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Endogenous knowledge of the supply services provided by woody plants in cocoa-based agroforestry systems in the Bonon department (west-central Ivory Coast)

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Abstract

Cocoa farming in Ivory Coast has contributed to the decline of forest cover, leading to the the loss of woody species they preserved and the decline of the ecosystem services they provided. Given this situation, agroforestry appears to be a solution for the conservation of these plants and their associated services. However, this conservation is influenced by several factors, including traditional knowledge of the services provided. This study assessed farmers' endogenous knowledge of the services provided by woody species in cocoa-based agroforestry systems. Ethnobotanical surveys were conducted among 50 randomly selected farmers in five villages located in Bonon a major cocoa-producing region in Central-West Ivory Coast. A generalised linear Poisson model was used to assess the influence of the socio-demographic characteristics of the people surveyed on the variation in their declared knowledge. The results show a certain mastery of the uses of plants associated with cocoa farms, as evidenced by the alignment between farmers' statements and previous work on the subject. Indeed, 53 woody species were cited by farmers as providing them with services. Their branches, bark, leaves, fruit, seeds, roots, sap and trunks are mainly used for food, medicine, construction, fodder and cosmetics. However, the use of these plants could be detrimental to the resilience of cocoa-based agrosystems to climate change. In addition, locality, ethnicity and level of education have been listed as differentiating factors in knowledge of the services provided. Integrating this knowledge into forest management programmes will ensure sustainable use of woody plants in cocoa-based agroforestry systems.

Keywords: West Africa; Agroforestry; Cacao Farming; Sustainable Management; Ecosystem Service

1. Introduction

Woody plants offer a number of material benefits to society, known as provisioning services [1]. In most developing countries, these services contribute to the well-being of several households [2]. Indeed, several organs or parts of these plants (leaves, bark, roots, stem, seed, fruit, sap and flower) are harvested for multiple uses such as food, handicrafts, medicine and packaging [3 ; 4], or sold on local, regional or even international markets [5].

Despite the importance of woody plants, the increasing intensity of human activities, including agriculture, is leading to their gradual decline or even disappearance, resulting in the disappearance of many rare and valuable species [6 ; 7].

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Like many Sub-Saharan African countries, Ivory Coast has focused its economic development on the agricultural sector since gaining independence in 1960 [8]. Public policies have contributed to farmers' preference for cocoa, which has become the main source of income from agriculture for both the Ivorian population and the state [9]. This emphasis on cocoa has enabled Ivory Coast to become the world's leading producer of cocoa beans, accounting for at least 43% of international production [10]. However, cocoa farming is generally involves clearing forest, has led to a resulting in a reduction in the forest cover and the woody species they retain, as well as the ecosystem services they provide [11 ; 12]. The loss of woody plants is a threat to many communities in developing countries as they depend heavily on these resources [13 ; 14]. Concrete, effective and sustainable actions are therefore needed to prevent the disappearance of woody plants in the coming decades. Various international conventions such as the Convention on Biological Diversity (CBD), the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), the International Union for Conservation of Nature (IUCN), the Convention on International Trade in Endangered Species (CITES), among others, advocate minimising human impact on biodiversity and safeguarding strategic species at different levels, from local to global [15 ; 16]. The strategies developed to achieve these objectives include : (i) managing the underlying causes of biodiversity loss by integrating biodiversity into all aspects of government and society ; (ii) reducing direct pressures on biodiversity and encouraging sustainable use ; (iii) improving the status of biodiversity by safeguarding ecosystems, species and genetic diversity ; (iv) enhancing the benefits derived by all from biodiversity and ecosystem services [16]. Thus, Agroforestry, defined as a land use system in which species are intentionally introduced or preserved in plantations [17 ; 18], appears to be a developed strategy for species conservation. It represents a more promising solution for conserving woody plants for the well-being of rural populations. These plants left in plantations provide several supply services such as food, medicine, construction and fodder, and thus help to improve the living conditions of farmers [19 ; 20].

However, the services provided by these cropping systems depend on the diversity of woody species found there and the range of knowledge accumulated by local populations about these species [21]. The diversity of species found there (which are spared by the farmers) depends in part on the farmers' traditional knowledge of the services provided by these plants. This traditional knowledge of the services provided by plants is acquired through practices and beliefs that are passed down from generation to generation [22]. The importance of assessing the diversity of communities' local knowledge lies in the fact that human relationships and nature are dynamic entities and are under the influence of several factors, including the socio-cultural group [23]. Consequently, within the same ecological zone, endogenous perceptions and practices for natural resource management may vary according to origins, ancestral legacies and intercultural transmissions [23 ; 13]. Previous studies have concluded that individual attributes such as age, gender, household and community roles and responsibilities, occupation, natural dispositions, intellectual abilities, ethnicity and proximity to other ethnic groups could influence endogenous knowledge of natural resources within the same community [6].

In Ivory Coast, studies on the socio-demographic characteristics of cocoa farmers and their endogenous knowledge of the material benefits provided by cocoa-based agroforestry systems are nearly non-existent. However, this information is vital for understanding the socio-ecological dynamics of these systems and for initiating strategies for the conservation and development of woody species in cocoa-based agroforestry systems, that provide services to populations due to the rural communities' dependence on these species.

This study therefore aims to address this gap by focusing on two main research questions : What are the supply services provided by woody plants in cocoa-based agroforestry systems (PLSAC) ? What socio-demographic characteristics influence local populations' endogenous knowledge of the supply services provided by PLSACs ?

