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ETHNOBOTANICAL KNOWLEDGE AND PRIORITIZATION OF INDIGENOUS FOOD PLANTS AROUND THE WARI-MARO CLASSIFIED FOREST IN BENIN (WEST AFRICA)

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ABSTRACT

In Benin, non-timber forest products (NTFPs) play a crucial role in the livelihoods of rural households, both for consumption and for commercial purposes. However, despite their importance and ongoing research efforts, few well-structured value chains exist to ensure the sustainable management and optimal promotion of these resources. This study aims to assess the diversity of plant species providing NTFPs, to identify priority indigenous fruit species for promotion and to analyze the socioeconomic factors influencing their use around the Wari-Maro classified forest. Ethnobotanical surveys were conducted with 102 individuals across four villages near the forest. Priority species were identified based on relative citation frequency (RCF), reported use value (RUV), and prioritization criteria. The study recorded 58 plant species providing NTFPs, belonging to 44 families. Fruits and leaves were the most commonly used parts, primarily for food and medicinal purposes. Species richness varied across localities, with villages near degraded areas showing a high citation frequency. Promoting these species could support food security and strengthen the local economy.

***Keywords*:** Plant diversity, Indigenous species, Promotion, West Africa

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1. INTRODUCTION

Globally, around two billion people face moderate to severe food insecurity, and more than 820 million people are still hungry. These alarming figures seriously undermine the achievement of Sustainable Development Goal 2: "Zero Hunger" by 2030 (Arora and Mishra 2022). In Africa, and particularly in West Africa, food insecurity is exacerbated by rapid population growth, the impacts of climate change, land degradation, and persistent poverty (Hall et al. 2017). In this context, natural resources, particularly forest resources, play a critical role in the survival of rural populations. Among these, non-timber forest products (NTFPs) stand out due to their direct contribution to household food, health and income.

NTFPs include all products derived from forest ecosystems other than timber. They include fruits, seeds, leaves, roots, bark, gums, mushrooms, resins and other natural substances. These products are used in households for food, medicinal, artisanal, cultural, religious and commercial purposes (Sardeshpande and Shackleton 2019; Masoodi and Sundriyal 2020; Gurung et al. 2021). Their accessibility and diversity enable marginalised rural populations to cope with lean seasons or food crises.

According to the FAO, more than 1.6 billion people worldwide depend on forests for their basic needs, including about 1.2 billion in developing countries (Malik 2024). In Central Africa, nearly 86 million people living near tropical forests depend on NTFPs for food (Shackleton and De Vos 2022). In West Africa, these products are also an important component of livelihoods, both in rural and urban settings. In Benin, several studies have highlighted the crucial role of NTFPs in local strategies for food security and income generation (Castro et al. 2022; Jerin et al. 2022; Maiguru 2023; Mondo et al. 2024; Zaman et al. 2025). For example, species such as *Celosia argentea* (wild crincrin), *Vitex doniana* (black plum), and *Adansonia digitata* (baobab) are highly valued for both their nutritional content and commercial potential. Sales of these products on local and regional markets generate millions of dollars annually, thereby contributing to local economies (Cvijanović et al. 2020; Nepal 2023).

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Despite their undeniable socio-economic importance, NTFPs remain undervalued mainly. To date, only a few products such as shea (*Vitellaria paradoxa*), cashew (*Anacardium occidentale*), and pineapple benefit from partially organized commercial value chains (Sardeshpande and Shackleton 2019). The majority of NTFPs are still collected and traded in an informal and unstructured manner, lacking technical support, policy support, or a clear valorization strategy. This situation limits their potential contribution to poverty alleviation and food security. The lack of systematic inventories, limited knowledge of priority species, and a lack of reliable economic data on their use value are major constraints to their promotion.

In the face of these challenges, prioritizing high-potential species emerges as a crucial step in any sustainable development strategy centered on NTFPs (Hounsou-Dindin et al. 2022). Such an approach would enhance plant resource conservation and optimize their integration into forest management and land-use planning policies.

