Nigeria. Specifically, the objectives of this study are to (1) assess the abundance of *Adansonia* species about their spatial distribution and habitat characteristics; (2) examine the distribution patterns of *Adansonia* species in the study area; and (3) analyze the species-area relationship and quadrat-based distribution of *Adansonia* species.

THE STUDY AREA

The study's locations are the latitudes of 11°00'00 " "N and 12°25'40" " N of the equator and the longitudes of 10°50'00E and 11°.50'00E of the Greenwich meridian. The Sahelization process is causing significant damage to the region, which is highly susceptible to desertification (Yahaya, 2018; Yahaya *et al.*, 2019). Significant investments have been made in cultivating trees to address the threat of desertification in the region. The overall geographical area of the research area is 8,695 km³. The ecosystem and way of life of the local population in the Sudano-Sahelian region of Nigeria, which encompasses the study area, are

endangered by desertification (UNESCO, 2000; UNDP, 2009; Orounye, 2009). The borders of Yobe State are the Niger Republic to the north, Borno State and Gombe to the south and the states of Jigawa and Bauchi to the west. It is home to a population of 2.7 million individuals who reside on 45,502 square kilometres of land, as per the 2006 National Census Population and Housing (NPC, 2007).

Regarding vegetation, the research region is situated in the Sudano-Sahelian Savannah tract. It is primarily composed of vegetation, with a few trees scattered throughout. Wattles (*Acacia spp.*), *Balanites aegyptiaca*, baobab (*Adansonia*), and doum palm (*Hyphaene thebaica*) are among the natural tree species that are frequently observed in the region. Alien tree species include *Eucalyptus camaldulensis*, *Prosopis Juliflora*, and Neem trees (*Azadirachta indica*) (Yahaya, 2023). The research territory is partitioned into two vegetation zones: the Sudan Savanna in the south and the Sahel in the north. The vegetation cover is minimal because the grass develops in small tufts, leaving barren surfaces. The grasses of the Sahel are tussocky and slender and stand at a height of 0.5 to 1.0 meters.

Scattered with dunes are the most common types. According to the Federal Ministry of Environment (2008), the *acacia* is a compact

tree with prickly foliage that is occasionally umbrella-shaped. The genuine vegetation of the Sahel Savanna ecosystem comprises a limited number of short grasses and stunted trees, with a height of 1.5 to 2.0 meters. Typical trees include baobab, silk cotton, doum palm, and *acacia*. Like a sponge, the baobab tree extracts water from its reservoir, which is situated in its trunk, during the arid season. Its crown is a dense, succulent stem that produces short, undersized branches. Long, upright branches characterize the doum palm's foliage and resemble a fan. The silk cotton tree is the highest in the genus, 9 to 15 meters in height. Pillows and mattresses are manufactured in the vicinity using silk cotton harvested from this tree.

Furthermore, the plant is employed for various medical and non-medical purposes. Currently, most of it is employed to produce mats, thatched roofing, and combustible wood. The ecosystem is presently at risk of desertification due to deforestation (Adesina & Gadiga, 2014). The federal (Shelterbelts), state, and municipal governments annually initiate tree-planting initiatives to revitalize the ecosystem. The research region is characterized by the presence of characteristic Sahelian vegetation, which indicates the type of vegetation that is present (Nigeria Geological Survey, 2016).