2. Materials and methods

2.1. Study area

This study was carried out in one of the largest cocoa production zones in Ivory Coast, namely the second largest zone, located in the centre-west of the country, in the sub-prefecture of Bonon (Figure 1). Belonging to the Marahoué region, the study area benefits from a Guinean-type climate characterised by four seasons : a long rainy season (May to mid-July), a short rainy season (September-November), a long dry season (December-February) and a short dry season (mid-July to September). The landscape of Bonon is also dominated by a hydrographic network made up exclusively of temporary watercourses that feed a succession of low-lying areas and short, narrow slopes that join the tributaries of the Marahoué. The relief is made up of low plateaux with an altitude of 260 m and small, rarely encountered lowlands [24]. The soils are mostly ferralitic, moderately denatured and predominantly sandy-clay [11]. The population of Bonon consists of indigenous people (Gouro), non-native Ivorians (Baoulé, Sénoufo, and Tagbana), and foreign settlers (Burkinabé, Malian, and Beninese). The work took place in five villages in the Bonon sub-prefecture, namely Dabouzra,

Ouarebota, Blaisekro 2, N'Guatakoukro and Koffikro (Figure 1). The main activity of the population of these villages is agriculture, based on the cultivation of cocoa, coffee and food crops such as plantain, rice, yams and maize.

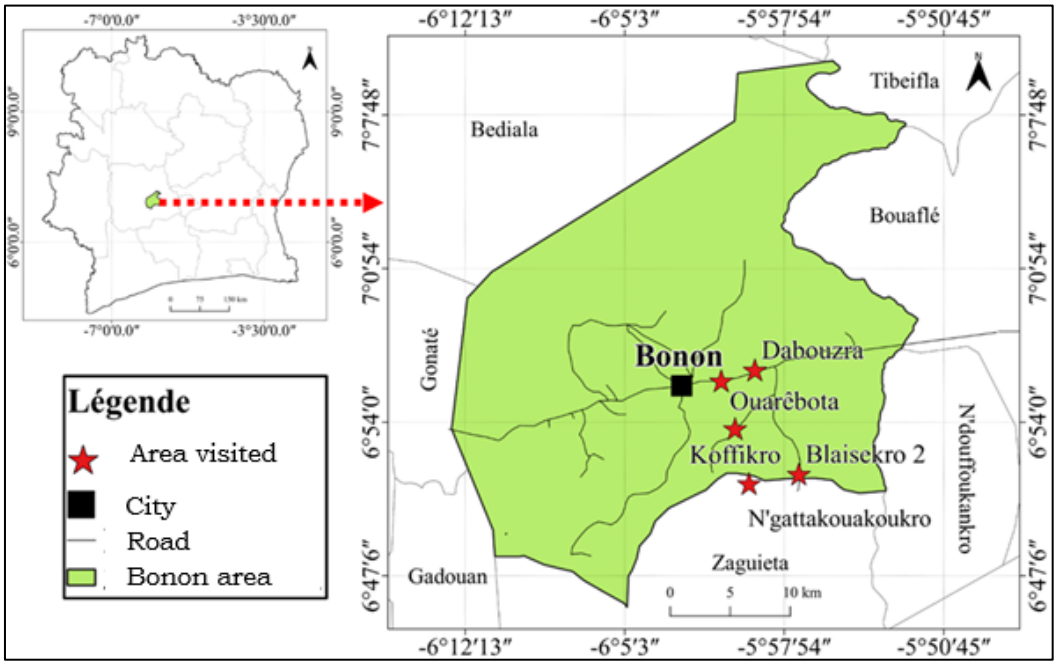


Figure 1 Breakdown of the surveyed localities

2.2. Sampling and data collection

Semi-structured ethnobotanical surveys were used to collect data. This method made it possible to interview cocoa farmers who could provide information on the supply services provided by PLSACs. In the absence of census data on the local population, we counted the number of cocoa farmers practising agroforestry. After this count, the sample to be surveyed was drawn up by quota, applying a 10% sampling rate to the number of cocoa farmers practising agroforestry in each surveyed village. As a result, a total of 50 farmers from the Bonon sub-prefecture were interviewed. The respondents included men and women of various ages, levels of education and ethnicities from different localities.

During the surveys, the collected information mainly concerned the names of the woody species spared in their plantations and the different parts of the woody plants used (leaf, bark, root, trunk, fruit, seed, others to be specified). The questionnaire also covered the categories of supply services provided by the woody species (food, medicinal, construction, fodder or other).

2.3. Data processing and analysis

Determining the endogenous knowledge of the supply services provided by PLSACs

The nomenclature of the plant species collected from riparian populations followed [25] while species names were based on the APG 4 system. The botanical families of the species were determined using reference documents such as the flora of Ivory Coast by [26 ; 27] and APG 4. The frequency of citation (Fc) of a species, the part of the species used or a category of service provided is expressed as a percentage (%) and is estimated by the following formula :

$$Fc = \frac{(Ni \ x \ 100)}{Ne} \qquad \ldots\ldots\ldots \quad \text{(Equation 1)}$$

Where *Ni* is the sum of citations for a species, part used, use or category of supply service provided and *Ne* is the sum of citations for all species, parts used, uses or categories of service provided. When Fc approaches 0, the species or part of the species is poorly used and the provisioning service is minimally provided. Conversely, the opposite trend is observed when F tends towards 100.

