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Diversity and availability of woodfuel used in rural areas by Koulango and Lobi populations on Eastern periphery of Comoé National Park (Côte d'Ivoire)

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ABSTRACT: This study aims to investigate the diversity of species and assessing the availability of woodfuel plants used in rural areas by Koulango and Lobi populations on Eastern periphery of Comoé National Park. Two surveys were conducted in ten villages: a house-to-house interview and an individual walk-in-the woods interview with some informants. Frequency of citation use value were used to estimate the local knowledge of woodfuel plants. Floristic inventory based on random plot sampling method was applied on 200 small squares. A qualitative analysis through the households has showed that firewood was the fuel most used in households. Among the useful species, 6 plants were the most use species by both local populations. According to plants availability, in Comoé National Park, juvenile individual of 12 plants such as *Berlinia grandiflora, Burkea africana* and *Vitellaria paradoxa* were the most abundant species. Adult individual of plants were the most abundant species. In rural area, 8 plants like *Daniellia oliveri,* and *Vitellaria paradoxa* were the most abundant species. *Annona senegalensis, Saba senegalensis* and *Vitellaria paradoxa* were the 3 most abundant species. However, juvenile individual and adult individual of 16 plants such as *Bombax costatum Margaritaria discoidea* and *Raphia sudanica* were very rare in both areas (CNP and rural area).
The study pointed out the importance of use value as tool to select the species which conservation must be emphasized in the management plans to meet not only the need of the populations but also to improve the conservation statute of the species. Finally, this study raises the fact that there is an urgent need to develop methods for a sustainable use of these plants from Eastern periphery of Comoé National Park.

KEYWORDS: Wood fuel plants, Use value, Abundance, Comoé National Park, Côte d'Ivoire.

1 INTRODUCTION

In Côte d'Ivoire, Forest cover 8.14 million ha for 1960s [1]. According these authors, the 1980s and 2000s have respectively forest cover of about 2.6 million ha and 1.35 million ha. The forest area is almost reduced to a few shreds of secondary forests, isolated in a succession of plantations and fallow land [2]. These periods are characterized by high fragmentation and loss of rain forests in Côte d'Ivoire. Some factor could justify this situation. In Côte d'Ivoire, plants represent direct inputs to satisfy different household needs for food [3], medicine [4], materials for construction [5] and fuel [6]. Concerning fuel, it must also be noted that energy use depends upon their accessibility/availability as well as energy costs. Seen the poverty of developing countries and the price increase for petroleum products, firewood is still the most used fuel in rural areas, charcoal is mainly intended for large cities. Thus, the demand for fuelwood for cooking and heating is often cited as the most important cause of deforestation in developing countries [7]. However, people in any given community do not use and value all plant species equally [8]. Population growth in Côte d'Ivoire [9], particular population on Eastern periphery of Comoé National Park [10]. The Comoé National Park is the biggest protect area of Côte d'Ivoire [11]. With the increase of population on Eastern periphery of Comoé National Park, it is expected that the number of people relying on wood as their source of fuel will continue to rise. This high pressure exerted on forest resources and natural ecosystems in Northem Côte d'Ivoire [12] make it urgent to predict energy demand in the long run for policy adjustments. This investigation seem very important and aimed to evaluate diversity and avaibility of plants (in Comoé National Park and rural area) used like woodfuel by Koulango and Lobi populations on Eastern periphery of Comoé National Park.

2 METHODS

2.1 STUDY AREA

The Comoé National Park is located in the North-East of Côte d'Ivoire between 8°30' and 9°40' N and 3°10' and 4°20' W [10]; [13]. The Comoé National Park belongs to the geophysical region of the "Northern Plateaus", a vast peneplain with an average altitude of 300 m [14]. This group of level or softly undulated plateaus is locally dominated by some hills and barriers of green rocks with North-South orientation, whose altitude is between 500 and 600 m. With a tropical climate of a subhumid type, the hydrographic network of the CNP is almost entirely made up of the Comoé River from which it derives its name. Around 87 % of its total area are drained over a length of 200 km from North to South [11]; [13]. Its location in the transition area between the savanna and the Guinean forest zone gives it high biological diversity and a variety of landscapes [15]. It covers a total area of 1 149 150 ha and is one of the three links of the country's "ecological diagonal" [10]; [16]. Numerous scientific researches on CNP flora have lead to list of 620 plant species composed of 191 ligneous species (62 trees, 129 shrubs and vines) and 429 herbaceous Species including 104 grasses On a touristic level, it offers the best perspectives for viewing large fauna A large number of mammal's characteristic of the West African savanna was recorded in the Comoé National Park. Its estimate around 135 species of mammals including 68 large species, 27 rodent and insectivore species and 40 chiroptera species [11].

