ISSN: 3064-9846
Research Article
Journal of Agricultural, Earth and Environmental Sciences

Characterization of Managed Ecosystems in Buffers Zones of the DJA Biosphere Reserve: Implication for Tree Domestication and Biodiversity Conservation

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Submitted: 30 September 2024 **Accepted:** 08 October 2024 **Published:** 10 October 2024

https://doi.org/10.63620/MKJAEES.2024.1055

Citation: *Mouaffo, A. G., Nongni, C. N., & Mbouwe, I. F. (2024). Characterization of Managed Ecosystems in Buffers Zones of the DJA Biosphere Reserve: Implication for Tree Domestication and Biodiversity Conservation. J of Agri Earth & Environmental Sciences 3(5), 01-18.*

Abstract
Improving and maintaining landscapes that provide ecosystem services has been identified as a critical goal for sustainable natural resource management and conservation. This study was conducted with the aim of identifying priority plants species whose domestication would contribute most to the sustainable management of wood resources and to the improvement of the well-being of local communities. Plots have been realized for the inventory of the forests and the agroforests and also for the description of trees, shrubs and regeneration. Socio-economic and ethnobotanical surveys provided information on agroforestry systems established, the level of integration of agroforestry and the different plants used. Results indicate that 100% of agroforestry households use a complex agroforestry system based on cocoa and banana. 70% of respondents believe that the practice of agroforestry has a positive impact on production yields. Populations harvest the majority of non-timber forest products (NTFPs) for food and medicinal purposes in forests with 53% of harvests made exclusively in forest, 41% in both forests and agroforests, and only 6% in agroforests. 82% of respondents believe that domestication of NTFPs and their integration into agroforestry plots would be essential for their wellbeing. Plants are mainly used for food (46%) and medicinal purposes (30%). Baillonella toxisperma is the most used plant in the village. The most common species in the forest is Petersianthus macrocarpus, followed by Heisteria pavifolia and Plagiostyles africana. Forests have a diametrical structure in the form of a decreasing exponential function characteristic of tropical dense forests. The shanon index shows us that the diversity of Somalomo forests is close to that of agroforests. The priority index (PI) for domestication considering ethnobotanical and ecological data was calculated. Priority woody species, whose domestication would contribute to biodiversity conservation, are: Alstonia boonei (PI=72), Dichapetalum sp (PI=68), Strombosia pustulata (PI=68), Baillonella toxisperma (PI= 66.68)

Keywords: Domestication, NTFPs, Ethnobotany, Well-being, Biodiversity.

Introduction

Rural populations living in forest areas are still largely dependent on natural resources to meet their basic needs [1, 2]. According to estimates by the World Health Organization, 80% of people living in developing countries use wild plants to meet some of their health and nutritional needs. They derive most of their food and medicinal resources from forests and increasingly tend to commercialize these resources to earn cash income [3, 4].

Today, large quantities of plant material are collected by commercial harvesters and then sold to urban traders and herbalists through a growing number of informal dealers [5]. This transition from subsistence use to commercial exchanges leads to an increase in anthropogenic pressure which, coupled with increasing demographic pressure, will lead to a scarcity of the plants used, or even their extinction [6-8].

To protect these species, states have come together to establish joint conservation efforts and have ratified various conventions such as the Convention on Biological Diversity (CBD).and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Ratification of these conventions is seen as a pledge of their commitment to act to preserve biodiversity. Among the various conservation strategies implemented, the creation of protected areas is seen as a priority for the sustainable management of biodiversity [9, 11]. After the Rio Conference in 1992, the expectations of the international community regarding the preservation of biodiversity and tropical forests increased. Thus, various environmental groups, considering that the network of protected areas in the world was insufficient and seeing this as a cause for concern, called for at least 12% of the land area to be included in the protected areas category [12].

Faced with these concerns and with the aim of conserving the exceptional biodiversity found within the country, Cameroon has set up a vast network of protected areas covering just over 20% of the national territory [13]. Among these protected areas, we find the Dja Biosphere Reserve (DBR) which enjoys significant biodiversity in terms of both flora and fauna. The DBR is home to a multitude of animal species, including the African forest elephant, the African grey parrot, the bongo, the leopard, and a very wide variety of primates including the western lowland gorilla and the chimpanzee. This specific richness and the presence of endangered species led to its establishment as a biosphere reserve in 1982 and a UNESCO world heritage site in 1987 [14].