The Sankey diagram was constructed to illustrate the relationships between supply services and the plant parts used by farmers. The diagram was produced using RStudio software version R.3.5.2.

Identification of Sociodemographic Factors Influencing Local Knowledge on Provisioning Services Provided by PLSAC

First, the Fidelity Index of supply services was calculated according to ethnicity and locality and a Correspondence Factorial Analysis (CFA) performed on the matrix obtained to describe the associations between these parameters and PLSAC supply services. The CFA was performed using RStudio 3.5.2. software with the 'FactoMineR' package [28].

Secondly, the number of supply services cited by each respondent was used to assess the influence of socio-demographic characteristics (gender, age class, level of education, ethnicity and locality) on local knowledge of the services provided by the species. To this end, a generalised linear Poisson model was used to test the effect of socio-demographic characteristics on the number of services cited. The saturated model (containing the main effects of all the factors and their possible interactions) was specified first. The parsimonious model, containing fewer factors, was then selected.

3. Results

3.1. Diversity of PLSACs providing supply services

The respondents listed 53 species belonging to 43 genera and 23 botanical families that provide them with supply services (Table 1). The most represented botanical families are Moraceae (18.87 %), Sterculiaceae (9.43 %) and Rutaceae (7.55 %). In contrast, Clusiaceae, Combretaceae, Lauraceae, Meliaceae, Mimosaceae, Myrtaceae, Rubiaceae, Sapotaceae and Verbenaceae are the least represented botanical families, with a frequency of 1.89 % each (Figure 2). The species most cited by farmers are fruit species such as *Mangifera indica* (10.13 %), *Elaeis guineensis* (8.57 %), *Persea americana* (7.01 %) and *Citrus sinensis* (6.62 %). *Artocarpus heterophyllus*, *Cordia platythyrsa*, *Cordia senegalensis*, *Delonix regia*, *Ficus lutea*, *Ficus mucuso*, *Ficus religiosa*, *Garcinia afzelii*, *Mansonia altissima* and *Spondias mombin* are the species with the lowest citation frequencies (0.13 %) (Table 1).

The people of the Bonon sub-prefecture identified five (05) areas in which they use PLSACs (Figure 3). These are food, construction, fodder, medicine and cosmetics. Food and medicine were the services most frequently cited by the population, with frequencies of 48.18 % and 31.04 % respectively. The cosmetic service is the least represented (0.65 % of citations).

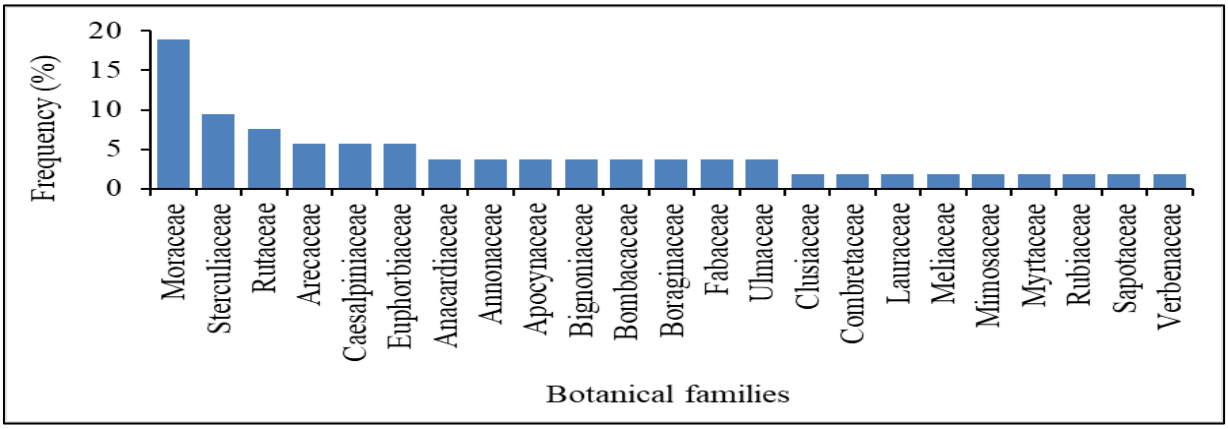


Figure 2 Botanical families of species used by cocoa farmers in the Bonon sub-prefecture

Table 1 Frequency of PLSAC citations identified

Species	Family	Frequency of quotation (%)
Mangifera indica	Anacardiaceae	10.13
Elaeis guineensis	Arecaceae	8.57
Persea americana	Lauraceae	7.01
Citrus sinensis	Rutaceae	6.62
Morinda lucida	Rubiaceae	5.84