2.2 DATA COLLECTION

Data were through conducting semi-structured interviews with local residents and our field-based observations. Between September 2015 and April 2016, a semi- structured questionnaire was used to investigate ten Eastern periphery Koulango villages of Comoé National Park (Assoum 1, Bania, Biguilaye, Koflandé, Kointan, Kokpingué, Kounzié, Saye, Yalo, Vigoli,). Between August and December 2016 same manner was done in Lobi population in the same village. In each village a local language was used with the help of translator. Some household visits were carried out before population occupation of the day. Another household visits were carried out at the end of the day after locals came back from their occupation. The households were sampled opportunistically. To avoid recurrent information, each person (>18 years) per house was questioned individually. Three homes were hostile to our visit and refused to answer.

2.3 PLANT USE STUDY

2.3.1 HOUSE-TO-HOUSE SURVEYS

The first survey method was achieved during a house-to-house interview Koulango = 434 and 436 Lobi, age ranging from 18 to 75 years. In these surveys streets were selected at random and all households within those streets were approached by the interviewer moving from house-to-house [17]. According these authors, data arising will have limited bias and it should therefore be possible to extrapolate results from the sample as the total number of households in the community is known. The house-to-house surveys all included social housing. Questions were: What is the traditional energy do you use? Which plants do you use? Where do you collected them? How much do you cost them in other cases?

2.3.2 WALK-IN-THE WOODS METHOD

Before comparative study was carried out, information on plant names and uses was collected by walking around the village and nearby area with our traditional experts and guides. This exercise was known as the "walk in the woods". This is a standard ethnobotany method used to obtain information through the study of living plants [4]. This approach helped establish the credentials of our informants, identify any useful plants of the area not included in the comparative study, and improved the quality of the comparative data, by obtaining some names in advance that assisted identification of the herbarium specimens.

2.4 EVALUATION OF LOCAL KNOWLEDGE

There are several indices to scientifically estimate indigenous knowledge in a specific field [4]. However, the most commonly used are those based on informant consensus, i.e. the level of agreement among various interviewees These indices, using spontaneous quotations, are based on the principle that the greater the salience of a given plant or use in the community, the more likely it is to be mentioned [18]. In this study, we determined the level of knowledge of plant uses with frequency of citation (FC) and the intensity of use of the plants was calculated using the ethnobotanical use value.

2.4.1 FREQUENCY OF CITATION

One of the simplest and best known is the frequency of citation (FC), i.e. the number of informants who mentioned a given species. It is a good index to evaluate the credibility of collected information and the level of knowledge within a surveyed population [18].

The frequency of citation (FC) is calculated as [20]:

$$\mathrm{FC} = \frac{\mathrm{n}}{\mathrm{N}} \times 100$$

Where n is the number of persons cited species for a particular wood fuel and N is the total number of persons interweaved.

The frequency of citation is ranges from 0 to 100 (maximum importance).

The FC indicates the level of knowledge on use according to ethnic groups: $0 \leq FC < 25\%$: low level of knowledge, $25 \leq FC < 50\%$: enough level of knowledge, $50 \leq FC \leq 100\%$: very good level of knowledge

2.4.2 USE VALUE

In addition, the use value (UV) was calculated for each plant using. The importance of plant according to different ethnic groups was determined through the computation of the use value for each ethnic group [20]. This method is used by several authors [21]. The use value of a given species in a use category is represented by its mean use score within that category. It is calculated by the formula:

$$\mathrm{VU(i)} = \frac{\sum_{\mathrm{i}}^{\mathrm{n}} \mathrm{Sj}}{\mathrm{N}}$$

Where, UV (i) is the ethnobotanical use value of species i within a given use category, Si is the use score assigned by respondent and N is the number of respondents.

Two scores were set to assess the level of species used in each use category: 2 = very important or highly used; 1 = moderately important or medium used and 0 = species unimportant or without use.

The use value is ranges from 0 to 2 (maximum importance).

The UV indicates the intensity of use of the plants according to ethnic groups: $0 \leq UV < 0.66$: low intensity, $0.66 \leq UV < 1.2$: medium intensity, $1.2 \leq UV \leq 2$: very good intensity.