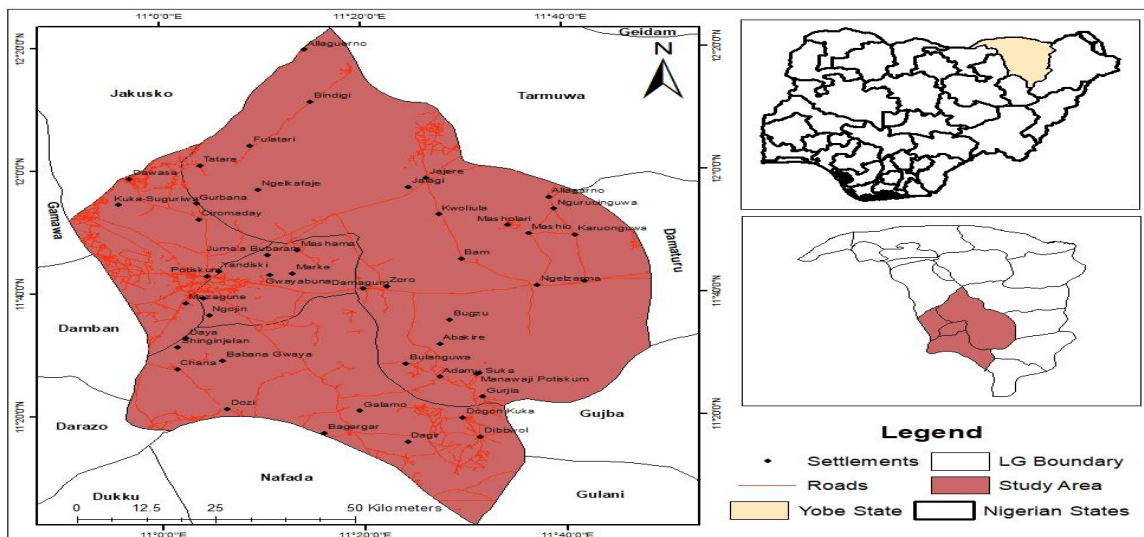


Figure 1: Yobe State, showing the study area
Source: Adopted from administrative map of Yobe State (2023).

METHODOLOGY

The study employed a quadrat-based sampling design, using purposive sampling to construct quadrats. The size of the quadrats varied, ranging from 100 by 100 meters to 500 by 500 meters, depending on the availability of *Adansonia* species in the area. This flexible quadrat size approach was deliberately chosen to accommodate the varying densities and spatial distributions of *Adansonia* species across the study area. By using larger quadrats (500x500 meters) in areas with low species density, the study aimed to capture the species' broader spatial patterns and distribution. Conversely, smaller quadrats (100x100 meters) were used in areas with high species density to provide more detailed information on the species abundance and spatial arrangement. This adaptive approach allowed for a more efficient and effective sampling design, ultimately enhancing the accuracy and reliability of the study's findings. A combination of morphological characteristics and field observations were used to identify the *Adansonia* species. The identification process involved examining the shape, size, and arrangement of leaves, flowers, and fruits, as well as some structural characteristics of the *Adansonia* species. The species were identified based on their distinctive characteristics, and their identifications were verified using existing literature, including flora guides and taxonomic keys.

Once the species were identified, their abundance was assessed using Semi-Quantitative Abundance ratings, specifically the D.A.F.O.R. and A.C.F.O.R. scales. These scales provided a standardized method for estimating the abundance of each species in the quadrats. The A.C.F.O.R. scale categorized species as Abundant, Common, Frequent, Occasional, or

Rare, while the D.A.F.O.R. scale categorized species as Dominant, Abundant, Frequent, Occasional, or Rare. The ACFOR and DAFOR abundance rating scales, commonly used in botanical surveys, have limitations as semi-quantitative measures, as they rely on subjective estimates and lack precision, potentially leading to inconsistent and biased results. This research addressed these limitations by employing a more quantitative approach, using quadrat-based sampling, which provided a more accurate and reliable assessment of the abundance of *Adansonia digitata* in the study area. The abundance data were used to calculate the Plant Population Density (PPD) using the formula: $Density = S/Q$, where S is the total number of individuals of a species in all sampling units, and Q is the total number of sampling units studied. The percentage frequency of each species was also calculated as: $(\text{Number of sample units containing species}) / (\text{Total number of sampling units used in the study}) * 100$. The data collected from the quadrats were analyzed to generate a species-area curve, which was used to evaluate the relationship between the area sampled and the number of *Adansonia* species.

