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Useful Plants in Cocoa Plantations: A Heritage to Be Preserved for Resilient Agroforests in Côte d'Ivoire

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Abstract

In Côte d'Ivoire, cocoa is an important source of income for the population and the state. However, its production has led to massive deforestation, reducing forest cover and the associated ecosystem services. In order to reconcile cocoa production with conservation, agroforestry is being promoted; however, its success hinges on the traditional knowledge of the services provided by these plants, which remains poorly documented. This study aims to document the endogenous knowledge of rural populations regarding the ecosystem services provided by woody plants in cocoa-based agroforestry systems. To this end, ethnobotanical surveys were conducted among 50 farmers in five villages located within one of Côte d'Ivoire's primary cocoa production regions. These surveys were supplemented by a literature review and principal component analysis. A total of 53 woody species were identified, including 37 indigenous and 16 introduced species. They provide services for food (48.18%), medicinal care (31.04%), construction (14.16%), fodder (5.97%) and cosmetics (0.65%). Organs used include leaves, fruit, bark, roots, etc. Despite their usefulness, 54% of these species are on the IUCN Red List, underlining their vulnerability. In addition, locality and ethnicity have been identified as differentiating factors in knowledge of the services provided. Integrating this local knowledge into forest management programs will ensure the sustainable use of woody plants in cocoa-based agroforestry systems. In addition, in view of the threats to biodiversity, work needs to be done on prioritizing the conservation of these species. A participatory approach involving researchers, decision-makers and rural communities is essential to preserve woody plants while maintaining cocoa profitability.

Keywords

West Africa, Cocoa Farming, Agroforestry, Biodiversity, Traditional

Knowledge

1. Introduction

Côte d'Ivoire, the world's leading cocoa producer, has based a significant part of its economic development on this crop, which has become a key source of income for rural [1]. Indeed, like other countries in Sub-Saharan Africa, Côte d'Ivoire has focused its economic development on the agricultural sector since gaining independence in 1960 [2]. Public policies have contributed to planters' preference for cocoa, which has become the main source of agricultural income for both the Ivorian population and the state [3]. This emphasis on cocoa has enabled Côte d'Ivoire to become the world's leading producer of cocoa beans, accounting for at least 43% of global production [1].

This expansion of cocoa production has been achieved at the expense of forest ecosystems, since cocoa farming usually takes place after the forest has been cleared. This has led to a significant reduction in vegetation cover and woody plants. The ecosystem services they provide (support, provisioning, regulation and socio-cultural services) are also affected [4] [5].

In the face of environmental degradation, agroforestry is emerging as a promising solution for reconciling agricultural productivity and biodiversity conservation. However, the sustainable conservation of woody plants in cocoa-based agroforestry systems depends largely on farmers' traditional knowledge of their uses and services [6] [7], which is still poorly documented. This local knowledge, transmitted from generation to generation, plays a crucial role in the sustainable management of natural resources, but is in danger of disappearing under the impact of socio-economic and environmental changes.

The aim of this study is to address a scientific and practical gap by systematically documenting the endogenous knowledge of rural populations regarding the ecosystem services provided by woody plants in agroforestry cocoa farms. This documentation is essential for three main reasons:

1) Scientific justification: Traditional knowledge of the uses of woody plants is not well formalized in academic literature [6], even though it represents a critical lever for biodiversity conservation and adaptation to climate change [7].

2) Socio-economic justification: Understanding the socio-economic functions of these plants (medicinal, food, etc.) makes it possible to assess their contribution to the resilience of rural households and to guide inclusive public policies [8] [9].

3) Environmental rationale: Identifying the factors influencing their conservation (cropping practices, economic pressures, etc.) is necessary to design sustainable agroforestry models aligned with the Sustainable Development Goals.

Specifically, we will:

- Identify the species used by local populations;
- Determine the socio-economic functions of these species;

- Determine the factors influencing their conservation.

2. Methodology

2.1. Presentation of the Study Area

This study was carried out in the Bonon sub-prefecture, the second largest cocoa-producing area in Côte d'Ivoire. This sub-prefecture is located in west-central Côte d'Ivoire, in the Marahoué region (Figure 1), covering an area of 520 km^2. Bonon is located in a forest mosaic zone of 456 ha [10] and benefits from a Guinean-type climate characterized by four seasons: a long and short rainy season, and a long and short dry season. According to [11], Bonon had a population of 167,397 in 2021, made up of natives (Gouro), non-natives (Baoulé, Sénoufo and Tagbana) and non-natives (Burkinabé, Malian and Beninese) whose main activity is agriculture, based on cocoa cultivation. Work took place in five villages in the Bonon sub-prefecture, namely Dabouzra, Ouarebota, Blaisekro 2, N'Guatakouakoukro and Koffikro (Figure 1).