2.5 AVAILABILITY STUDY

This study aimed at evaluating availability of plants from Northern Côte d'Ivoire. Floristic inventory based on random plot sampling method was applied on 200 small squares (30 m x 30 m). In each small square, number of individuals of plant is enumerate. Finally, dbh was measured. In this study, all trees species with dbh < 3.18 cm are juvenile and we considered all trees species adult when dbh ≥ 3.18 cm (Fig. 1)

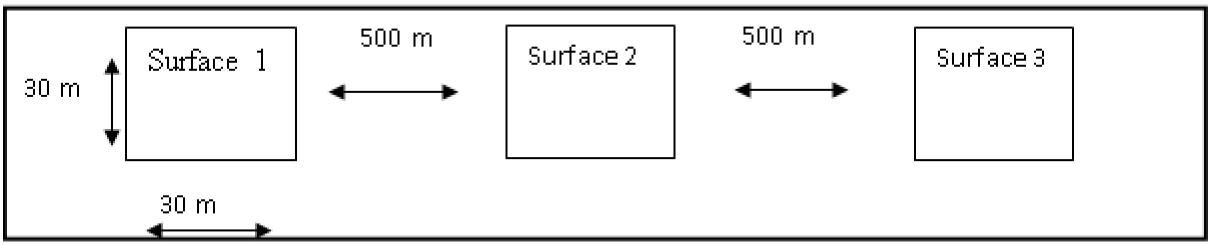

Fig. 1. Experimental dispositive instal in Comoé National Park and rural area.

The rarefaction index (RI) is calculated as:

$$Ri= (1-\frac{ni}{N})\ X\ 100$$

Ri rarefaction index of specie *i, ni* number of area where the specie *i* collected and *N* total number of areas. This index range to 0 à 100. It belonging to six classes (Table I). So, specie which rarefaction index is between 80 and 100% give evidence of rarely of this specie.

Table 1. Interpretation of rarefaction index value

Rarefaction index (%)	Characteristic
Ri < 10	Abundant specie
10 ≤ Ri < 20	Frequent specie
20 ≤ Ri < 40	Constant specie
40 ≤ Ri <60	Accessoiry specie
60 ≤ Ri < 80	Accidental specie
80 ≤ Ri ≤ 100	Rare specie

2.6 VOUCHERS IDENTIFICATION

The collected vouchers were identified at the Laboratory of Botany of Nangui Abrogoua University (Abidjan) with some document such as [22], [23], [24], [25]; [26]. Plant scientific name and confirmed at the Herbarium of Ivorian National Floristic Centre (ABJ). Voucher specimens were deposited at the Laboratory of Botany of Nangui Abrogoua University (Abidjan).

3 RESULTS

By Koulango and Lobi population, 62 plants belonging to 51 genera and 22 families are used to make firewood and charcoal. Many plants cannot be to use as firewood and charcoal. Wood of *Berlinia grandiflora* and *Daniellia oliveri,* contains too much moisture and must be dried. Women and children (Fig. 2) are most collectors and collected trees after rain season. They do not fell live trees for firewood. By Koulango and Lobi population, charcoal prices have been stable at around 100 F CFA per kilogram. The price of medium sack included 2500 F CFA to 5000 F CFA and the big sack cost 7500 F CFA to 10. 000 F CFA.

Fig. 2. Collectors of firewood in rural area by Koulango and Lobi

3.1 TYPE OF TRADITIONAL ENERGY USING IN HOUSEHOLDS

They are two traditional types of energy (Fig. 3 A and 3 B). Our research revealed that firewood (FC = 79.08%) is the dominant fuel type used by rural households. After firewood, 20.92 % of population used both (firewood and charcoal). But, in this study, nobody used only charcoal (Table 2).