Psidium guajava	Myrtaceae	4.42
Milicia excelsa	Moraceae	3.77
Cola nitida	Sterculiaceae	3.51
Ficus exasperata	Moraceae	3.51
Citrus limon	Rutaceae	3.38
Nesogordonia papaverifera	Sterculiaceae	2.99
Ricinodendron heudelotii	Euphorbiaceae	2.86
Newbouldia laevis	Bignoniaceae	2.73
Alstonia boonei	Apocynaceae	2.47
Triplochiton scleroxylon	Sterculiaceae	2.47
Tectona grandis	Verbenaceae	2.21
Annona muricata	Annonaceae	1.95
Citrus reticulata	Rutaceae	1.95
Ficus sur	Moraceae	1.95
Parkia biglobosa	Mimosaceae	1.95
Ceiba pentandra	Bombacaceae	1.69
Antiaris toxicaria	Moraceae	1.56
Citrus maxima	Rutaceae	1.56
Azadirachta indica	Meliaceae	1.43
Millettia zechiana	Fabaceae	1.43
Vitellaria paradoxa	Sapotaceae	1.3
Xylopia aethiopica	Annonaceae	1.3
Artocarpus altilis	Moraceae	1.04
Cocos nucifera	Arecaceae	0.91
Tamarindus indica	Caesalpiniaceae	0.78
Holarrhena floribunda	Apocynaceae	0.65
Sterculia tragacantha	Sterculiaceae	0.65
Baphia nitida	Fabaceae	0.52
Bauhinia thonningii	Caesalpiniaceae	0.52
Margaritaria discoidea	Euphorbiaceae	0.52
Terminalia superba	Combretaceae	0.52
Bombax buenopozense	Bombacaceae	0.39
Jatropha curcas	Euphorbiaceae	0.39
Borassus aethiopum	Arecaceae	0.26
Celtis zenkeri	Ulmaceae	0.26
Kigelia africana	Bignoniaceae	0.26
Milicia regia	Moraceae	0.26
Trema guineensis	Ulmaceae	0.26

Artocarpus heterophyllus	Moraceae	0.13
Cordia platythyrsa	Boraginaceae	0.13
Cordia senegalensis	Boraginaceae	0.13
Delonix regia	Caesalpiniaceae	0.13
Ficus lutea	Moraceae	0.13
Ficus mucuso	Moraceae	0.13
Ficus religiosa	Moraceae	0.13
Garcinia afzelii	Clusiaceae	0.13
Mansonia altissima	Sterculiaceae	0.13
Spondias mombin	Anacardiaceae	0.13

Farmers in Bonon sub-prefecture use **eight plant parts** from woody species to meet their needs. These are branches. bark. leaves. fruit. seeds. roots. sap and trunk. The plant parts most frequently mentioned were fruit (43.64 %) and leaves (19.22 %). The least cited parts are roots. sap and branches. with frequencies of 3.12 %. 1.56 % and 0.91 % respectively (Figure 3).

For food purposes. Farmers use four plant organs : leaves. fruit. seeds and sap. In medicinal. they used the bark. leaves. fruit and roots. The branches. seeds and trunks of species are primarily used for construction. For fodder. only the leaves are used. and for cosmetics. three plant parts (fruit. leaves and bark) are used. In addition. based on the number of parts used by farmers. 15 categories of supply services are provided by woody plants in cocoa-based agrosystems in the sub-prefecture. These include four service categories for food and medicine. three for construction and cosmetics. and a single service category for fodder (Figure 3).

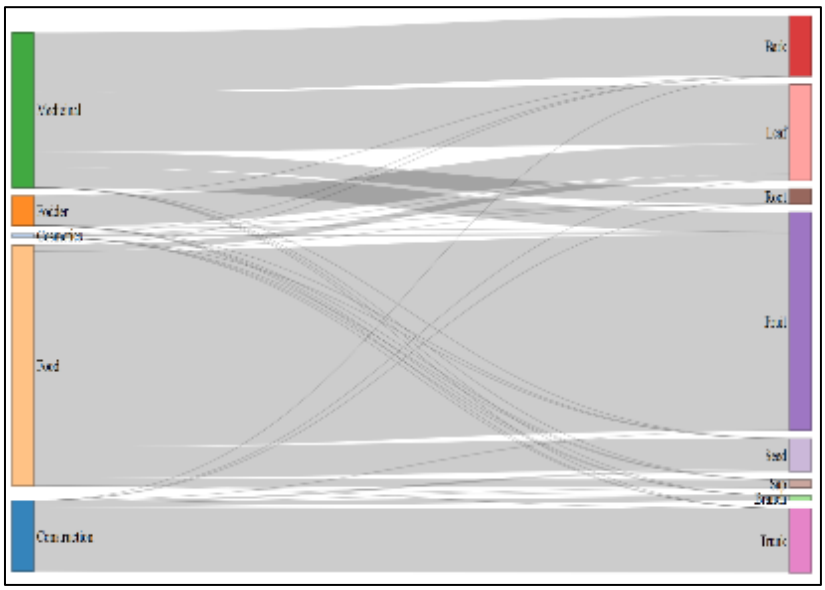


Figure 3 Types of supply services provided in connection with PLSAC bodies

A total of 21 species. belonging to 17 genera and 12 families. are used by the surveyed populations for food purposes through the consumption of leaves. fruit and plant sap (Table 2). They represent 39 % of all species cited for all uses. The food species with the highest fidelity indices are *Mangifera indica* (100%). *Citrus sinensis* (98%). *Elaeis guineensis* (96%) and *Persea americana* (96%). Conversly. *Artocarpus heterophyllus*. *Bombax buenopozense*. *Spondias mombin* and *Sterculia tragacantha* with a loyalty index equal to 2% are the least cited food species. There are 19 species used for their fruit. with *Mangifera indica* (100%). *Citrus sinensis* (98%) and *Persea americana* (96%) having the highest fidelity index. Two species are used for their leaves. These are *Bombax Buenopozense* (02%) and *Ceiba pentandra* (16%). Only one species. *Elaeis guineensis* is consumed for its seeds. with a fidelity index of 96%. In addition. the sap of this species is also used for human consumption with a fidelity index of 24% (FI = 24%).