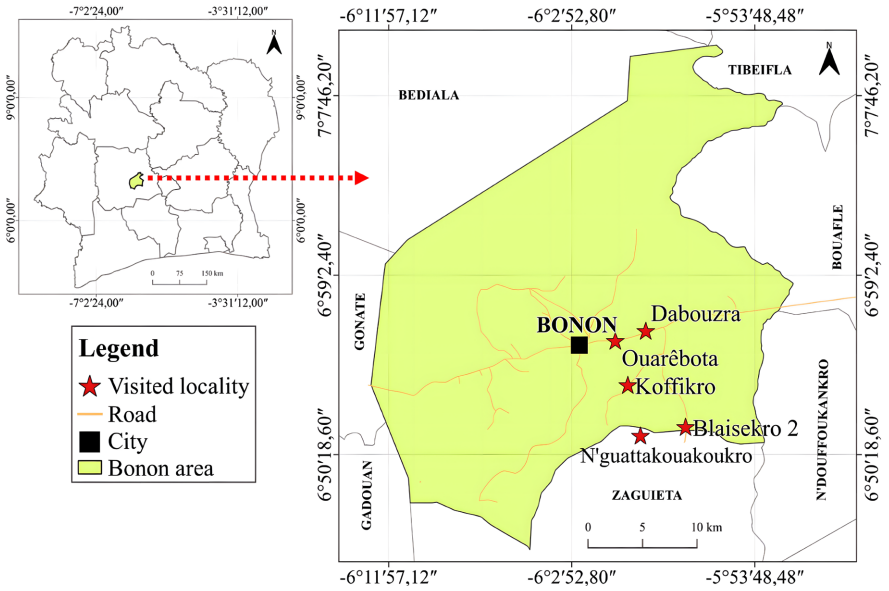

Figure 1. Geographical location of the sub-prefecture.

2.2. Data Collection

This research aims to identify woody species associated with cocoa agroforestry systems in the Bonon region (Côte d'Ivoire) and to assess their provisioning services for local populations. An ethnobotanical approach was adopted, combining semi-structured surveys of 50 farmers in five villages (Dabouzra, Ourebota, Blaisekro 2, N'Guatakouakoukro and Koffikro) in one of the main cocoa production areas of Côte d'Ivoire, a literature review and a principal component analysis. The choice of different villages was based on the diversity of ethnic groups in the area, for a good triangulation of the services provided by the species. At least 10% of randomly surveyed farmers practicing cocoa-based agroforestry, mostly educated (66%)

and from different ethnic groups (Baoulé, Gouro, Sénoufo, etc.), provided information on the species used for their food, medicinal, construction, fodder and other needs.

2.3. Data Processing and Analysis

Botanical nomenclature was verified according to [12] and APG IV, while species origin (native and exotic) as well as endangered or endemic species were identified from the works of [13]-[15] and [16]. Citation frequencies (*FC*) were calculated to assess the relative importance of species and their uses using the following formula:

$$FC = \frac{(Ni \times 100)}{Ne} \quad (1)$$

where *Ni* is the sum of citations for a species, organ used, use or category of supply service provided, and *Ne* is the sum of citations for all species, organs used, uses or categories of service provided. When *FC* tends towards 0, the species or species organ is poorly used and the provisioning service is poorly provided, and an opposite trend is observed when F tends towards 100.

In addition, the influence of socio-demographic characteristics (gender, age, level of education, ethnicity and locality) on knowledge of ecosystem services provided by species was assessed. To this end, the number of services cited by each participant was analyzed using a Poisson family generalized linear model (GLM). To do this, a two-stage approach was adopted: 1) a saturated model, including all main effects and their possible interactions, was tested; 2) the parsimonious model (simpler, with fewer factors) was then selected to retain the most significant variables. This method makes it possible to identify which socio-demographic variables significantly influence knowledge of local ecosystem services.

This study thus highlights the diversity of woody species useful in cocoa agroforests, while identifying those that are vulnerable or endemic, thus contributing to better management and conservation of these resources.

3. Results and Discussion

3.1 Results

3.1.1. Diversity of Woody Plants Used in Bonon Department

Surveys carried out in the Bonon sub-prefecture identified 53 plant species, divided into 43 genera and 23 botanical families, used by the local population for their supply services (**Table 1**). The most represented families are Moraceae (18.87%), Sterculiaceae (9.43%) and Rutaceae (7.55%) (**Figure 2**).

Among these species, a distinction is made between native forest species (69.81% of species cited) and introduced species (16 species recorded). The most frequently mentioned native forest species are *Morinda lucida* (5.84%), *Milicia excelsa* (3.77%), *Cola nitida* (3.51%), *Ficus exasperata* (3.51%), *Nesogordonia papaverifera* (2.99%), *Ricinodendron heudelotii* (2.86%) and *Newbouldia laevis* (2.73%) (**Figure 3**).

Table 1. Species used for each type of provisioning service provided by woody species.