This study aims to document the diversity of plant-based NTFPs exploited in the Wari-Maro classified forest, a forest area of high ecological value located in central Benin, and to identify the native fruit tree species considered priorities for valorization and conservation. Specifically, this research aims to: (i) inventory the plant-based NTFPs harvested in the Wari-Maro classified forest; and (ii) identify priority native fruit species to be promoted in this forest.

2. MATERIALS AND METHODS

2.1. Study Area

The present study was conducted in the classified forests of Wari-Maro, located in central Benin (Fig. 1). The forest, which covers an area of approximately 111,095 hectares, lies within the Sudano-Guinean transition zone (Adomou et al. 2006). It is under important anthropogenic pressure from shifting cultivation, deforestation, etc. In 2013, the forest-adjacent population reached 122,860 inhabitants with a rapid population growth rate of 8.35% per year, fueled by the influx of agricultural migrants. The main ethnic groups in the area are the Nago and Bariba, who are mainly farmers and hunters (Adomou et al. 2006).

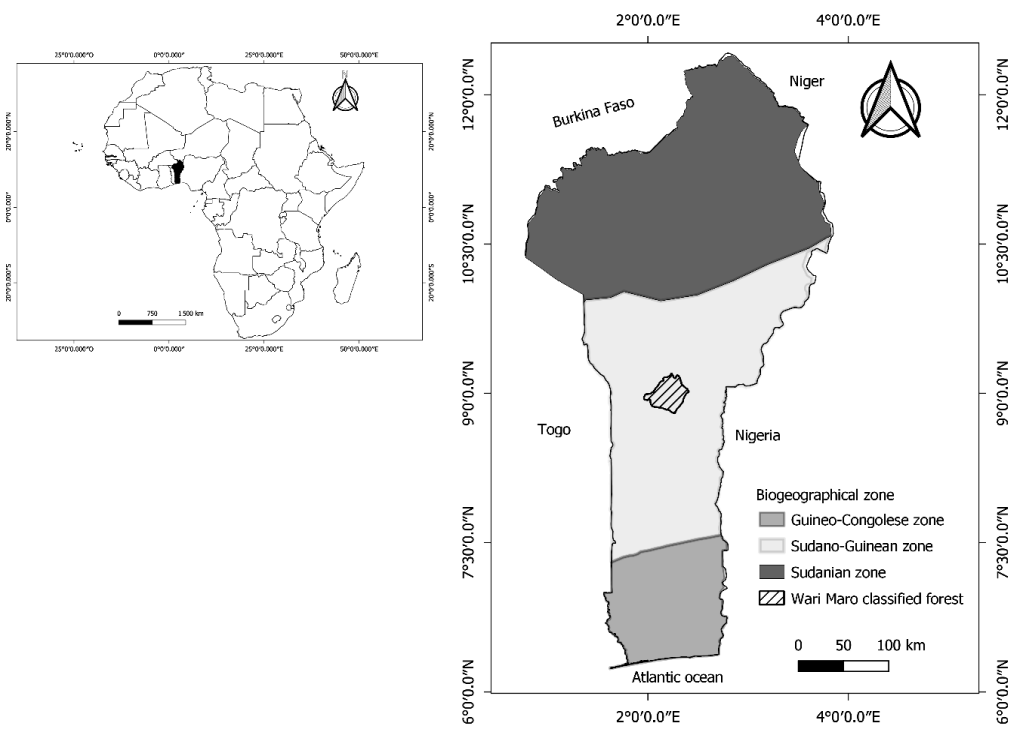

Fig. 1: Geographical location of the study area.

The forest is characterized by a variety of vegetation types: open forests, wooded savannas, dense dry forests, gallery forest, etc. and hosts key species such as *Isoberlinia doka*, *Monotes kerstingii*, and *Anogeissus leiocarpa*. The fauna is also rich, with more than 227 bird species and numerous mammals (Ahoyo et al. 2018).

The climate is sub-humid, with a single rainy season, temperatures ranging between 21 and 40°C, and a notable influence of the harmattan during the dry season (Adomou et al. 2006). The study focused on eight forest-adjacent villages, selected for the ethnobotanical data collection on Non-Timber Forest Products (NTFPs).