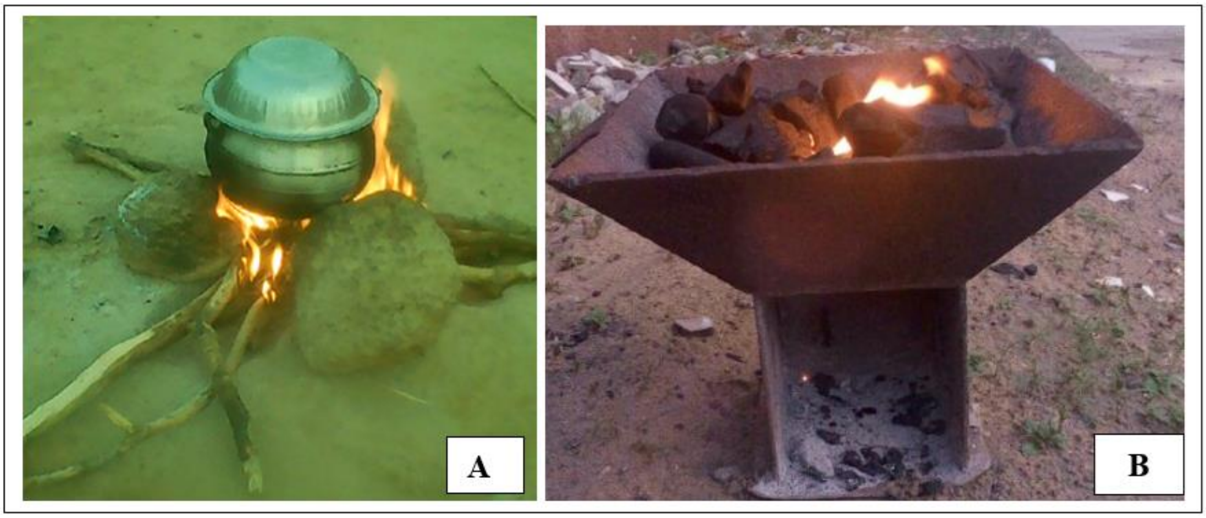

Fig. 3. Type of traditional energy using in households. A: firewood; B: Charchoal

Table 2. Fuel mixes in households

Fuel mixes	Proportion (%) in general	Proportion (%) by Koulango	Proportion (%) by Lobi
Only Fuelwood	79.08	35.86	43.22
Only Charcoal	0	0	0
Fuelwood and Charcoal	20.92	14.02	6.9

3.2 COLLECTION SOURCE

Koulango and Lobi collected trees to make firewood essentially in fallow (FC =61%) The second source is own farms (FC = 30.88). The last source where they collected trees in vegetation (FC = 8.12) after fire of bush (Fig. 4). All charcoal producers collected trees in vegetation.

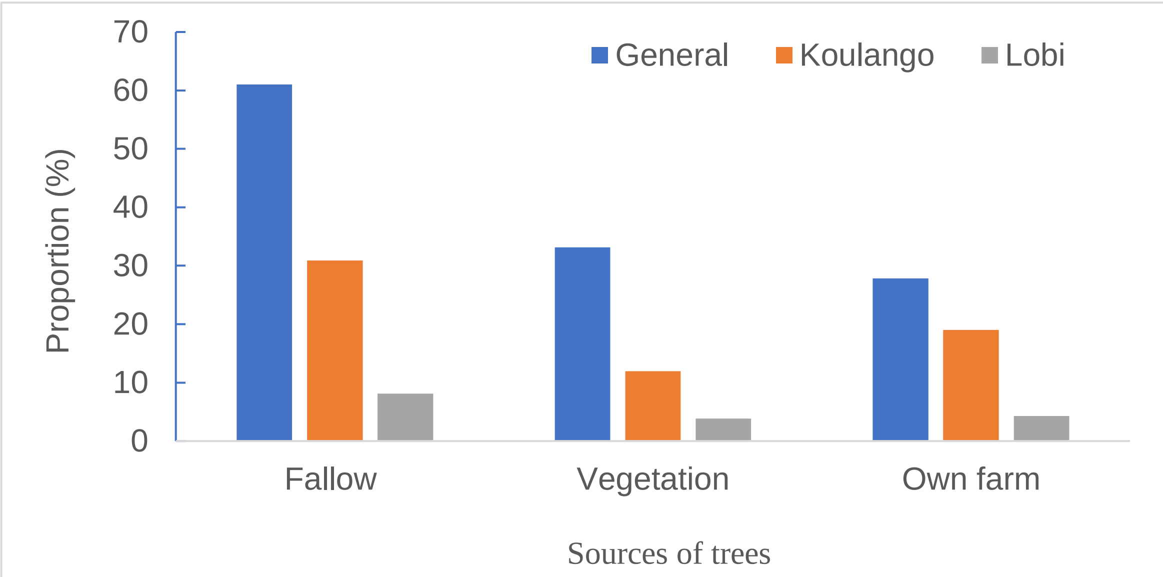

Fig. 4. Sources of trees collected to make firewood

3.3 FREQUENCY OF CITATION

Analysis of data based on their frequency of citation showed that, eight species level of knowledge had very well. They were *Vitellaria paradoxa* (FC = 85.15%), *Detarium microcarpum* (FC = 77.75%), *Pterocarpus erinaceus* (FC = 71.25%), *Terminalia avicennioides* (FC = 67.55%), *Isoberlinia doka* (FC = 63.85%), *Burkea africana* (FC = 63.75%), *Lophira lanceolata* (FC = 61.45%) and *Parinari curatellifolia* (FC = 60%). Without this first group many plants such as *Bobgunnia madagascariensis* (FC = 0.42%), *Lannea barteri* (FC = 0.48%) and *Margaritaria discoidea* (FC = 0.72%) level of knowledge were fair (Fig. 5).