Table 2 Species used for each type of supply service provided by woody species

Species	Al_Fe	Al-Fr	Al_Gr	Al_Se	Cons-Br	Cons_Gr	Cons_Tr	Cos_Ec	Cos_Fe	Cos_Fr	Four_Fe	Med_Ec	Med_Fe	Med_Fr	Med_Ra	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 sur	-	-	-	-	-	-	-	-	-	-	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
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
Total	2	19	1	1	2	1	15	1	1	1	6	23	25	8	7	

Al = Food ; Med = Medicinal ; Cons = Construction ; Four = Fodder ; Cos = Cosmetic ; Fe = Leaf ; Fr = Fruit ; Ec = Bark ; Ra = Root ; Tr = Trunk ; Gr = Seed ; Se = Sap ; Br = Branch ; x = Present ; - = Absent.

For medicinal use. 29 species divided into 27 genera and 19 families are used by farmers in the Bonon sub-prefecture (Table 2). They represent 54.72% of all the species cited by farmers.

The species used for medicinal purposes with the highest fidelity indices are *Morinda lucida* (56%). *Mangifera indica* (48%). *Newbouldia laevis* (22%) and *Tectona grandis* (22%). while those with the lowest fidelity indices are *Celtis zenkeri*. *Citrus maxima*. *Kigelia africana*. *Milicia excelsa* and *Trema guineensis*. each with a fidelity index of 2%. Regarding plant parts used. farmers utilize 23 species for their bark. 25 species for their leaves. eight (8) species for their fruits. and seven (7) species for their roots. Among the species used for their bark. those with the highest fidelity indices are *Morinda lucida* (50%). *Mangifera indica* (46%) and *Alstonia boonei* (20%). *Morinda lucida* (20%). *Psidium guajava* (18%). *Tectona grandis* (16%). *Araridatcha indica* (16%) and *Newbouldia laevis* (16%) have the highest fidelity indices among species whose leaves are used for medicinal purposes. As for the fruits. *Xylopia aethiopica* (16%). *Citrus limon* (12%) and *Tectona grandis* (12%) have the highest fidelity indices. Of the seven species used for their roots. *Morinda lucida* and *Newbouldia laevis* have the highest fidelity indices. equal to 10% and 7% respectively.

For construction. 17 species belonging to 13 genera and 09 families are commonly used (Table 2). They represent 26.42% of all the species cited by farmers. The most frequently used species were *Milicia excelsa* (54%). *Nesogordonia papaverifera* (40%). *Triplochiton scleroxylon* (38%) and *Antiaris toxicaria* (18%). In contrast. *Celtis zenkeri*. *Delonix regia*. *Garcinia afzelii* and *Mansonia altissima* are the least popular. each with a fidelity index of 02%. Regarding plant parts. the branches of *Elaeis guineensis* and *Baphia nitida* are used for construction. with fidelity indices of 08% and 06%. *Elaeis guineensis* is the only species whose seed is used for construction. with a fidelity index of 3%. As for the trunk. 15 species are used. with *Milicia excelsa* (54%). *Nesogrodonia papaverifera* (40%) and *Triplochiton scleroxylon* (38%) being the most popular.

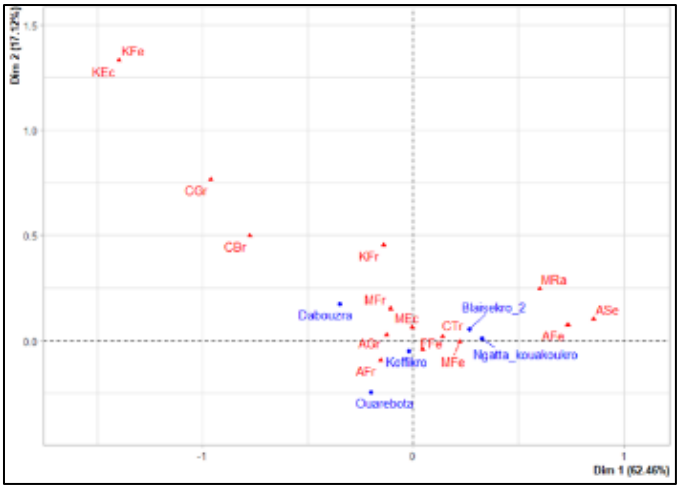
In terms of forage Six (06) species (*Ficus exasperata*. *Ficus sur*. *Bombax buenopozense*. *Ficus lutea*. *Ficus mucuso* and *Ficus religiosa*) are used by farmers (Table 2). *Ficus exasperata* (54%) and *Ficus sur* (30%) are the most used by farmers. They account for 11.32% of all the species cited.

For cosmetics. the bark. leaves and fruit of a single species (*Vitellaria paradoxa*) are used by farmers. This species has a loyalty index of 6% (Table 2). The species with the highest number of uses are *Vitellaria paradoxa*. *Elaeis guineensis*. *Holarrhena florinbunda* and *Sterculia tragacantha*. with 6 and 4 uses respectively (Table 2). *Vitellaria paradoxa* is valued for both cosmetic and medicinal purposes. utilizing its bark. leaves. and fruit. *Elaeis guineensis* serves multiple purposes : its seed and sap are consumed as food. while its branches and seed are used for construction. *Holarrhena floribunda* is exclusively used for medicinal purposes. with its bark. leaves. fruit. and roots all playing a role. Similarly. *Sterculia tragacantha* is used for both food and medicine : its leaves are consumed. while its bark. leaves. and roots are used medicinally.