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2.2. Sampling and Data Collection

An exploratory survey was conducted in each village bordering the Wari-Maro classified forest. This allowed us to familiarize ourselves with the study area, understand the realities on the ground, and establish the necessary and useful contacts for the subsequent phases of data collection. The sample size was determined for each village. To do this, a random sample of thirty (30) individuals was selected in each village, and they were interviewed about their knowledge and use of non-timber forest products (NTFPs) in the area. The proportion p of individuals with knowledge of these species was calculated and used to determine the final sample size using the formula of Dagnelie (1998):

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

Pi represents the proportion of individuals who are familiar with and make use of Non-Timber Forest Products (NTFPs),

$U^2_{1-\propto/2}$= 1,96 and represents the value of the normal random variable for a risk level α equal to 0.05. The margin of error **d** considered is 8%.

A total of 102 individuals were surveyed across 5 villages covering the entire study area. In each village, semi-structured interviews were conducted with residents living near the relevant ecosystems, including both men and women, from all age categories and various sociolinguistic groups. The information collected included the following:

- Identification of the respondent (full name, age, gender, ethnicity, religion, occupation, education level, residence status, and marital status);
- Main known non-timber forest product (NTFP) plant species (including indigenous fruit trees, edible leafy vegetables, spices/aromatic plants, dyes/sponges); and
- The uses are associated with each of these species.

Six criteria were developed to identify the priority indigenous fruit species. These criteria were used in the prioritization process to highlight the species with the greatest potential for valorization. The criteria were inspired by those proposed by Brehm et al. (2010), applied by Idohou et al. (2013), Assogbadjo et al. (2017) and revised by Kell et al. (2017). The criteria and their respective categories are as follows:

- Species origin with two categories
- Economic importance of each species with three categories
- Usage of the species with five categories
- Availability of the species with two categories
- Number of plant parts used per species with three categories
- Level of economic valorization of each species with three categories

2.3. Data Processing

The frequency of citation (FC) was calculated to document the diversity of plant-based NTFPs as follows: FC = n/N x 100, where *n* is the number of respondents who mentioned a species or its uses, and *N* is the total number of respondents (Pardo-De-Santayana et al. 2007). The FC was used to rank the different specific uses of species according to their relative importance. High FC values for a specific use typically indicate a consensus (shared knowledge) for that use of the organ within the community. Uses reported by more than 20% of respondents (FC > 20%) are considered to be shared knowledge, i.e., consensual. However, knowledge reported by less than 20% of respondents is considered less important within certain socio-cultural groups.

To assess the ethnobotanical knowledge of the biological diversity of different species groups within the Wari-Maro classified forests, several indices and parameters were calculated and compared between the two forests:

- **Species richness "S":** This is the number of species from the different biological groups recorded in each forest.
- **Generic coefficient:** This is the ratio of the number of genera to the number of species: CG = G/S, where *G* is the number of genera and *S* is the number of species.

The preferred species by local people were also determined by calculating the reported use value (VURi) for each species (Gomez-Beloz 2002). This index, expressed in uses per respondent, allowed us to measure and compare respondents' knowledge of the uses of each species based on its abundance levels and across different social groups. The groups with the highest average VURi values are those that generally have more knowledge about the uses of the plant. Descriptive statistics, including frequency histograms and synthesis tables were also created to better present the results for each forest.

The methodology developed by Brehm et al. (2010) was slightly modified to highlight the species prioritized for valorization. For each parameter of the formula, the modalities were identified and ranked, and scores were assigned to each species based on their characteristics relative to the chosen modalities.

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Thus, the overall score for each species is obtained by summing the scores of each criterion (Brehm and Eisenhauer 2008) as follows:

$$\textbf{Overall Score} = \sum_{i=1}^{6}(score_{Origin} + score_{\ economic\ importance} + score_{usage} + score_{davailability} + score_{organs\ valorized} + score_{\ level\ of\ valorization})$$

The species displaying the highest scores are prioritized for valorization programs.