Species	Foo_ Lea	Foo_ Fru	Foo_ See	Foo_ Sap	Cons_ Bra	Cons_ See	Cons_ Tru	Cos_ Bar	Cos_ Lea	Cos_ Fru	Fodd_ Lea	Med_ Bar	Med_ Lea	Med_ Fru	Med_ Roo	Total
Alstonia boonei	-	-	-	-	-	-	-	-	-	-	-	x	x	-	x	3
Annona muricata	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Antiaris toxicaria	-	-	-	-	-	-	x	-	-	-	-	x	x	-	-	3
Artocarpus altilis	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Artocarpus heterophyllus	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Azadirachta indica	-	-	-	-	-	-	-	-	-	-	-	x	x	-	x	3
Baphia nitida	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	1
Bauhinia thonningii	-	-	-	-	-	-	-	-	-	-	-	x	x	-	x	3
Bombax buenopozense	x	x	-	-	-	-	-	-	-	-	x	-	-	-	-	3
Borassus aethiopicum	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	1
Ceiba pentandra	x	-	-	-	-	-	x	-	-	-	-	-	-	-	-	2
Celtis zenkeri	-	-	-	-	-	-	x	-	-	-	-	x	-	-	-	2
Citrus limon	-	x	-	-	-	-	-	-	-	-	-	-	x	x	-	3
Citrus maxima	-	x	-	-	-	-	-	-	-	-	-	-	-	x	-	2
Citrus reticulata	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Citrus sinensis	-	x	-	-	-	-	-	-	-	-	-	-	x	-	-	2
Cocos nucifera	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Cola nitida	-	x	-	-	-	-	-	-	-	-	-	x	-	x	-	3
Cordia platythyrsa	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	1
Cordia senegalensis	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	1
Delonix regia	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	1
Elaeis guineensis	-	-	x	x	x	x	-	-	-	-	-	-	-	-	-	4
Ficus exasperata	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	1
Ficus lutea	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	1
Ficus mucuso	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	1
Ficus religiosa	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	1
Ficus on	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	1
Garcinia afzelii	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	1
Holarrhena floribunda	-	-	-	-	-	-	-	-	-	-	-	x	x	x	x	4
Jatropha curcas	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	1
Kigelia africana	-	-	-	-	-	-	-	-	-	-	-	x	x	-	-	2
Mangifera indica	-	x	-	-	-	-	-	-	-	-	-	x	x	-	-	3
Mansonia altissima	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	1
Margaritaria discoidea	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	1
Milicia excelsa	-	-	-	-	-	-	x	-	-	-	-	x	x	-	-	3
Milicia regia	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	1
Millettia zechiana	-	-	-	-	-	-	x	-	-	-	-	-	x	-	-	2
Morinda lucida	-	-	-	-	-	-	-	-	-	-	-	x	x	-	x	3
Nesogordonia papaverifera	-	-	-	-	-	-	x	-	-	-	-	x	x	-	-	3
Newbouldia laevis	-	-	-	-	-	-	-	-	-	-	-	x	x	-	x	3
Parkia biglobosa	-	x	-	-	-	-	-	-	-	-	-	x	x	-	-	3

Continued

Persea americana	-	x	-	-	-	-	-	-	-	-	-	x	x	-	-	3
Psidium guajava	-	x	-	-	-	-	-	-	-	-	-	x	x	-	-	3
Ricinodendron heudelotii	-	x	-	-	-	-	-	-	-	-	-	x	x	-	-	3
Spondias mombin	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Sterculia tragacantha	-	x	-	-	-	-	-	-	-	-	-	x	x	-	x	4
Tamarindus indica	-	x	-	-	-	-	-	-	-	-	-	x	x	-	-	3
Tectona grandis	-	-	-	-	-	-	-	-	-	-	-	x	x	x	-	3
Terminalia superba	-	-	-	-	-	-	-	-	-	-	-	x	x	x	-	3
Trema guineensis	-	-	-	-	-	-	-	-	-	-	-	x	x	-	-	2
Triplochiton scleroxylon	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	1
Vitellaria paradoxa	-	-	-	-	-	-	-	x	x	x	-	x	x	x	-	6
Xylopia aethiopica	-	x	-	-	-	-	-	-	-	-	-	-	-	x	-	2
Grand total	2	19	1	1	2	1	15	1	1	1	6	23	25	8	7	

Foo = Food; Med = Medicinal; Cons = Construction; Fodd = Fodder; Cos = Cosmetic; Lea = Leaf; Fru = Fruit; Bar = Bark; Roo = Root; Tru = Trunk; See = Seed; Sap = Sap; Bra = Branch; x = Presence; - = Absence.