The majority of protected areas are regulated and restricted in access, thus depriving millions of forest dwellers of their rights to the forest lands on which they often depend for their livelihoods (Cernea, 2005). Thus, after the creation of the DBR, and so that the populations living near it could continue to enjoy the natural resources without negatively impacting the biodiversity of the reserve, NGOs and development programs have set up alternatives to the anarchic exploitation of natural resources and the unsustainable felling of trees in order to establish agricultural plots; these alternatives were for the most part focused mainly on the popularization of agroforestry [15].

Problematic

The Dja Biosphere Reserve is an area of high population growth [16, 17]. This strong demographic growth not only leads to an increase in anthropogenic pressure on existing natural resources, but also negatively influences the standard of living of the populations [16, 17]. In order to improve their living conditions, these populations are increasingly turning to the commercialization of natural resources and extensive agriculture. These two activities have a significant impact on the biodiversity of the site due to the strong pressure that these natural resources are subjected to.

In the DBR, it is observed that the activities of local residents directly threaten the integrity of the reserve whether they are carried out on its periphery or even sometimes and regularly within it [16]. To address this, the practice of agroforestry would be an ideal solution, which consists of associating various multi-purpose trees with annual and/or perennial crops with a view to diversifying and improving the living conditions of local residents. This approach would allow rural farmers and/or local entrepreneurs to significantly meet their needs in terms of essential natural resources and improve their livelihoods [15].

Improving the quality, number and diversity of domesticated trees providing a wide range of Non-Timber Forest Products (NTFPs) is expected to strengthen the capacity of agroforestry to fully exploit its potential as a means of poverty reduction, as well as biodiversity conservation, as it would reduce anthropogenic pressure on these domesticated plants in their natural environments [18]. To do this, it would be important to identify plants whose domestication would contribute more to improving the standard of living of populations, and to the conservation of biodiversity on the periphery of the Dja biosphere reserve. The main research question that arises is therefore to know:

Which plants, if domesticated, would contribute most to improving the standard of living of populations and to the conservation of biodiversity on the northern periphery of the Dja biosphere reserve?

The following secondary questions can therefore be formulated:

- What are the different agroforestry systems existing around the Dja biosphere reserve and the level of integration of agroforestry by local populations?
- What are the plants most used by local populations on the outskirts of the Dja biosphere reserve?
- What is the floristic composition of the forest stands present on the periphery of the Dja biosphere reserve?
- What is the priority species that populations could integrate to diversify the agroforestry systems existing on the periphery of the Dja biosphere reserve?

Goals

The general objective of this study is the sustainable management of wood resources and the improvement of the standard of living of populations located on the periphery of the Dja biosphere reserve, through the identification of priority NTFPs for domestication.

More specifically, it will be a question of:

- Characterize the different agroforestry systems existing around the Dja biosphere reserve and take stock of the level of integration of agroforestry by local populations.
- Identify the NTFPs most used by local populations on the periphery of the Dja biosphere reserve.
- Assess the abundance and floristic diversity of forest stands present on the periphery of the Dja reserve.
- Prioritize flagship woody species for riverside populations on the periphery of the Dja biosphere reserve, the domestication of which would contribute to the conservation of biodiversity.

Research hypotheses

To answer the questions posed in this study, the following hypotheses were formulated:

- The majority of households located on the periphery of the Dja Biosphere Reserve practice agroforestry and use a complex agroforestry system based on cocoa trees [19].
- Baillonnella Toxispermais the plant most used by the riverside populations on the outskirts of the Dja Biosphere Reserve [20].
- The periphery of the Dja Biosphere Reserve is marked by a relative predominance of Euphorbiaceae representing more than 10% of all species identified in the field [21].

- The priority species for local populations are mainly plants for food use.

This can be raised in this study, thus highlighting the provisional nature of its results. The main limitation is linked to the time allowed for its realization, which combined with regular precipitations, did not allow us to inventory all the plots initially planned.

Methodology

Presentation of the Study Area

Location of the Area

This study was conducted in Somalomo village, located on the northern periphery of the Dja reserve, which is a village occupied by the Badjoué. This village belongs to a dense humid forest area and is located in the East region of Cameroon, Haut-Nyong department, Somalomo district. The location of Somalomo village on the map of Cameroon is shown in Figure 1.