3. RESULTS

3.1. Socioeconomic Characteristics of the Respondents

In the various villages surrounding the forest, men and women are relatively young, in the 30 to 60 age group (44.23%). The Nago sociolinguistic group is predominant in most surveyed areas (79%). The majority of respondents have no formal education (at least 60% of the respondents have no schooling). Of these, 42.31% of the women have no formal education (Table 1).

Table 1: Socio-economic characteristics of the surveyed individuals

Number of respondents:		102
Number of men	<30 years:	16
	30<age<60:	28
	>60 years:	14
Number of women:	<30 years:	10
	30<age<60:	15
	>60 years:	15
Average age of men (mean±SE):		44.28±18.21
Average age of women (mean±SE):		49.09±21.82
Dominant sociolinguistic group (%):		Nago (79)
Education level of men:	No formal education:	14
	Literate (non-formal):	0
	Primary:	5
	Secondary:	9
	University:	1
Education level of women:	Literate (non-formal):	0
	Primary:	2
	Secondary:	0
	University:	0
	No formal education:	22

In the forest, 58 species of NTFPs of plant origin belonging to 36 families were recorded (Fig. 2 and 3). These NTFPs include both food products (indigenous fruits and vegetables) and non-food products (rubber, dye, and cordage). Indigenous fruits, leafy vegetables, cordage, and gum have the highest number of species, with 33, 26, and 21 species belonging to 16, 21 and 15 families, respectively.

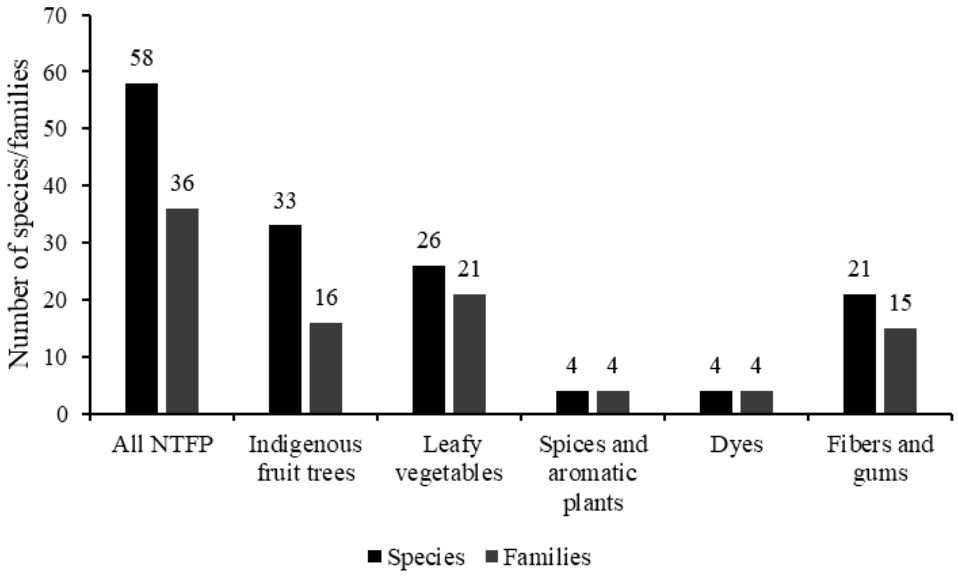

Fig. 2: Species richness and number of families of NTFPs identified in the surrounding territories of the Wari-Maro classified forest.