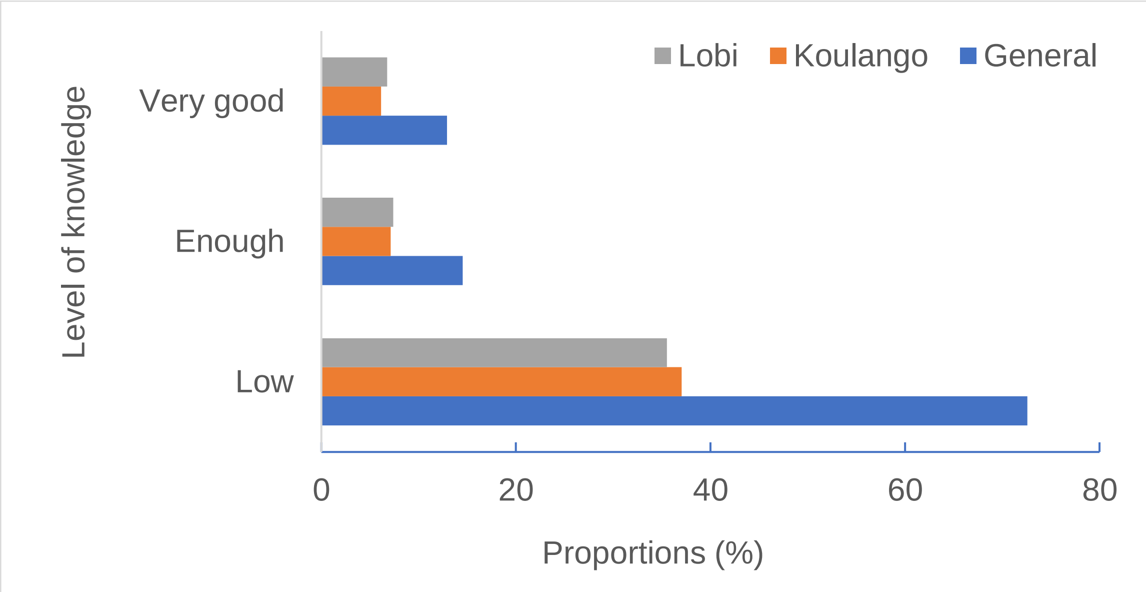

Fig. 5. Proportions of knowledge level of plant

3.4 PLANT USE VALUES

Among the use value, seven species were most commonly used (1.2 ≤ VU ≤ 1.78). For both ethnic groups, species with highest ethnobotanical use-values are: *Vitellaria paradoxa* (VU = 1.78), *Pterocarpus erinaceus* (VU = 1.48), *Detarium microcarpum* (VU = 1.47), *Isoberlinia doka* (VU = 1.24), *Terminalia avicennioides* (VU = 1.22), *Burkea africana* (VU = 1.2), *Lophira lanceolata* (VU = 1.2). Forty-seven species were most rarely used. *Berlinia grandiflora* (VU = 0.52), *Berlinia confusa* (VU = 0.02) and *Cassia sieberiana* (VU = 0.06) were range in this group (Fig. 6).