3.2. Socio-demographic factors influencing knowledge of woody species in agroforestry systems

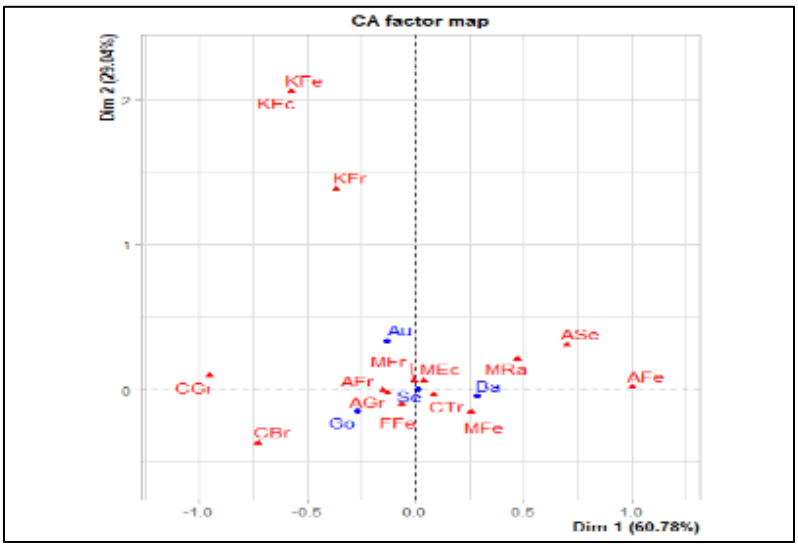
The factorial correspondence analysis (FCA) shows that the first two axes account for 79.58% of the variance in the relationships between the surveyed localities t and the supply services provided by the agrosystems (Figure 4). Three main groups of relationships were determined through the CFA. Examination of the factorial design reveals an axis 1 which accounts for 62.46% of the variance in the information and contrasts group 1 (G1) with group 2 (G2). On the positive side. this axis describes G1 representing the communities of Blaisekro 2 and N'Gatta Kouakoukro using the sap and leaves of woody plants for food and the leaves and roots of woody plants for medicinal uses. On the negative side. axis 1 characterizes G2. reflecting the populations of Dabouzra who derive food and construction materials from the leaves and branches of woody plants. respectively. Opposite axis 1 is axis 2. which accounts for 17.12% of the variance in information. Group 3 (G3) on the negative side of axis 2 shows Ouarebota farmers using bark for cosmetics and plant leaves for fodder. The factorial correspondence analysis (FCA) shows that the first two axes account for 89.82% of the variance in the relationships between ethnic groups and the supply services provided by agrosystems (Figure 5). Three main groups of relationships were identified. On axis 1 (60.78% of the variance of the information). on the positive side. we distinguish the Baoulés who benefit from food and medicinal services. On the food side. they use leaves and sap. while on the medicinal side. the leaves and roots of woody plants are used.

On the same axis (on the negative side). the indigenous Gouro benefit from food services (based on fruit) and construction (based on branches and seeds). On axis 2 (29.04% of the information variance). the other ethnic groups are characterized by their use of the bark. leaves and fruit of woody plants mainly for cosmetic purposes.



In blue. the localities investigated ; in red. the provisioning services provided by woody species.; Ase = Sap used in food; AFe = Leaf used in food; MRa = Root used in medicine; MFe = Leaf used in medicine; CTr = Tree trunk used in construction; AFr = Fruit used in food; AGr = Seed used in food; MEc = Bark used in medicine; MFr = Fruit used in medicine; KFr = Fruit used in construction; CBr = Branch used in construction; CGr = Seed used in construction; KEc = Bark used in cosmetics; KFe = Leaf used in cosmetics.

Figure 4 Factor map showing the distribution of supply services according to the localities surveyed



In blue. the uses of woody plants; in red. the supply services provided by woody species.; Ba = Baoulé; Go = Gouro; Se = Sénoufo; Au = Others; Ase = Sap used in food; AFe = Leaf used in food; MRa = Root used in medicine; MFe = Leaf used in medicine; CTr = Tree trunk used in construction; AFr = Fruit used in food; AGr = Seed used in food; MEc = Bark used in medicine; MFr = Fruit used in medicine; KFr = Fruit used in construction; CBr = Branch used in construction; CGr = Seed used in construction; KEc = Bark used in cosmetics; KFe = Leaf used in cosmetics.

Figure 5 Factor map showing the distribution of supply services based on ethnicity

In addition. the generalised linear Poisson family model revealed that the locality. level of education and ethnicity of the respondents influence endogenous knowledge on the number of supply services provided by woody species in cocoa-based agroforestry systems (Table 3). The people of Blaisekro 2 reported the highest number of uses. while the people of Dabouzra reported the lowest. In addition. respondents with secondary education reported more uses than those with primary education and those with no education at all. Finally. the Senoufos and Baoules listed more uses for woody species than the other communities. Howether. unlike education level. ethnicity and locality. which showed some differentiation in knowledge of the provisioning services provided by woody species. gender and age showed no effect. In fact. no significant difference was recorded in the number of uses cited by men and women on the one hand. and between young people. adults and the elderly on the other.