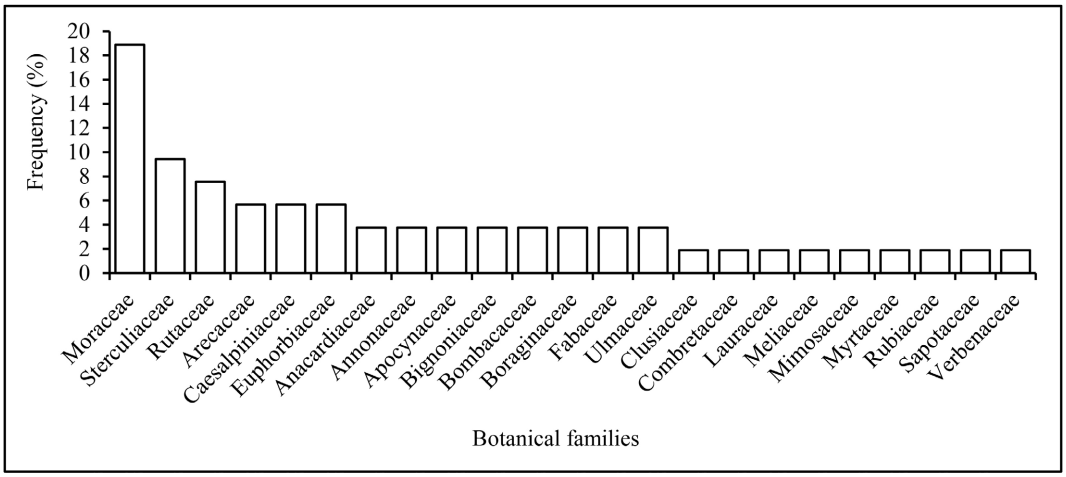

Figure 2. Botanical families of species used by cocoa growers in the Bonon sub-prefecture.

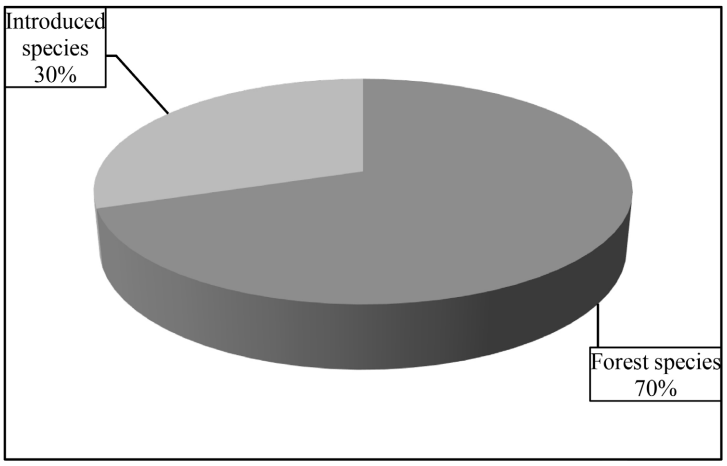

Figure 3. Origin of species used by populations for their well-being.

Of these plants associated with cocoa plantations, 32 are on the IUCN red list, representing 60.38% of the species recorded. They are divided into: 1) Vulnerable species (VU: 11.32%): *Cordia platythyrsa*, *Garcinia afzelii*, *Milicia regia*, *Nesogordonia papaverifera*, *Ricinodendron heudelotii* and *Vitellaria paradoxa*; 2) Species of Least Concern (LC: 45.28%) (Figure 4).

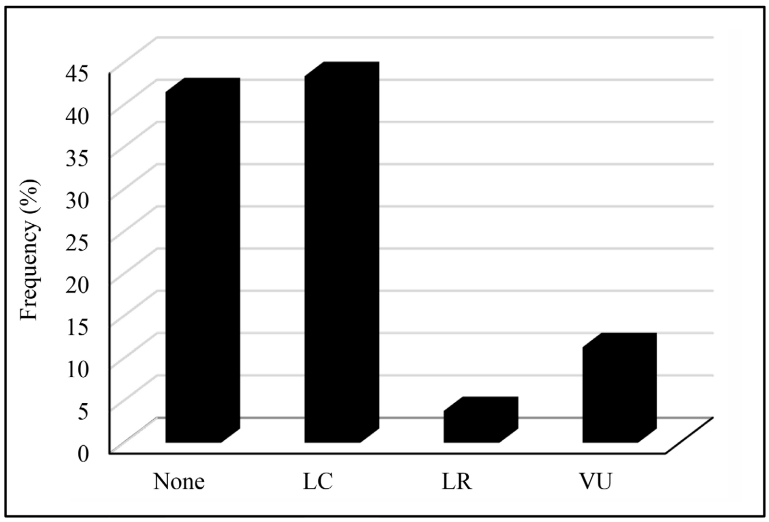

Figure 4. Conservation status of woody species used by populations in the Bonon department. None: Species not on the IUCN Red List; VU: Vulnerable; LC: Least concern; LR: Low risk of extinction.

3.1.2. Diversity of Services Provided by Woody Plants

People use eight plant organs to meet their needs: branches, bark, leaves, fruit, seeds, roots, sap and trunks (Table 1). Fruits (43.64%) and leaves (19.22%) are the most used, while roots (3.12%), sap (1.56%) and branches (0.91%) are less used. The number of organs used per species varies from 1 to 4, with a predominance of species where only one organ is used. Only *Holarrhena floribunda* and *Sterculia tragacantha* use four of their organs (leaves, bark, fruit, roots).

These plants are used for six purposes: 1) Food (48.18%) through the use of leaves, fruits, seeds, and sap; 2) Medicine (31.04%) through the use of bark, leaves, fruits, and roots; 3) Construction using branches, seeds, and trunks. For 4) Fodder, leaves are used by the population, and for 5) Cosmetics, fruits, leaves, and bark are used with a frequency of 0.65%. A total of 15 service categories were identified, including 4 for food and medicine, 3 for construction and cosmetics, and 1 for fodder (Table 1).