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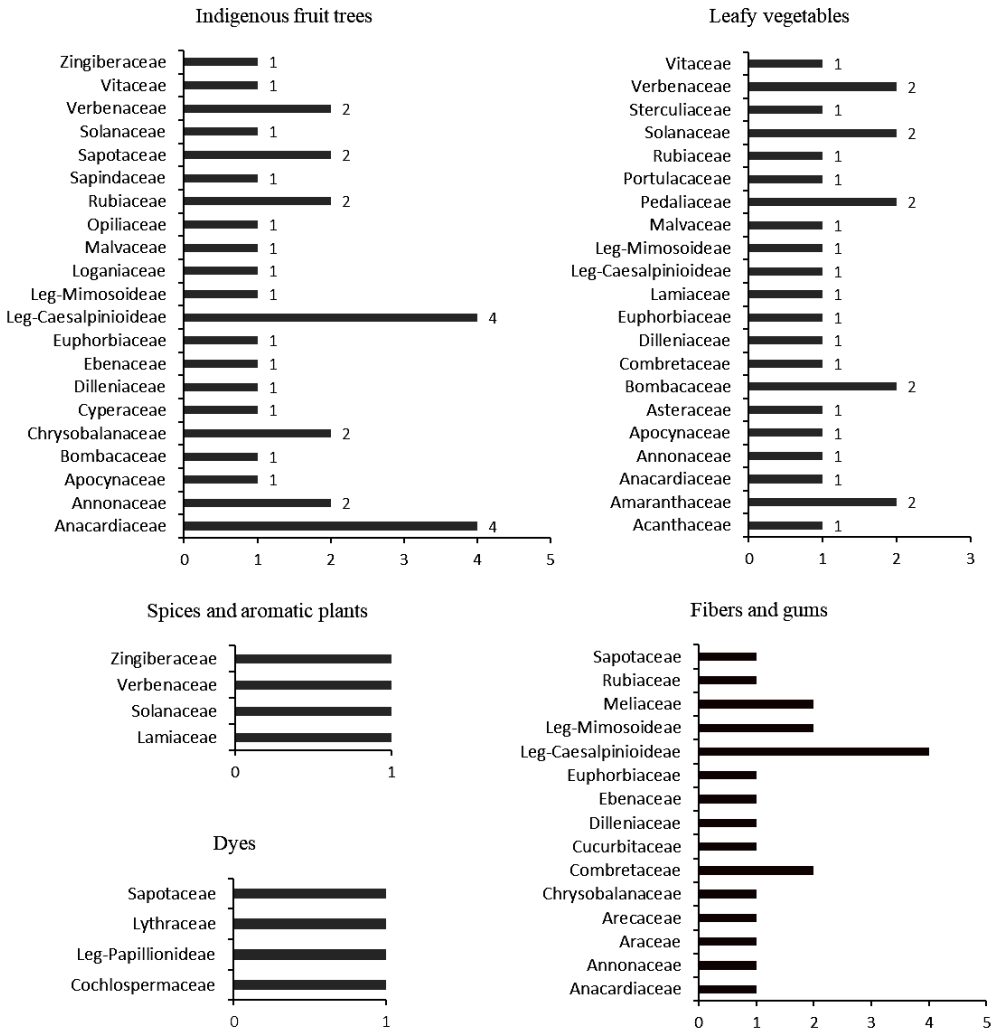

Fig. 3: Diversity of botanical families of NTFPs identified in the surrounding territories of the Wari-Maro classified forest.

This diversity of plant-based NTFPs represents a significant asset for the surrounding communities, providing opportunities for diversifying their activities and, thus, improving their living conditions. Indeed, the positive role of NTFPs is acknowledged for their contribution to improving the standard of living in rural areas, strengthening food security, and having a lower environmental impact compared to timber. Additionally, the economic potential of these products, at both national and international levels, should not be overlooked.

Focusing on the diversity of organs of indigenous fruit trees known and used by local populations, it is observed that most species (36%) are used for 5 different organs (Table 2). This reflects the versatility of NTFPs used by the surrounding communities. The fact that species are valued for several of their organs at the same time provides local people with alternative survival strategies. For example, in the case of species like baobab, the leaves are consumed locally while the fruits are sold, similar to other indigenous fruit trees in the area. The use of roots and bark is sometimes recognized as detrimental to the survival of the species. It is therefore, necessary to develop sustainable valorization strategies for all the multipurpose species in the area.