RESULTS AND DISCUSSION

Species distribution

Adansonia is made up of nine species; six of the species (*Adansonia grandidieri*, *A. madagascariensis*, *A. perrieri*, *A. rubrostipa*, *A. suarezensis*, and *A. za*) are common in Madagascar, two (*A. digitata* and *A. kilima*) are native to mainland Africa and the Arabian Peninsula, and one (*A. gregorii*) is native to North-Western Australia.

Table 1 revealed that 791 *Adansonia* species were sampled in twenty quadrats in the study area, of which 775 are *Adansonia digitata* species while 16 were *Adansonia kilima*.

Table 1: Distribution of *Adansonia* Species in the Study Area

QUADRAT	NUMBER OF TREES	ADANSONIA DIGITATA	ADANSONIA KILIMA	OTHERS
1	88	83	5	0
2	76	72	4	0
3	34	32	2	0
4	21	21	0	0
5	9	9	0	0
6	10	10	0	0
7	22	22	0	0
8	35	35	0	0
9	44	41	3	0
10	57	56	1	0
11	70	70	0	0
12	66	66	0	0
13	51	51	0	0
14	36	36	0	0
15	41	41	0	0
16	12	12	0	0
17	19	19	0	0
18	31	31	0	0
19	34	33	1	0
20	35	35	0	0
TOTAL	791	775	16	0

Source: Field work 2022.

Species abundance

The assessment of *Adansonia* species abundance in the study area revealed notable differences in their distribution and frequency. *Adansonia digitata* emerged as the most common and frequent species, indicating its adaptability and competitiveness in the local environment. In contrast, *Adansonia kilima* was found to occur only occasionally, suggesting that it may be more sensitive to environmental conditions or have narrower ecological niches. The remaining seven species, including *Adansonia suarezensis*, *Adansonia rubrostipa*, *Adansonia madagascariensis*, *Adansonia za*, *Adansonia perrieri*, *Adansonia grandidieri*, and *Adansonia gregorii*, were classified as rare. This rarity may be attributed to factors such as limited habitat suitability, competition with other species, or fragmented populations. The rarity of these species indicates a need for conservation efforts to protect and manage their populations sustainably.

The variation in abundance among *Adansonia* species has significant ecological implications. The dominance of *Adansonia digitata* may influence the local ecosystem's structure and function, potentially affecting the distribution and abundance of other plant species. Conversely, the rarity of other *Adansonia* species may indicate a loss of ecological resilience and biodiversity in the study area. The observed variation in *Adansonia* species abundance aligns with previous studies that reported species distribution and frequency differences across different regions (Wickens & Lowe, 2008). The dominance of *Adansonia digitata* in the study area is consistent with its widespread distribution and adaptability across Africa (Sidibe & Williams, 2002). In contrast, the rarity of other *Adansonia* species, such as *Adansonia suarezensis* and *Adansonia grandidieri*, may be attributed to habitat fragmentation and degradation, as reported in previous studies (Barnes et al., 2016). These

findings highlight the need for conservation efforts to protect and manage *Adansonia* species populations sustainably; however, further research is necessary to explore these

relationships and develop effective conservation strategies for the *Adansonia* species in the region.

Table 2: The Semi-Quantitative Abundance Ratings of *Adansonia* species

Abundant Species	Common Species	Frequent Species	Occasional Species	Rare Species
<i>Adansonia digitata</i>	<i>Adansonia digitata</i>	<i>Adansonia digitata</i>	<i>Adansonia kilima</i>	<i>Adansonia suarezensis, Adansonia rubrostipa, Adansonia madagascariensis, Adansonia za, Adansonia perrieri, Adansonia grandidieri and Adansonia gregorii</i>
Dominant Species	Abundant Species	Frequent Species	Occasional Species	Rare Species
<i>Adansonia digitata</i>	<i>Adansonia digitata</i>	<i>Adansonia digitata</i>	<i>Adansonia kilima</i>	<i>Adansonia suarezensis, Adansonia rubrostipa, Adansonia madagascariensis, Adansonia za, Adansonia perrieri, Adansonia grandidieri and Adansonia gregorii</i>

Source: Field work 2022.