A total of 21 plant species, divided into 17 genera and 12 families, are used for food, representing 39% of the species cited. The plants most frequently consumed are *Mangifera indica* (100%), *Citrus sinensis* (98%), *Elaeis guineensis* (96%) and *Persea americana* (96%). Fruit dominates this use (19 species), while two species (*Bombax buenopozense* and *Ceiba pentandra*) are exploited for their leaves (Table 1). *Elaeis guineensis* is also valued for its seed (96%) and sap (24%).

In traditional medicine, 29 species divided into 27 genera and 19 families are

listed, representing 54.72% of the species mentioned. *Morinda lucida* (56%), *Mangifera indica* (48%), *Newbouldia laevis* (22%) and *Tectona grandis* (22%) are the most widely used. The plant organs used are bark (23 species), leaves (25 species), fruit (8 species) and roots (7 species). *Morinda lucida* stands out for its bark (50%) and leaves (20%), while *Xylopia aethiopica* (16%) and *Citrus limon* (12%) are preferred for their fruit.

For building, 17 species (13 genera, 9 families) are used, representing 26.42% of quotations. *Milicia excelsa* (54%), *Nesogordonia papaverifera* (40%) and *Triplochiton scleroxylon* (38%) are the most popular, mainly for their trunks. *Elaeis guineensis* and *Baphia nitida* branches are also used, as are palm seeds (3%).

Six species (*Ficus exasperata*, *Ficus sur*, *Bombax buenopozense*, *Ficus lutea*, *Ficus mucuso* and *Ficus religiosa*) are used by farmers as fodder, with *Ficus exasperata* (54%) and *Ficus* sur (30%) the main resources (11.32% of species cited) (Table 1). In cosmetics, only *Vitellaria paradoxa* is mentioned (6%), exploited for its bark, leaves and fruit.

Finally, some plants have multiple uses. *Vitellaria paradoxa* (6 uses) is used in cosmetics and medicine. *Elaeis guineensis* (4 uses) is used for food (seeds, sap) and construction (branches, seeds). *Holarrhena floribunda* and *Sterculia tragacantha* (4 uses each) are exclusively medicinal, exploiting bark, leaves, fruit and roots (Table 1).

3.1.3. Factors Influencing Knowledge of Ecosystem Services

Generalized linear model analysis (Poisson family) reveals that:

- Locality: Inhabitants of Blaisekro 2 cite the most uses, unlike those of Dabouzra.
- Level of education: People with secondary education mention more uses than those with primary or no formal education.
- Ethnicity: Sénoufo and Baoulé have more extensive knowledge than other groups.

On the other hand, gender and age have no significant influence on knowledge of uses (Table 2).

Table 2. Socio-demographic factors influencing knowledge of woody species in cocoa-based agroforestry systems.

Sources of variation (Probability of significance)	Number of uses (Mean ± Standard deviation)
Locality	(Pr = 0.00)
Blaisekro_2	19.36 ± 6.20[a]
Dabouzra	13.08 ± 4.92[c]
Koffikro	16.25 ± 3.79[b]
N'Gatta_kouakoukro	16.60 ± 5.73[b]
Ouarebota	12.20 ± 2.25[d]

Continued

Schooling	(Pr = 0.02)
None	14.06 ± 3.52[b]
Primary	14.72 ± 3.53[b]
Secondary	17.73 ± 7.49[a]
Ethnicity	(Pr = 0.04)
Baoulé	18.37 ± 4.05[a]
Gouro	12.20 ± 3.09[c]
Sénoufo	19.00 ± 7.79[a]
Others	14.75 ± 5.12 [b]
Age group	(Pr = 0.47)
Young	16.25 ± 7.17
Adult	14.95 ± 4.68
Old	15.37 ± 4.48

Values of the same factor indexed by the same letter form a homogeneous group at 95% confidence according to the Newman-Keuls test at the 5% threshold.

3.2. Discussion

3.2.1. Diversity of Woody Plants

The study reveals notable floristic richness in the Bonon department, with 53 species belonging to 23 botanical families. The most represented families are Moraceae, Sterculiaceae and Rutaceae. This reflects the ecological and socio-cultural importance of these families in tropical regions, particularly with regard to their role in agroforests and their traditional applications. The dominance of these families in agroforests has also been demonstrated in studies [17]-[19]. The diversity of species associated with cocoa-based agroforestry systems used by local populations has also been noted in cocoa plantations in other regions of Côte d'Ivoire, such as in the Agnibilékro region, where 63 species have been recorded [20], and in the San Pedro region, where 105 species have been recorded [17]. Similar findings have been reported in other countries, including Togo, where 174 species have been documented [18]. These various studies have shown that the number of CFA species used by local populations for their daily needs varies. The predominance of native forest species (69.81%) underlines the dependence of local communities on natural ecosystems, but also their vulnerability to deforestation. This fact has already been highlighted by several authors, including [21]. Species such as *Milicia excelsa* and *Ricinodendron heudelotii* are both useful and threatened, requiring conservation measures. The presence of introduced species reflects the adaptation of populations to new resources (e.g., introduced fruit or medicinal species), but also the possible risk of competition with native flora. Furthermore,

the presence of 60.38% of species on the IUCN red list, with 11.32% classified as vulnerable (e.g., *Vitellaria paradoxa*), indicates strong anthropic pressure and the need to regulate their use.