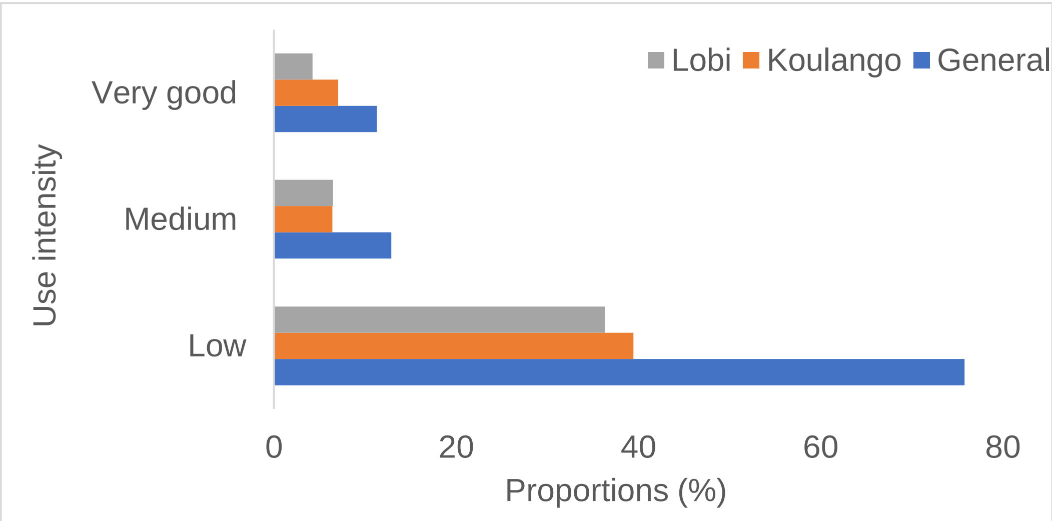

Fig. 6. Proportions of plants use intensity

3.5 IMPACT OF TREE HARVESTING FOR FUELWOOD

Many trees are collected to make firewood and charcoal by Koulango and Lobi. Parts use are branch) of plants are use. Firewood and charcoal use in rural areas has been concern about the environmental impact that is because collected firewood is mostly from deadwood or small branches, though charcoal is mainly produced from living trunks or branches.

3.6 SPECIE AVAIBILITY

A total of 200 sample plots (100 in CNP and 100 in rural areas) were established to study the plant species abundance in the study area. Concerning juvenile individual, in Comoé National Park, *Acacia dudgeonii, Annona senegalensis, Berlinia grandiflora, Burkea africana, Daniellia oliveri, Detarium microcarpum, Hymenocardia acida, Isoberlinia doka, Pericopsis laxiflora, Saba senegalensis, Terminalia avicennioides* and *Vitellaria paradoxa* were the 12 most abundant species. However, 16 plants such as *Adansonia digitata, Bombax costatum Lannea barteri, Margaritaria discoidea* and *Raphia sudanica* were very rare. In rural area, *Annona senegalensis, Burkea africana, Daniellia oliveri, Hymenocardia acida, Isoberlinia doka, Saba senegalensis, Terminalia avicennioides* and *Vitellaria paradoxa* were the 8 most abundant species. Except for these plants, 23 plants that *Adansonia digitata, Azadirachta indica, Blighia sapida, Flacourtia indica* and *Ceiba pentandra* were very rare (Fig. 7).

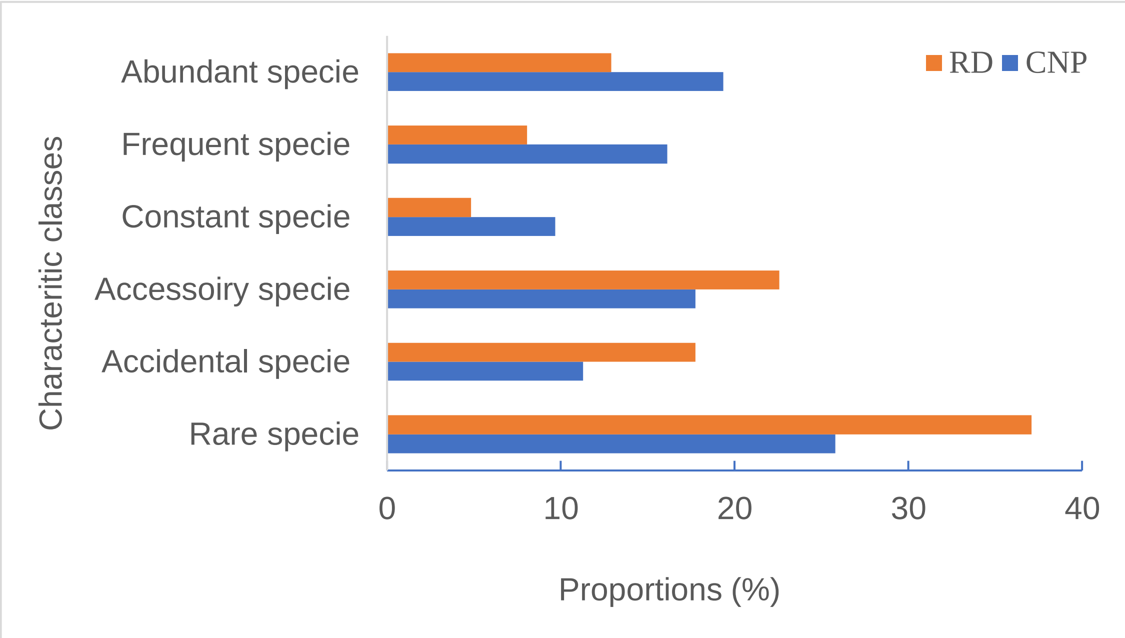

Fig. 7. Availability of Juvenile species (RD: Rural Domaine; CNP: Comoé National Park)