Population distribution of *Adansonia* species

The population distribution of *Adansonia* species in the study area was assessed by calculating the number of individuals per unit area. The results showed that *Adansonia digitata* was the most abundant species, with approximately 39 individuals per unit area. At the same time, *Adansonia kilima* had a significantly lower density, with only about 1 individual per unit area. The high population density of *Adansonia digitata* per unit area has significant implications for the ecosystem. The intense intra- and inter-specific competition for resources such as water, organic matter and sunlight may lead to the survival of the most assertive individuals and the elimination of weaker ones. This process, as described by Darwin's theory of natural selection, drives the evolution of species over time.

In this context, the xerophytic nature of *Adansonia* species may confer an adaptive

advantage, enabling them to thrive in areas with severe climatic conditions. However, this advantage may also lead to the suppression of other plant species that are less adapted to these conditions. The resulting dominance of *Adansonia digitata* may have cascading effects on the ecosystem, influencing the distribution and abundance of other plant and animal species.

The observed high population density of *Adansonia digitata* in the study area is consistent with previous studies that reported similar densities in other parts of Africa (Kondombo *et al.*, 2009). The dominance of *Adansonia digitata* in the study area may be attributed to its ability to adapt to harsh environmental conditions, as suggested by previous research (Wickens & Lowe, 2008). However, the potential cascading effects of this dominance on the ecosystem highlight the need for further research on the ecological

implications of *Adansonia digitata*'s high population density. Nonetheless, these findings highlight the importance of considering the

complex interactions between species and their environment to manage and conserve ecosystems effectively.

Table 3: Population Densities of *Adansonia* species

Plant Species	<i>Adansonia digitata</i>	<i>Adansonia kilima</i>	Others	
Number of Individuals in each Quadrat	1	83	5	0
	2	72	4	0
	3	32	2	0
	4	21	0	0
	5	9	0	0
	6	10	0	0
	7	22	0	0
	8	35	0	0
	9	41	3	0
	10	56	1	0
	11	70	0	0
	12	66	0	0
	13	51	0	0
	14	36	0	0
	15	41	0	0
	16	12	0	0
	17	19	0	0
	18	31	0	0
	19	33	1	0
	20	35	0	0
Total number of individual (s)	775	16	0	
Total number of quadrats (Q)	20	20	0	
Density (Number of Individuals per unit area) D=(S/Q)	38.75	0.8	0	

Source: Field Work 2022

Percentage Frequency of *Adansonia* in the study area

The frequency analysis of *Adansonia* species in the study area revealed distinct distribution patterns. Despite the frequency limitations as a pseudo-characteristic of vegetation analysis, the results provided valuable insights into the presence and absence of *Adansonia* species in the 20 quadrats. *Adansonia digitata* emerged as the most widespread species, with a frequency of 100%. This indicates that *A. digitata* was present in all 20 quadrats, suggesting its

adaptability and ability to thrive in various environments within the study area. In contrast, *Adansonia kilima* had a frequency of 30%, appearing in only 6 out of 20 quadrats. This suggests that *A. kilima* may be more restricted in distribution due to specific habitat requirements or environmental limitations.

The remaining *Adansonia* species were absent from all 20 quadrats, indicating a frequency of 0%. This raises concerns about these species' potential rarity or extinction risk in the study area. The frequency patterns observed in this

study have significant ecological implications. The widespread distribution of *A. digitata* may contribute to its dominance in the ecosystem, potentially influencing the composition and structure of plant communities. Equally, the restricted distribution of *A. kilima* and the absence of other *Adansonia* species indicate a need for conservation efforts to sustainably protect and manage these species. The widespread presence of *A. digitata* has been reported in other studies, highlighting its adaptability and ability to thrive in various

environments (Sidibe & Williams, 2002). In contrast, the restricted distribution of *A. kilima* and the absence of other *Adansonia* species may be attributed to habitat fragmentation, environmental degradation, or other anthropogenic factors (Barnes *et al.*, 2016). These findings emphasize the need for conservation efforts to protect and manage *Adansonia* species populations sustainably, particularly in the face of environmental challenges.