3.2.2. Ecosystem Services Provided

Woody plants meet a wide range of needs, with varying degrees of organ exploitation. Indeed, analyses show that the fruits (43.64%) and leaves (19.22%) of woody plants are widely used for food and medicine. This observation is in line with common practice in West Africa (e.g., wild fruits used to supplement diets, leaves for pharmacopoeia). Unlike these plant organs, roots and sap are little used. Their removal is often destructive, which could explain why they are rarely used (risk of threatening plant regeneration).

The high use of woody plants in the food sector (48.18%) is due to the key role of fruits and seeds in food security. The frequency with which medicinal services are cited (31.04%) is due to the high use of bark and leaves, confirming the importance of traditional knowledge for health care in rural areas. This high proportion of species used in traditional medicine could be justified by the fact that, faced with poverty, farmers are turning to traditional medicine through the use of plant species to treat a number of pathologies. Indeed, medicinal plants are a precious resource for the vast majority of rural populations in Africa, where over 80% of the population use them for health care [22] [23]. Conventional healthcare facilities remain relatively expensive in relation to their purchasing power and are rare in different localities. The local population harvests medicinal plants from their farms, which are known to alleviate certain ailments.

Building and fodder services are less frequently mentioned, but are essential for housing and livestock. However, this lack of mention of fodder services may be due to the low involvement of Bonon zone populations in livestock farming, or to the low representativeness of these species in the environment, due to their felling during the establishment and maintenance of agricultural plots.

3.2.3. Factors Influencing Local Knowledge

The analyses revealed that knowledge of the supply services provided by PLSACs is influenced by the ethnicity, level of education and locality of the respondents.

The variation in knowledge of the provisioning services provided by woody plants between ethnic groups is thought to be due to the habits and customs handed down from generation to generation within the same ethnic group. This finding corroborates that of several authors who have reported significant ethnic variation in knowledge of *Adansonia digitata* in Togo [24], *Triplochiton scleroxylon* in Benin [25] and several other species in Burkina Faso [26]. Ethnicity is thus one of the major factors differentiating plant knowledge and use within communities. Contrary to this work, [27] showed no ethnic variation in knowledge of the services provided by agroforestry species in the Sudanian zone of Burkina. Moreover, the Sénoufos and Baoulés have a more extensive knowledge, reflecting their history of interaction with the forest (agriculture, gathering). Ethnocultural differences thus

influence the perception of ecosystem services.

The variation in knowledge of the provisioning services provided by plants according to locality is due to the dominance of certain ethnic groups in localities, often differing from one locality to another. Indeed, several authors, including [28] and [29], have shown that villages are sometimes inhabited by several ethnic groups, but that there is almost always a numerically dominant or more long-established ethnic group. This is the case, for example, in Koffikro, Blaisekro 2 and N'Gatta kouakoukro, which are dominated by the Baoulé, and Ouarebota and Dabouzra, which are dominated by the Gouro. In addition, the existence of a cultural heritage within the same locality could justify the use of the sap and leaves of woody plants for food, and the leaves and roots for medicinal purposes by the populations of Blaisekro 2 and N'Gatta Kouakoukro, dominated by the same ethnic group (Baoulé). This homogeneity in the knowledge of services in the same locality would be due to a sharing of knowledge and a transmission of habits and customs between the different ethnic groups making up the population of this locality. Indeed, according to [30] and [31], traditional knowledge is acquired through practices and beliefs that are passed down from generation to generation. The locality of the respondents was also listed by [32] as a differentiating factor in knowledge of the services provided by woody species. Moreover, at locality level, the inhabitants of Blaisekro 2 cite more uses than those of Dabouzra. This could be explained by the Dabouzra population's lack of knowledge of the services provided by plants, or by the unavailability of natural resources in cocoa plantations due to their felling by the population to allow only cocoa trees to grow.

As far as education is concerned, people with a secondary education are more familiar with uses. Formal education seems to reinforce (but not replace) traditional knowledge, perhaps through a better ability to categorize uses. This result shows the importance of formal learning in achieving a desired level of knowledge.

Unlike other studies, where women or older people (elders) hold more knowledge (e.g., medicinal plants), here these factors are not significant. This could indicate a homogenization of knowledge or less differentiated survey methods.

4. Conclusions and Recommendations

This study documented the endogenous knowledge of the rural populations of Bonon (Côte d'Ivoire) on the ecosystem services provided by woody plants associated with agroforestry cocoa plantations. The results reveal that 53 plants, mostly indigenous forest species (69.81%), including several threatened species on the IUCN red list (60.38%), played a pivotal role in providing food and traditional medicines, as well as being used for other socio-economic purposes.