Concerning adult individual, in Comoé National Park, *Annona senegalensis, Daniellia oliveri, Hymenocardia acida, Isoberlinia doka, Terminalia avicennioides* and *Vitellaria paradoxa* were the 6 most abundant species. However, 23 plants such as *Adansonia digitata, Anogeissus leiocarpus, Bombax costatum, Ceiba pentandra, Flacourtia indica* and *Phoenix reclinata* were very rare. In rural area, *Annona senegalensis, Saba senegalensis* and *Vitellaria paradoxa* were the 3 most abundant species. Except for these plants, 23 plants that *Adansonia digitata, Anogeissus leiocarpus, Bombax costatum, Ceiba pentandra, Flacourtia indica, Phoenix reclinata* and *Vitex doniana* were very rare (Fig. 8).

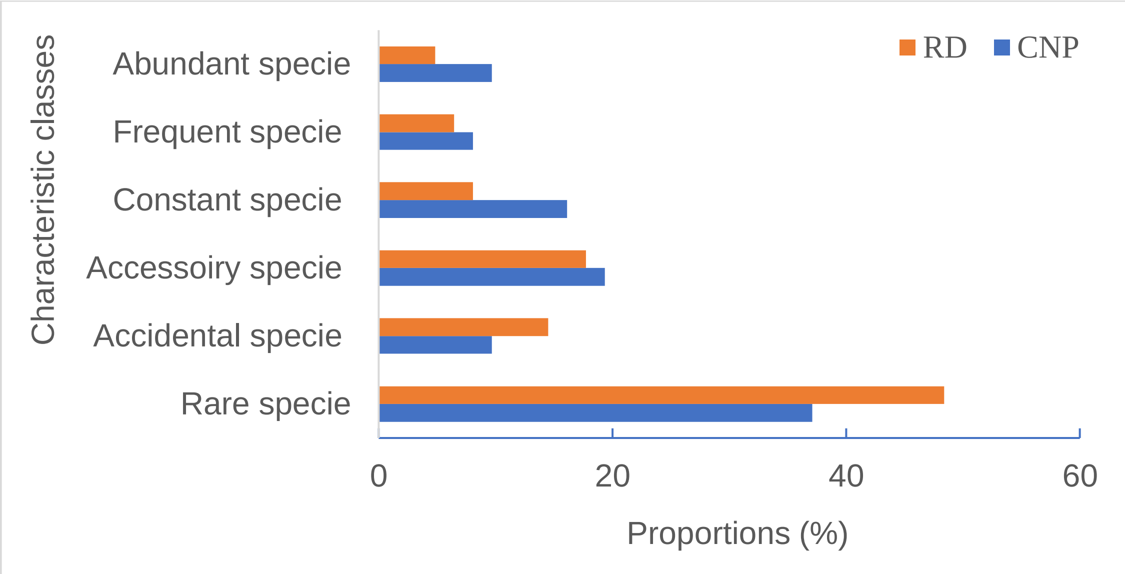

Fig. 8. Availability of adults species (RD: Rural Domaine; CNP: Comoé National Park)

4 DISCUSSION

Women and children collected trees after rain season. They do not fell live trees for firewood. The reasons for collecting fuelwood in this manner are several. First, live trees are difficult to cut down, especially when compared to the ease with which and dead branches are harvested. Second, live wood cannot be burnt immediately. The wood contains too much moisture and must be dried before it can serve as fuel. Wood from *Combretum spp*. is said to dry the fastest, and villagers report that it takes a minimum of a week under the hot season sun before it is combustible.

The proportions indicate the percentage of households using a particular fuel mix. Fuelwood is the most important source of domestic energy in the rural areas by Koulango and Lobi populations on Eastern periphery of Comoé National Park. This result could justify itself by the fact that several rural households cannot afford modern fuels such as liquefied petroleum gas (LPG) or electricity; hence, they resort to firewood [27]. The higher percentage depending on fuelwood further supports the earlier argument on heavy dependence on this energy source by households. Similarly, as reported by [28], the mix of fuelwood and charcoal comes second in terms of energy source for most rural households in Kakamega Forest, Western Kenya. However, the production and use of woodfuel (firewood and charcoal) is an important in Sub-Saharan Africa, close to 90% of the population rely on it as primary energy source [29]. Notably missing is the use of electricity or even liquefied petroleum gas; indicating clearly that households depend entirely on natural resource base for their energy source.