Table 3 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]
Gender (Pr = 0.61)	
Men	15.58 ± 5.39
Women	13.80 ± 3.42
Age group (Pr = 0.47)	
Young	16.25 ± 7.17
Adult	14.95 ± 4.68
Old	15.37 ± 4.48
School enrolment (Pr = 0.02)	
No	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]
Other	14.75 ± 5.12 [b]

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

4. Discussion

4.1. Diversity of supply services provided by PLSACs

The aim of this study was to assess local community's knowledge of the supply services provided by PLSACs for their sustainable conservation.

Surveys revealed that 53 woody plants in cocoa-based agroforestry systems provide supply services to the people of Bonon. This number of species associated with cocoa plantations highlights the importance of agroforestry systems in conserving biodiversity [29 ; 30] and improving people's quality of life through the services they provide [31 ; 32]. With population growth and the increasing need for farmland. few woody plants are spared when crops are cleared [33]. This is the case for full-sun cropping systems in which rural populations retain almost no tree species [34 ; 35]. In addition. the variability of species associated with cocoa-based agroforestry systems is thought to be due to several factors such as the socio-demographic characteristics (age. gender. membership of an ethno-cultural group and level of education) of farmers [36 ; 37]. farm size [38 ; 39]. the ecological services they provide [40 ; 12] and the diversification of income sources [41 ; 42]. The diversity of species associated with cocoa-based agroforestry systems used by local populations

has also been noted in cocoa farms in other departments of Ivory Coast. such as Agnibilékro [20]. San Pédro [19]. Man [43]. Gagnoa [44]. etc. and in several other countries such as Benin [45]. Cameroon [30 ; 46]. Nigeria [47]. Togo [42] and the Democratic Republic of Congo [29].

In addition. woody plants in cocoa-based agroforestry systems offer five categories of supply services to farmers in Ivory Coast's second largest cocoa-producing area. These are medicinal. food. construction. fodder and cosmetics.

The study revealed that several plant species are used by the people of Bonon department to meet their medicinal needs. 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 various pathologies. In fact. medicinal plants are precious resources for the vast majority of rural populations in Africa. where more than 80 % of the population rely on them for healthcare [48 ; 49]. Conventional healthcare facilities remain relatively expensive in relation to their purchasing power. and are rare in the various localities. The local population collect medicinal plants from their farms. which are known to relieve certain ailments. The species used for medicinal purposes in Bonon with the highest fidelity indices are *Morinda lucida*. *Mangifera indica*. *Newbouldia laevis* and *Tectona grandis.* The use of *Morinda lucida* has been documented by several authors. including [50] and [51]. The whole plant. leaves. stem bark and roots of this species are known for their medicinal properties. *Morinda lucida* is rich in vitamins A. K and E. alkaloids and flavonoids. which act as free radical scavengers. It also possesses anti-allergic. anti-inflammatory. antiviral. anti-proliferative. anti-carcinogenic. antibacterial and anti-plasmodium properties. The use of *Mangifera indica* in traditional medicine has also been proven worldwide. Indeed. this species is prized in several countries around the world (India. China. Thailand. Indonesia. Pakistan. Mexico. Brazil. Bangladesh. Nigeria. Philippines. etc.) for its therapeutic virtues [52 ; 53]. These authors have shown that *Mangifera indica* has antidiabetic. antioxidant. antiviral. anti-inflammatory. antifungal. anthelmintic. antiparasitic. anticancer. anti-HIV. anti-bone resorption. antispasmodic. antipyretic. antidiarrhoeal. immunomodulatory. hypolipidaemic. antimicrobial. hepatoprotective and gastroprotective properties. As for *Newboulda laewis*. its flowers. stems and roots are mainly used in traditional African medicine for the treatment of numerous illnesses and conditions such as diabetes [54 ; 55]. hypertension [55]. skin diseases. ulcers [56 ; 57]. tumours. infectious diseases. inflammation. dysentery. sickle cell disease [58 ; 59] and sexual impotence. Other notable species are used in traditional pharmacopoeia. namely *Alstonia boonei*. *Ceiba pentendra. Capsidium guava*. *Artocarpus heterophyllus. Alstonia boonei*. The latter species is recognised for its effectiveness in treating malaria [60]. *Ceiba pentendra* is reputed to treat headaches. dizziness. constipation. mental disorders. fever. hypertension and diabetes [61 ; 62]. In Cameroon. almost all organs of *Ceiba pentandra* are used to treat numerous illnesses such as sexually transmitted diseases (syphilis. gonorrhoea]. fever and skin diseases [63] and Buruli ulcer [64]. In Nigeria. the leaves. bark. shoots and roots are widely used [65].

The findings of this study reveal a variation in knowledge of the services provided by plants across different countries. The results also showed that In Bonon. leaves are the most widely used plant parts for medicinal purposes. This high rate of use of leaves could be explained. on the one hand. by the ease and speed of harvesting and. on the other. by the fact that they are the storage site for the secondary metabolites responsible for the biological properties of medicinal plant species [66 ; 67]. Other research works such as those by [68] and [69] abound in the same direction and reveal that leaves have been mentioned as the most widely used organs in traditional pharmacopoeia. Furthermore. although the results of this study show that roots and branches are the least used plant organs. their removal can be detrimental to the viability of the populations of the species from which they are taken [70].