The most frequently cited provisioning services are for food (48.18%) and medicine (31.04%), with fruits and leaves being exploited preferentially. Factors influencing local knowledge include ethnicity (with Baoulé and Sénoufo having greater knowledge of uses), level of education (with those with secondary education citing more services) and locality (Blaisekro 2 standing out for greater diversity of uses).

On the other hand, gender and age had no significant impact.

These results underline the importance of traditional knowledge in the sustainable management of cocoa agroforests, while highlighting the risks associated with the overexploitation of certain vulnerable species. For more resilient cocoa farming, it is essential to integrate this local knowledge into conservation strategies while promoting sustainable agroforestry practices. Further studies, including a quantification of harvesting and an analysis of ritual uses, would enable us to refine these recommendations for better preservation of biodiversity in Côte d'Ivoire. Furthermore, given the threats to biodiversity, work needs to be carried out to prioritise the conservation of these species.

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Statement of Informed Consent

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Statista (2024) World Cocoa Bean Production by Country in 2022. Study Report. https://fr.statista.com/statistiques/571638/co-coa-main-producers-by-value-world-wide/statisticContainer

[2] Ducroquet, H., Tillie, P., Louhichi, K. and Gomez-Y-Paloma, S. (2017) A Closer Look at Agriculture in Côte d'Ivoire, Inventory of Plant and Animal Production Sectors and Review of Agricultural Policies. Joint Research Centre, 58-63.

[3] Alliot, C., Cortin, M., Feige-Muller, M., Ly, S. and Pigneur, J. (2016) Societal Costs as Indicators of Sustainable Development in Global Value Chains. The Example of the Cocoa Chain in Côte d'Ivoire and Peru. *RIODD* 2016, Saint-Étienne, 6-8 July 2016, 78 p.

https://riodd2016.sciencesconf.org/114577/RIODD_2016_ALLIOT_CORTIN_FEIGE_MULLER_LY_PIGNEUR.pdf

[4] Kouakou, A.T.M., Assalé, A.A.Y. and Barima, Y.S.S. (2018) Impact of Anthropogenic Pressures on the Flora of the Haut-Sassandra Classified Forest (Central-Western Côte d'Ivoire). *Tropicultura*, **36**, 155-170.

[5] Assalé, A.A.Y., Barima, Y.S.S., Sangne, Y.C., Bleu, D.K.C.R. and Kpangui, K.B. (2020) Evaluation of the Provisioning Services Provided by Anthropized State-Owned Areas: The Case of the Haut-Sassandra Classified Forest (Central-Western Côte d'Ivoire). *Canadian Journal of Forest Research*, **50**, 1002-1011. https://doi.org/10.1139/cjfr-2019-0443

[6] Bakwaye, F.N., Termote, C., Kembelo, A.K. and Van Damme, P. (2013) Identification and Local Importance of Medicinal Plants Used in the Mbanza-Ngungu Region, Democratic Republic of Congo. *Bois & Forêts des Tropiques*, **316**, 63-77. https://doi.org/10.19182/bft2013.316.a20531

[7] Hedjazi, N. and Afoufou, S. (2022) Ethnobotanical Study and Evaluation of the Biological Activities of Medicinal Plants in the Dairas of El Ma Labiodh, El Aouinet and Ouenza (Wilaya of Tébessa). Doctoral Dissertation, Larbi Tébessi-Tébessa University.

[8] Scoones, I. and Thompson, J. (2009) Farmer First Revisited: Innovation for Agricultural Research and Development. Practical Action Publishing, 385 p.

[9] Shackleton, C. and Shackleton, S. (2004) The Importance of Non-Timber Forest Products in Rural Livelihood Security and as Safety Nets: A Review of Evidence from South Africa. *South African Journal of Science*, **100**, 658-664.

[10] Krouba, G.I.D., Ouattara, A.A., Kouakou, A.C.A., Adopo, A.R.I., Fauret, P., Coulibaly, B., Kaba, D., Julius, K., Assi Kaudjhis, J. and Courtin, F. (2018) Population Dynamics and Landscape Changes in the Southern Rural Area of Bonon in 2000 and 2015 (Marahoué Region, Côte d'Ivoire). *Tropicultura*, **36**, 271-280.

[11] Kouadio, K.A.L. (2022) Typology of Cocoa-Based Agroforestry Systems Using Aerospace Technology in the Sub-Prefecture of Bonon (Central-Western Côte d'Ivoire). Master's Thesis, Jean Lorougnon Guédé University, 67 p.

[12] Cronquist, A. (1988) The Evolution and Classification of Flowering Plants. New York Botanical Garden, 230 p.

[13] Aké-Assi, L. (1998) Impact of Logging and Agricultural Development on the Conservation of Biological Diversity in Côte d'Ivoire. *Le Flamboyant*, **46**, 20-21.

[14] Aké-Assi, L. (2001) Flora of Côte d'Ivoire 1, Catalog, Systematics, Biogeography and Ecology. Conservatory and Botanical Garden, 396 p.