Table 4: Plant Species Percentage Frequency

Plant Species	<i>Adansonia digitata</i>	<i>Adansonia kilima</i>	Others	
Quadrats	1	P	P	0
	2	P	P	0
	3	P	P	0
	4	P		0
	5	P		0
	6	P		0
	7	P		0
	8	P		0
	9	P	P	0
	10	P	P	0
	11	P		0
	12	P		0
	13	P		0
	14	P		0
	15	P		0
	16	P		0
	17	P		0
	18	P		0
	19	P	P	0
	20	P		0
Number of quadrats in which the species is present (N)	20	6	0	
Percentage Frequency (F)	100%	30%	0%	
F=N/Q*100				

Species Area Relationships (Curve) of the plants in the study area

Species Area Curve

The relationship between the number of *Adansonia* species and their occupied area was investigated using the species-area curve concept. This concept describes the relationship between the number of species within a habitat and the area of that habitat. The results, illustrated in figures 5-8, showed that the relative abundances of *Adansonia* species followed a systematic mathematical relationship, with larger areas generally having higher species densities. The study area was divided into five quadrat sizes, ranging from 100x100 meters to 500x500 meters. The results showed that the number of *Adansonia* species increased rapidly in the smaller quadrats (100x100 meters and 200x200 meters), with 9 and 21 species, respectively. However, the rate of increase slowed down in the larger quadrats (300x300 meters to 500x500 meters), with 34, 76, and 500 trees, respectively.

The species-area curves for the different quadrat sizes showed varying patterns. The curves for quadrats 1-5 showed a rapid increase in species number with area, while those for quadrats 6-10 and 11-15 showed slower increase rates. In contrast, the curve for quadrats 16-20 showed a more balanced relationship between species number and area.

The results show a significant correlation between the number of *Adansonia* species and the area they occupy. This is consistent with the theory of island biogeography proposed by Robert MacArthur and Edward O. Wilson,

which states that the species richness of an island is determined by its size and distance from the mainland. The implications of the species-area curve results are significant. They suggest that larger areas are more likely to support more species due to reduced competition for resources and space. This has important implications for conservation efforts, which should prioritize protecting larger areas to maintain biodiversity. Additionally, the results highlight the importance of considering the relationships between species and their environment when managing ecosystems.

The species-area curve results from this study are consistent with previous research on the relationship between species richness and area. For instance, Drakare *et al.* (2006) analyzed species-area relationships across different taxonomic groups and found that the relationship is influenced by geographical context and evolutionary history. Similarly, Holt *et al.* (2013) explored the mechanisms underlying species-area relationships and highlighted the importance of considering ecological and evolutionary processes. The observed patterns of species accumulation with increasing area in this study also align with the theory of island biogeography, which has been supported by recent studies (Kareiva & Marvier, 2012). However, the study's findings also highlight the importance of considering the specific ecological characteristics of the study area, such as the distribution and abundance of *Adansonia* species, when applying general theories and models.

Table 5: Species Area Curve of the *Adansonia* species

Quadrat Sizes (M)	Quadrat 1-5	Quadrat 6-10	Quadrat 11-15	Quadrat 16-20
100*100	9	10	36	12
200*200	21	22	41	19
300*300	34	35	51	31
400*400	76	44	66	34
500*500	88	57	70	35

Source, Field work 2022.