With regard to the knowledge and preferences of local populations regarding the various species present in their environment, it should be noted that in the Wari-Maro classified forest, the most frequently cited species are *V. paradoxa* (94.23%), *P. biglobosa* (90.38%), and *A. digitata* (78.85%) (Fig. 4). The citation frequencies of these species do not necessarily depend on their availability in the environment, but mainly on their importance in meeting the needs of the surrounding populations. They are also related to the ease or difficulty of access to the forest. These most frequently cited species are the best known, most used, and most valued in the area. High citation frequencies also reflect a strong pressure on these resources. This is the case, for example, with the néré, where all the seeds are collected for agro-food processing, thus disrupting its natural regeneration and affecting the dynamics of its populations in their natural habitats. The same applies to certain baobab individuals, where the leaves are entirely harvested for domestic consumption or commercialization.

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Table 2: Diversity of used organs of non-timber forest products in the surrounding territories of the Wari-Maro classified forest

Species	Family	Plant parts used					Total
		Fruit	Leaf	Bark	Stem/trunk	Root	
Adansonia digitata	Bombacaceae	X	X	X	X	X	5
Aframomum meleguetta	Zingiberaceae	X	X		X		3
Aframomum sceptrum	Zingiberaceae	X	X	X	X	X	4
Anarcadium occidentale	Anacardiaceae	X					1
Annona senegalensis	Annonaceae	X	X	X	X	X	5
Blighia sapida	Sapindaceae	X					1
Bombax costatum	Bombacaceae	X	X	X	X		4
Borassus aethiopum	Arecaeae	X				X	2
Bridelia ferruginea	Euphorbiaceae	X	X	X	X		4
Cissus populnea	Vitaceae	X					1
Cola millenii	Malvaceae	X					1
Cyperus esculentus	Cyperaceae	X					1
Daniellia oliveri	Leguminosae-Caesalpinioideae	X	X		X		3
Detarium microcarpum	Leguminosae-Caesalpinioideae	X	X		X		3
Diospyros mespiliformis	Ebenaceae	X	X	X	X		4
Gardenia ternifolia	Rubiaceae	X	X	X	X	X	5
Hexalobis monopetalus	Annonaceae	X	X		X		3
Landolphia owariensis	Apocynaceae	X	X	X	X		4
Lannea acida	Anacardiaceae	X					1
Opilia amentacea	Opiliaceae	X		X			2
Parinari curatellifolia	Chrysobalanaceae	X	X	X	X	X	5
Parkia biglobosa	Leguminosae-Mimosoideae	X	X	X	X	X	5
Piliostigma thonningii	Leguminosae-Caesalpinioideae	X	X				2
Pouteria alnifolia	Sapotaceae	X	X				2
Sarcocephalus latifolius	Rubiaceae	X					1
Sclerocarya birrea	Anacardiaceae	X	X				2
Spondias mombin	Anacardiaceae	X	X	X	X		4
Strychnos spinosa	Loganiaceae	X	X		X		3
Tamarindus indica	Leguminosae-Caesalpinioideae	X	X	X	X	X	5
Terminalia avicennioides	Combretaceae	X					1
Tetracera alnifolia	Dilleniaceae		X				1
Vitellaria paradoxa	Sapotaceae	X	X	X	X	X	5
Vitex doniana	Verbenaceae	X	X	X	X		4

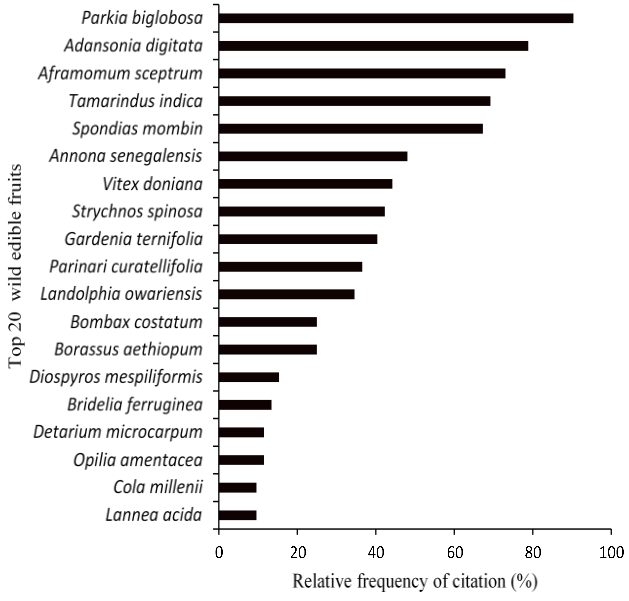

Fig. 4: Relative citation frequencies of the 20 most frequently mentioned indigenous fruit tree species in the communities surrounding the Wari-Maro classified forest.