[15] Aké-Assi, L. (2002) Flora of Côte d'Ivoire 2, Catalog, Systematics, Biogeography and Ecology. Conservatory and Botanical Garden, 441 p.

[16] IUCN (2020) The Global Red List of Threatened Species. https://uicn.fr/liste-rouge-mondiale

[17] Adou Yao, Y.C., Kpangui, K.B., Vroh, B.T.A. and Ouattara, D. (2016) Cultural Practices, Use Values and Farmers' Perception of Cocoa Companion Species in Traditional Agroforests in Central Côte d'Ivoire. *Revue d'Ethnoécologie*, No. 9, 1-17.

[18] Djiwa, O., Pereki, H. and Guelly, K.A. (2021) Ethno-Cultural Perceptions of Ecosystem Services Rendered by Cocoa-Based Agroforests in Togo. *Biotechnology, Agronomy, Society and Environment*, **25**, 208-222.

[19] Ndiaye, M.S. (2024) Woody Flora in Cashew-Based Agroforests in Casamance (Senegal). *Territories, Environment and Development* (*TED*), **3**, 62-71.

[20] Kougbo, M.D., Djah, F.M., Diop, A.L., Amenan, S.K. and Dogba, M. (2023) Usages

et impacts des espèces arborescentes dans les exploitations cacaoyères de l'Indénié-Djuablin, Côte d'Ivoire. *VertigO*. https://doi.org/10.4000/vertigo.37570

[21] FAO (2020) Global Forest Resources Assessment 2020. Food and Agriculture Organization of the United Nations. https://openknowledge.fao.org/server/api/core/bitstreams/9f24d451-2e56-4ae2-8a4a-1bc511f5e60e/content

[22] Jdaidi, N., Selmi, H., Aloui, F., Jedidi, S. and Chaabane, A. (2023) Evaluation of Potential Threat and Vulnerability Factors for Medicinal and Aromatic Plants in Northwest Tunisia. *Moroccan Journal of Agricultural and Veterinary Sciences*, **11**, 14-21.

[23] Peter, I.T., Agera, S.I.N., Dachung, G. and Ndagi, H.I. (2023) Survey of Medicinal Plant Species Utilization in Home Gardens in Jema'a Local Government Area, Kaduna State, Nigeria. *Journal of Research in Forestry, Wildlife and Environment*, **15**, 1-9.

[24] Kébenzikato, A.B., Wala, K., Atakpama, W., Dimobé, K., Dourma, M., Woégan, A.Y. and Akpagana, K. (2015) Ethnobotanical Knowledge of the Baobab Tree (*Adansonia digitata*) au Togo. *Base*, **19**, 247-261.

[25] Ganka, G., Salako, V.K. and Fandohan, B.A. (2022) Importance des cultes dans la préservation des espèces d'arbre, le cas du samba (*Triplochiton scleroxylon* K. Schum.) au Bénin. *Bois & Forets des Tropiques*, **351**, 53-65. https://doi.org/10.19182/bft2022.351.a36866

[26] Traoré, L., Hien, M. and Ouédraogo, I. (2021) Usages, disponibilité et stratégies endogènes de préservation de *Canarium schweinfurthii* (Engl.) (Burseraceae) dans la région des Cascades (Burkina Faso). *Ethnobotany Research and Applications*, **21**, 1-17. https://doi.org/10.32859/era.21.01.1-17

[27] Cissé, M., Bationo, B.A., Traoré, S. and Boussim, I.J. (2018) Perception of Agroforestry Species and Their Ecosystem Services by Three Ethnic Groups in the Boura Watershed, Sudanese Zone of Burkina Faso. *Tropical Woods & Forests*, **338**, 29-42.

[28] Guérin, M., Hardy, A., Chính, N.V. and Hwee, S.T.B. (2018) From Mountain Dwellers to Ethnic Minorities: What Kind of National Integration for the Populations of the Highlands of Vietnam and Cambodia? Institute for Contemporary Southeast Asian Studiesh, 354 p.

[29] Reyniers, C. (2019) Agroforestry and Deforestation in the Democratic Republic of Congo. Environmental Miracle or Mirage? *Developing World*, **47**, 113-132.

[30] Tareau, M.A., Dejouhanet, L., Odonne, G., Palisse, M. and Ansoe, C. (2019) Thinking about the Collection of Wild Medicinal Plants in Societies in Transition: The Case of French Guiana. Echo-Géo, 47 p.

[31] Pelletier, C. (2022) Transmission of Indigenous Ethnobotanical Knowledge and Practices: A Case Study of Blueberries (Minic) among the Atikamekw Nehirowiskwewok (Atikamekw Women) of Wemotaci. Ph.D. Thesis, University of Quebec in Abitibi-Témiscamingue, 146 p.

[32] Badjaré, B., Kokou, K., Bigou-laré, N., Koumantiga, D., Akpakouma, A., Adjayi, M.B. and Abbey, G.A. (2018) Ethnobotanical Study of Woody Species in the Dry Savannas of Northern Togo: Diversity, Uses, Importance, and Vulnerability. *Base*, **22**, 152-171.