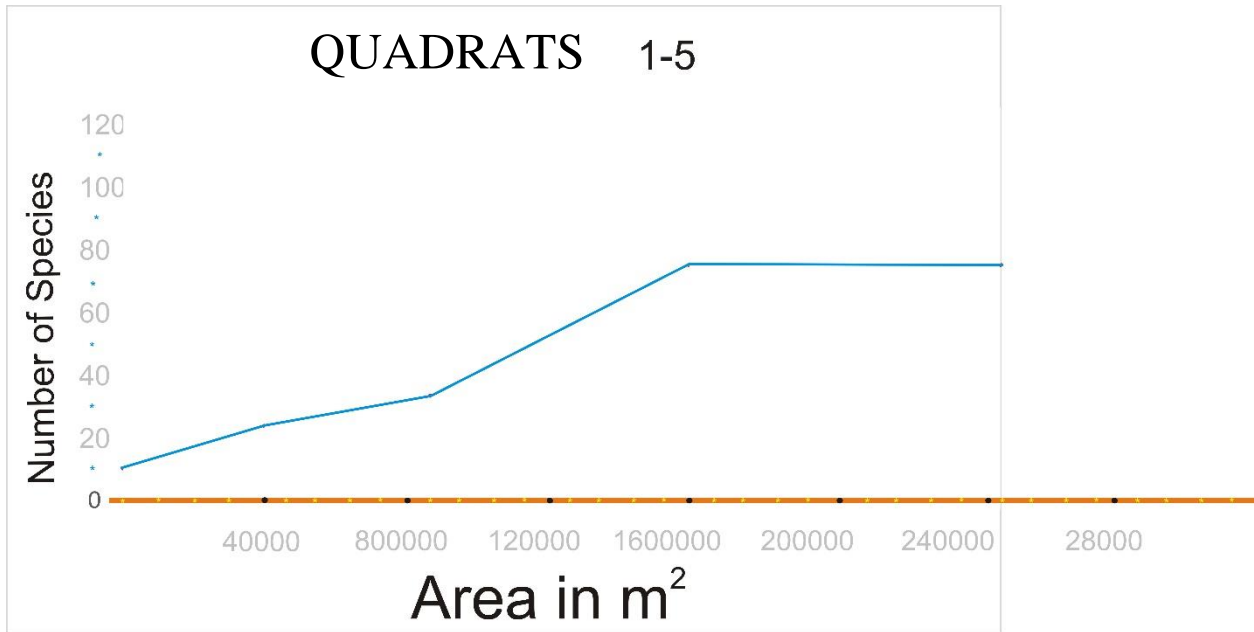


Figure 2: Species area curve for quadrats 1-5
Source: Fieldwork (2022)