3.2. Prioritization of NTFPs for Valorization

The species prioritized for valorization are those that obtained the highest scores in all the environments surveyed (Table 3). They are not necessarily those with the highest citation frequency (e.g., *Spondias mombin*). In fact, the scoring process took into account several dimensions of economic valorization and should be regarded as a very good indicator for the strategic selection of species to be valorized. For the Wari-Maro classified forest, the five species considered by the surrounding populations as priorities for valorization, in order of importance, are: *Adansonia digitata*, *Tamarindus indica*, *Spondias mombin*, *Vitellaria paradoxa*, *Parkia biglobosa* and *Aframomum sceptrum*.

These species are recognized for their nutritional, economic, social, religious, and/or cultural potential. Locally, for example, it has been noted that baobab organs are used in the treatment of at least 19 different diseases and various infections. From an economic standpoint, these priority species are marketed and bring income to households. They are species found in natural formations and agroforestry systems and are thus in the process of being domesticated by surrounding populations.

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However, the valorization of all these species remains low when considering their global economic and nutritional potential. Indeed, baobab and tamarind organs are internationally processed and marketed by pharmaceutical companies and large supermarkets.

Table 3: List of priority species for valorization in the communities surrounding the Wari-Maro classified forest

Species	Origin	Economic Importance	Use	Availability	Valued plant parts	Level of valorization	Total
Adansonia digitata	1	2	2	2	2	2	11
Spondias mombin	1	2	1	2	2	2	10
Tamarindus indica	1	2	2	1	2	2	10
Vitellaria paradoxa	1	2	1	2	1	1	8
Parkia biglobosa	1	1	2	1	2	1	8

4. DISCUSSION

4.1. Ethnobotanical Assessment of the NTFP Biodiversity

This study highlights the importance of promoting and enhancing indigenous species identified as priority resources in the Wari-Maro classified forest in Benin. The results showed that local communities living around these forests rely heavily on plant-based NTFPs for food, medicine, firewood, crafts, forage and cultural or religious purposes. Through field inventories, 58 NTFP species from 57 genera and 36 families were documented in the Wari-Maro Forest areas. Among these were indigenous fruit trees, leafy vegetables, and fiber or gum-producing plants. Indeed, knowledge and use of NTFPs vary significantly between communities, reflecting distinct sociocultural backgrounds. This supports earlier observations by Balick and Cox (2020) and Malaisse (2010) that food and plant knowledge are deeply rooted in cultural identity.

Interestingly, the number of food plant species identified in this study is higher than that reported by Agbahoungba et al. (2016) for the Lama Forest but lower than the one of Assogbadjo et al. (2012) across agroforestry systems in Benin. These differences may be due to both cultural preferences and ongoing forest degradation that threatens biodiversity. Nonetheless, the rich diversity of NTFPs documented here offers promising opportunities for livelihood diversification, improved food security, and better nutrition through dietary diversity-a key pillar of sustainable development, as emphasized by Malaisse (1997).

4.2. Diversity of Used Plant Parts of in the Surrounding Territories of the Forest

Analysis of the use of non-timber forest product (NTFP) in the villages bordering the Wari-Maro classified forest reveals a strong local knowledge and reliance on a wide range of plant resources, totaling 86 species. However, the ways in which these resources are utilized remain relatively narrow. Across all surveyed localities, NTFPs are primarily valued for their fruits and leaves, which are mostly used for food and medicinal purposes. Other uses, such as for cordage, are less common.