The populations surveyed in the Bonon department use 21 woody species associated with cocoa-based agroforests for their food. The importance of plant species in the human diet in Africa has also been revealed in numerous studies [71 ; 72]. Thus. the species left in plantations enable rural populations to meet their vital needs by consuming leaves (*Bombax buenopozense*. *Ceiba pentandra.* etc.). fruits (*Annona muricata. Artocarpus altilis. Parkia biglobosa. Ricinodendron heudelotii. Tamarindus indica*. etc.) and plant sap (*Elaeis guineensis*). The use of these plant organs (leaves. fruits. seeds. sap) for food has been documented by several researchers [73 ; 74]. Leaves are particularly valued for their rich content of vitamins A. B. C. E. and K. which are essential for the growth and maintenance of all cells and for the proper development of the foetus [75 ; 76]. Fruits contain numerous nutrients. These include dietary fibre. vitamins (A. C. B2. B6. K. folic acid. etc.). minerals (potassium. iron. magnesium. calcium. copper. etc.) and several antioxidant compounds [77 ; 78]. The sap used is that of the palm tree. commonly known as palm wine. which is known to be rich in several nutrients such as vitamins C. K. P. Mg and various sugars [7]. It is non-toxic and has anti-inflammatory and antioxidant activities. which would justify its traditional use [79 ; 80]. Palm wine is also used in medicine and rituals. This drink is used in several countries other than Ivory Coast [81]. such as Benin [23b]. Guinea Bissau [82] and Senegal [83]. In addition. the study showed that the food species with the highest fidelity indices are fruit species such as *Mangifera indica*. *Citrus sinensis*. *Elaeis guineensis* and *Persea americana*. which are cultivated species *that are* often introduced. The high use of these species has been strongly demonstrated by several authors. including [84] and [85].

In contrast. the species least used in the study area are *Artocarpus heterophyllus*. *Bombax buenopozense*. *Spondias mombin* and *Sterculia tragacantha*. This low use of these species is believed to result from their low abundance in the environment and/or a lack of awareness of the food services they could provide for local populations.

Six forage species (*Ficus exasperata*. *Ficus sur*. *Bombax buenopozense*. *Ficus lutea*. *Ficus mucuso* and *Ficus religiosa*) are used by farmers. with *Ficus exasperata* and *Ficus sur* being the most popular. Ficus species are renowned for their fodder properties. They are used in Ivory Coast [86]. Senegal [87] and Ghana [88] to feed cattle. goats. and other livestock. The lack of mention of this service may be due to the low level of involvement of people in the Bonon area 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.

For cosmetics. the bark. leaves and fruit of a single species (*Vitellaria paradoxa*) are used by farmers in the Bonon department. The species produces berries similar to small avocados with an edible pulp. from which butter called shea butter is extracted and used for skin care [89 ; 90]. In addition to this use. shea butter is used in the preparation of food [91 ; 92]. The limited use of *Vitellaria paradoxa* by people in the Bonon department is thought to be due either to the low density of this species in the Bonon cocoa trees or to people's ignorance of its uses. *Vitellaria paradoxa* is frequently found in the northern part of Ivory Coast. hence its widespread use in Sahelian countries such as Burkina Faso [93]. Mali [90]. Togo [94]. Benin [95]. Ghana [96] and Uganda [97].

4.2. Socio-demographic factors influencing endogenous knowledge

The analyses revealed that knowledge of the supply services provided by PLSACs is influenced by the locality. level of education and ethnicity of the respondents. This variation in knowledge between ethnic groups reveals the existence of a cultural heritage within the same ethnic group and/or the lack of sharing of knowledge from one ethnic group to another. Traditional knowledge is acquired through practices and beliefs that are passed down from generation to generation [98 ; 99]. This observation corroborates that of several authors who have reported significant ethnic variation in the knowledge and use value of *Tamarindus indica* in Togo [5]. Niger [100]. Ethiopia [101]. Uganda [102]. *Adansonia digitata* in Togo [103]. *Triplochiton scleroxylon* in Benin [104] and several other species in Burkina Faso [105]. Ethnicity therefore remains one of the major factors differentiating plant use and knowledge within communities. The variation in knowledge of supply services depending on the locality could be attributed to the dominance of certain ethnic groups in the locality. Indeed. several authors. including [106] and [17]. have shown that villages are sometimes inhabited by several ethnic groups. but that there is almost always one ethnic group that is numerically dominant or has been settled there longer. This is the case. for example. in Koffikro. Blaisekro 2 and N'Gatta kouakoukro. which are dominated by the Baoule. while 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 of woody plants for medicinal purposes by the populations of Blaisekro 2 and N'Gatta Kouakoukro. which are dominated by the same Baoule ethnic group. The locality of the respondents was also listed by [107] as a differentiating factor in knowledge of the services provided by woody species. Respondents with secondary education reported more uses than those with primary or no education. This result shows the importance of formal learning in expanding knowledge about plant resources.

5. Conclusion

This study assessed farmers' endogenous knowledge of the services provided by woody species in cocoa-based agroforestry systems. It was found that 53 woody species of CFAS provide 15 categories of supply services to cocoa farmers in the second epicentre of cocoa production in Ivory Coast. In addition. locality. ethnicity and level of education were listed as differentiating factors in knowledge of the services provided by woody species. Integrating this local knowledge into forest management programmes 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 carried out on prioritising the conservation of woody species associated with cocoa-based agroforestry systems providing supply services to the populations of the Bonon department.

Compliance with ethical standards

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Disclosure of conflict of interest

All of the authors declare that there are no conflicts of interest in connection with this paper.

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.

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