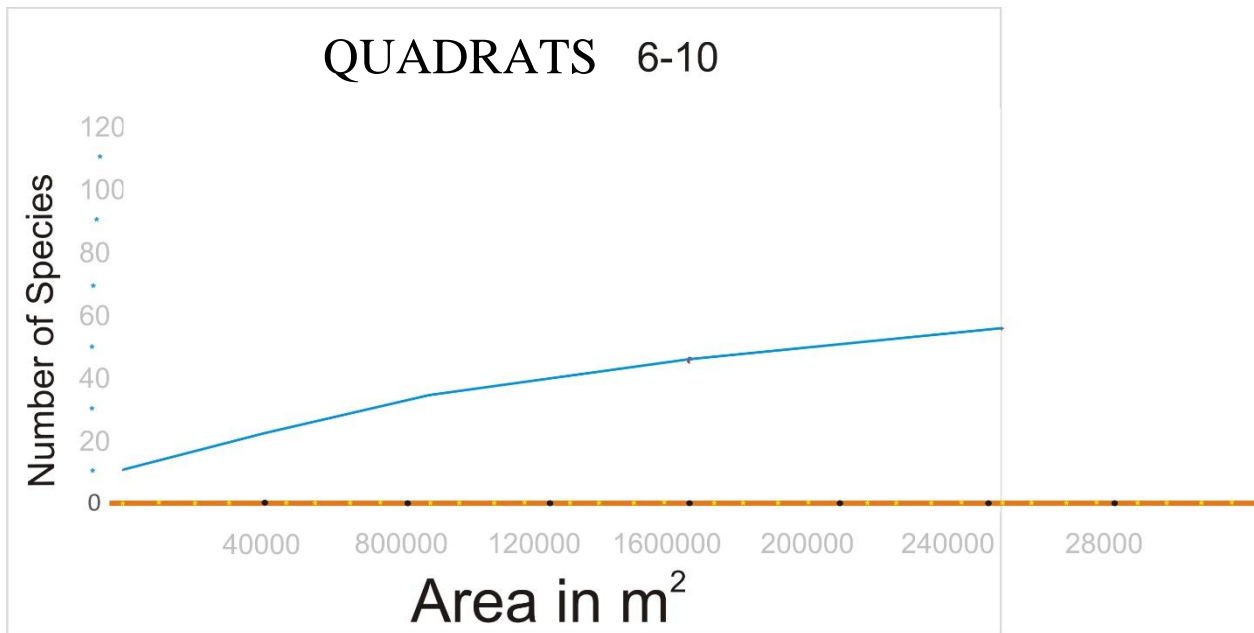


Figure 3: Species area curve for quadrats 6-10
Source: Fieldwork (2022)

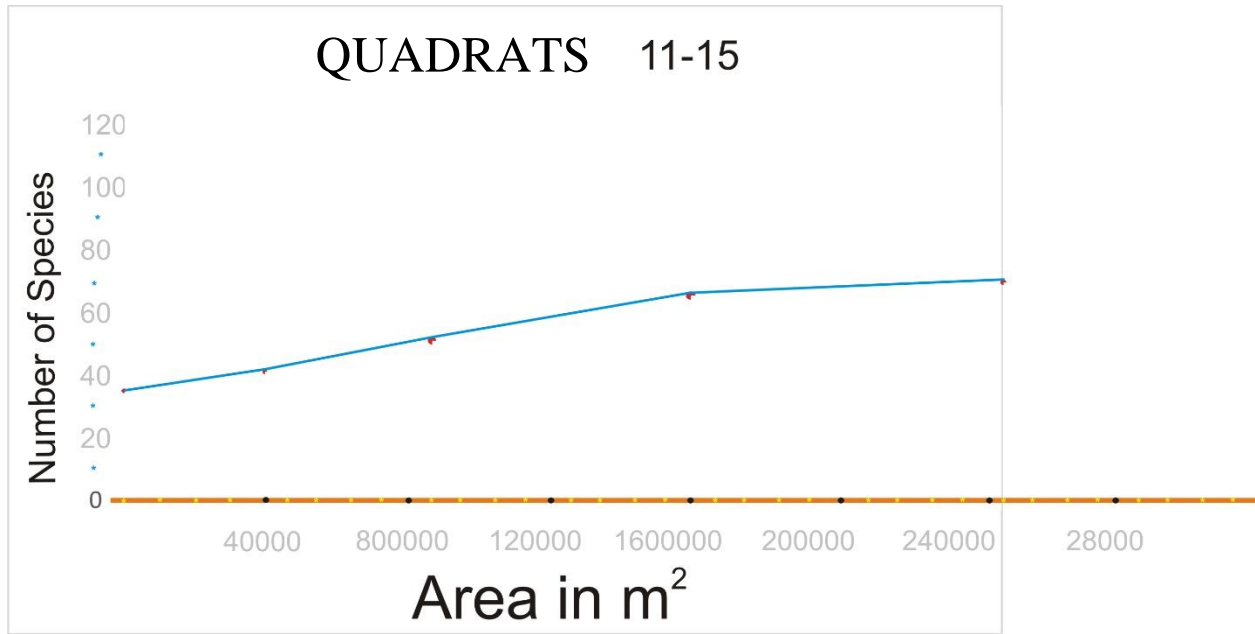


Figure 4: Species area curve for quadrats 11-15

Source: Fieldwork (2022)