Firewood collection sites are generally fallow fields that will be cultivated again in the future. This firewood collection sites are corroborated by [30]. But, in Kakamega Forest, Western Kenya, population collected trees in own farms [28]. All charcoal producers collected trees in vegetation. But, in Uganda it difficult to identify the origin of trees that were cut to produce charcoal [31].

By Koulango and Lobi population, charcoal was selling. Its same observations in many areas. In sub-Saharan Africa, charcoal prices have been surprisingly stable at around 10 US cents ($0.10) per kilogram for the past couple of decades [32]. Moreover, the charcoal sector has considerable economic value for example, an estimated US$650 million and US$1.6 billion annually for the United Republic of Tanzania and Kenya, respectively [33]. In urban and rural Communities in Yedashe Township, the annual household of firewood and charcoal income ranged from US$720 to $24,000 [34].

The ethnobotanical use value is widely recognized as a reliable tool to quantify the relative importance of a species for a community [35]. Species with highest ethnobotanical use values for the two ethnic groups are: *Vitellaria paradoxa, Pterocarpus erinaceus, Detarium microcarpum, Isoberlinia doka, Terminalia avicennioides, Burkea africana* and *Lophira lanceolata*. According to [36], when the use value of a scarce species is high, it may reflect a high pressure on the species. This indication is expected to suggest specific conservation measures to avoid overexploitation. Caution should however be taken in interpreting the results of use values, because the method does not clearly distinguish between past, present and potential uses of the species [37].

Many trees are collected to make firewood and charcoal. All women observed during the course of the study collected fuelwood by breaking dead limbs and felling snags. Further, they reported that they do not fell live trees for fuelwood. This fuelwood collection technique is corroborated to some degree by [30]. Also, rural fuelwood demands may not be problematic at present, other concerns present themselves given current land management practices. [30] note that fuelwood is a by-product of agriculture. Some of the woody biomass cleared during agricultural field preparation is used as fuelwood. Whether tree harvesting for charcoal production causes deforestation [38]. Similarly, as reported by [39] and [34] studies in Myanmar have reported that firewood collection and charcoal production contribute to deforestation there. With population growth on Eastern periphery of Comoé National Park, Côte d'Ivoire [10], globally, the use of wood fuels has been growing in line. Because, the needs of a growing population in rural landscapes have driven exploitation of ecosystems, causing degradation of their services [29]. Accordingly, using of trunks or branches collected to charcoal contribute necessarily to deforestation. As [34] previously mentioned thing in urban and rural communities in Yedashe Township, Myanmar.

The most juvenile and adult abundant plants in both areas (CPN and rural area) were *Annona senegalensis, Terminalia avicennioides* and *Vitellaria paradoxa*. Among 16 plants (*Adansonia digitata, Azadirachta indica, Blighia sapida, Flacourtia indica* and *Ceiba pentandra*) in both areas were rare and threatened. Concerning the Comoé National Park, bush fires, plants intensity regeneration and sometime, agriculture contribute to the loss of plants. In rural area, overexploitation, agriculture, demographic pressure, grazing and bush fires contribute to the loss of indigenous plants. So, it is necessary to sensitize populations on quantity of plants must be collected. Plantings of some plants would help to restore the declining resources of many important species and could also have positive benefits on the environment.

5 Conclusion

This study revealed that 62 plants used as firewood and charcoal on Eastern periphery of Comoé National Park. The study through that deadwood or small branches were collected to firewood and trunks or branches were collected to charcoal. Generally, women and children collected trees for firewood in fallow fields and all charcoal producers collected trees in vegetation. The study clearly showed differences in use value of the species. Species with highest ethnobotanical use values for the two ethnic groups are: *Vitellaria paradoxa, Pterocarpus erinaceus, Detarium microcarpum, Isoberlinia doka, Terminalia avicennioides, Burkea africana* and *Lophira lanceolate*. Juvenile and adult individual of 16 plants such as *Adansonia digitata, Azadirachta indica, Blighia sapida, Ceiba pentandra* and *Flacourtia indica* were rare and threatened in both areas. This study raises the fact that there is an urgent need to develop methods for a sustainable use of these plants on Eastern periphery of Comoé National Park.

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