The most commonly harvested plant parts are leaves (63.06%), followed by fruits (52.31%) and stems or trunks (38.46%). These findings are in line with those reported by Dossou et al. (2012). The predominance of leaves and fruits in local usage can be attributed to their ease of access and rapid collection, as suggested by Pandey and Savita (2017). In addition, the relatively low exploitation of roots and barks—which are often critical to a plant's survival-may reflect a conscious effort by communities to avoid practices that threaten plant regeneration.

This behavior may indicate an implicit form of conservation embedded in traditional knowledge systems, where communities seek to conserve species that play an important role in local diets and traditional medicine. Such use patterns emphasize the importance of promoting sustainable harvesting practices and strengthening awareness of the ecological consequences of overexploitation. Overall, these practices suggest a balance between use and conservation, highlighting the importance of local knowledge in resource management.

4.3. Prioritization of Indigenous Fruit Trees in the Wari-Maro Classified Forests for Valorization

Following an ethnobotanical assessment of plant-based non-timber forest products (NTFPs), subsequent research focused on indigenous fruit species with the aim of identifying priority species for valorization in the Wari-Maro classified forests. This approach was inspired by Barazani et al. (2008) in Israel, who classified indigenous plants into groups to facilitate targeted conservation efforts, especially when conservation resources are limited. Talukdar et al. (2021) highlighted that sustainable evaluation of economically significant NTFPs requires the identification of priority species, as this enables more effective interventions to mitigate the growing pressure on these species, which are often overexploited due to their high utility across multiple domains, including food, medicine, crafts, forage, and fuel.

There are different methodological approaches to species prioritization. In this study, six criteria were developed, drawing on the frameworks proposed by Brehm et al. (2010) and adapted by Kell et al. (2017). The approach applied here slightly modifies the methodology used in previous studies (e.g., Idohou et al. 2013;

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Assogbadjo et al. 2017), in line with recent advances in prioritization methods (Kell et al. 2017). The point-scoring procedure used in this study is flexible and provides producing valuable insights by assigning scores based on the species' characteristics relative to each parameter.

The prioritization revealed five species as the top priorities for valorization in the forest. These species consistently ranked highest in citation frequency and are valued for their nutritional, economic, social, spiritual and cultural significance. However, their valorization remains limited in comparison to their global potential.

This methodology differs from that used in other regions, such as whole Benin (Hounsou-Dindin et al. 2022), northeastern India (Saha and Sundriyal 2010), and southwest Cameroon. N'Danikou et al. (2011) emphasized the importance of incorporating local community criteria in prioritization. The prioritization of species is influenced by their utility and factors such as accessibility and availability. Assogbadjo et al. (2017) noted that successful management strategies must consider both economic and ecological factors, including conservation status and ecological distribution, to align valorization with conservation objectives and support sustainable resource management.

5. CONCLUSION

Non-timber forest products (NTFPs) play a crucial role in the lives of rural and urban populations in Benin. Used for food, medicine, and trade, they generate income and provide livelihoods in times of scarcity. In the forests classified as Wari-Maro, these species are exploited for their leaves, fruits, barks, roots, etc. Their use depends on accessibility, seasonal availability, and perceived utility by local people. The study highlights the pressure exerted on these resources, especially in sacred forests, fallows, homestead gardens, and agroforestry systems, due to their multiple uses. In particular, indigenous fruit trees are essential for the socio-economic well-being of the communities. In the context of forest degradation, there is an urgent need to include these species in reforestation and conservation programs. The study recommends implementing an information-education-communication system to raise awareness among local communities, thus ensuring the sustainable management of NTFPs through the involvement of local leaders.

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Consent to Participate: Verbal informed consent was obtained prior to the interview.

Author's Contribution: For multiple authors: RI, ES, AAO, and GP conceived and designed the experiment. RI and ES performed the study, and ES carried out the analyses. RI supervised and coordinated the data collection and statistical analyses. RI and ES prepared the draft of the manuscript. All authors critically revised the manuscript and approved the final version.

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