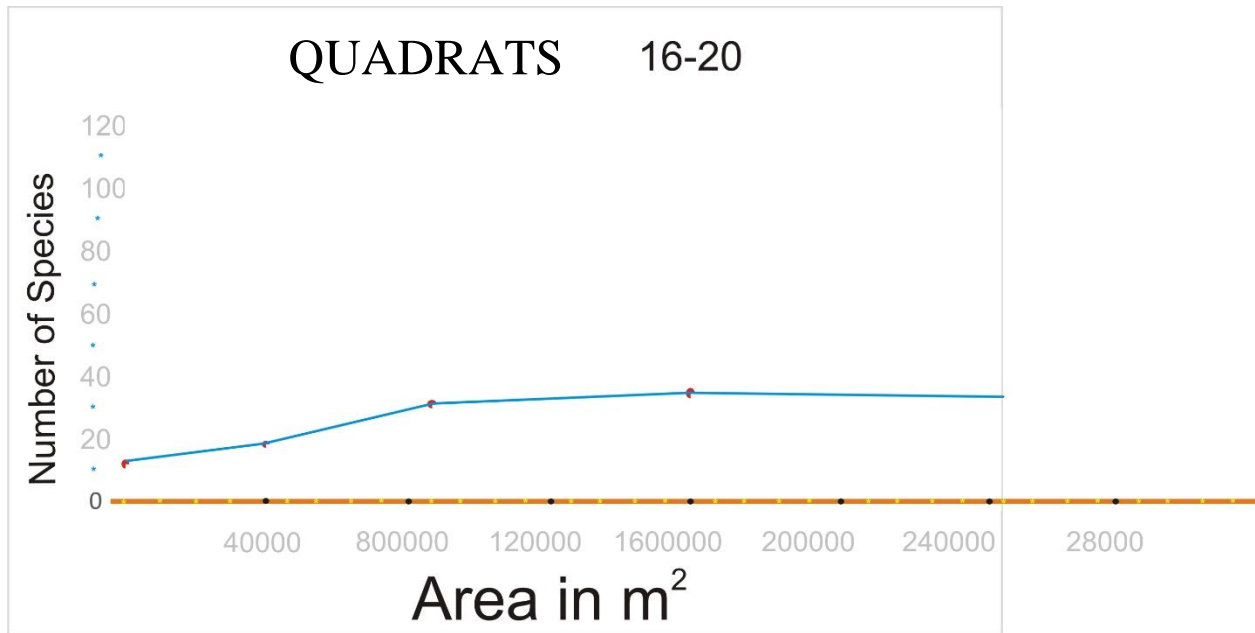


Figure 5: Species area curve for quadrats 16-20

Source: Fieldwork (2022)

CONCLUSION

This study provides novel insights into the abundance and distribution of *Adansonia* species in the Sahel Savanna habitat of Yobe State, Nigeria. The findings reveal that *Adansonia*

digitata is the dominant species in the region, occurring with high frequency and abundance, while *Adansonia kilima* is present in limited numbers. Notably, the remaining seven species of *Adansonia* were absent from the study area.

This research contributes to the existing body of knowledge on *Adansonia species*, shifting the focus from their well-documented nutritional and therapeutic benefits to their ecological distribution and abundance. The results corroborate previous studies that identified *Adansonia digitata* as the sole species in sub-Saharan Africa, highlighting its dominance in the study area.

The broader significance of this study lies in its contribution to our understanding of the ecological dynamics of *Adansonia* species in the Sahel Savanna ecosystem. The findings have important implications for the region's conservation efforts, ecosystem management, and sustainable land-use planning. Furthermore, this study highlights the need for continued research into the ecological and environmental factors that influence the distribution and abundance of *Adansonia* species. While this study provides valuable insights into the abundance and distribution of *Adansonia* species, it is not without limitations. The study's focus on a single region and using a limited number of quadrats may not represent the entire Sahel Savanna ecosystem. Future studies should expand the scope of the research to include multiple regions and a more significant number of quadrats. Additionally, further research is needed to investigate the ecological and environmental factors that influence the distribution and abundance of *Adansonia* species, such as climate change, soil quality, and human activities. Investigating the potential impacts of these factors on *Adansonia* species will be crucial for developing effective conservation and management strategies.

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