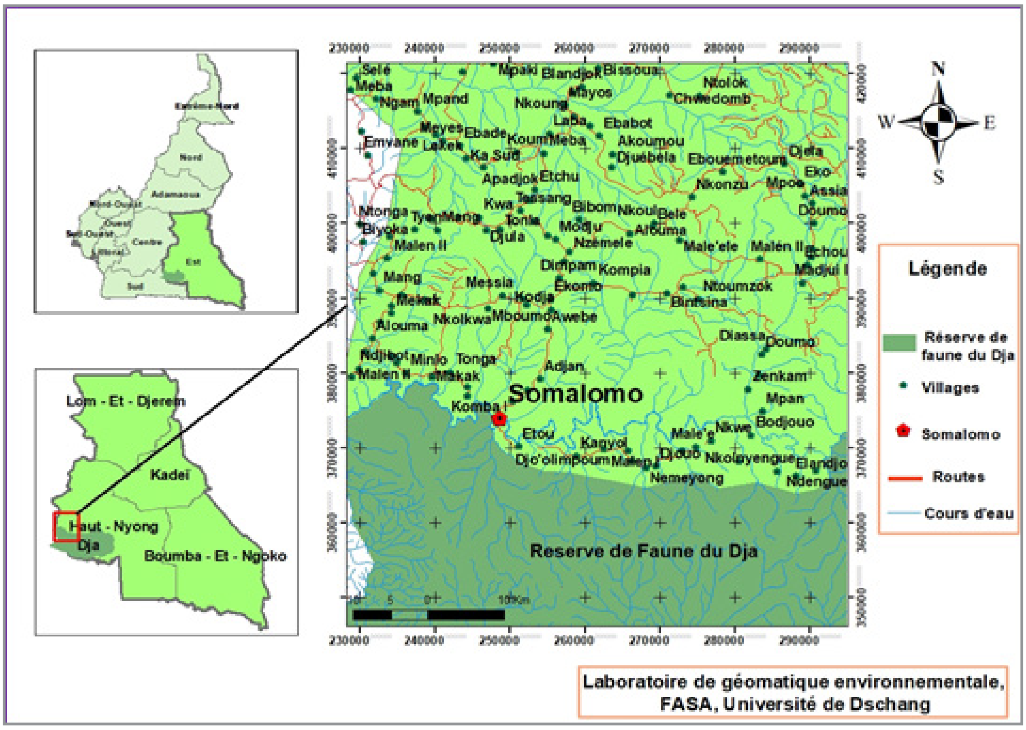


Figure1: Location of the village Somalomo on the map of Cameroon

The physical Environment

The climate of the study area is of the humid equatorial type with four seasons: a long rainy season from mid-August to mid-November; a long dry season from mid-November to mid-March; a short rainy season from mid-March to mid-June and a short dry season from mid-June to mid-August (Epanda, 2004) [22].

The hydrographic network is dense. Indeed, the tributaries of the Dja River have their source in the swamps of the East-West ridge line within the study area.

The relief is slightly undulating, crossed by close and shallow valleys. These valleys mark on both sides an East-West ridge line from which the watercourses flow towards the Dja River [23, 24].

The Dja wildlife reserve and its surroundings belong to the evergreen Cameroon-Congolese forest sector, more precisely to the Congolese district of Dja [26, 27, 28].The study area, like the RFD, is influenced by three phytogeographic domains: the area of dense Atlantic forests dominated by Caesalpiniaceae in the West; the area of dense semi-deciduous forests in the North dominated by Sterculiaceae and Ulmaceae; the Congolese domain of very heterogeneous dense evergreen forests in the South. The forests of Dja are heterogeneous both in terms of their structure and their floristic composition. According to Lejoly , there are three types of forests: those on rock (5%), those on hydromorphic soils (20%) and those on dry land (75%) [11]. A typology of the vegetation highlights some descriptive elements of the floristic ensemble [11]. There are primary forests, very old secondary forests, secondary forests and marshy meadows.

The fauna of the study area is very diverse. Indeed, the various studies carried out show that the fauna is composed of: 109 species of mammals, grouped into 10 orders and 34 families), 320 species of birds.

Human Environment

The northern periphery of the RFD includes two large human groups, namely the Badjoué or Kozimé and the Baka. “Badjoué” is the language spoken by the inhabitants of Somalomo. The populations practice slash-and-burn agriculture. Food crops are intended for self-consumption and cash crops are reserved for sale. The cash crops sold in the area are cocoa (Threobroma cacao), coffee (Coffea spp.).

In the study area, hunting is a cultural heritage that is practiced from generation to generation. Hunting is practiced exclusively by men. Hunting intensity is at its highest during the rainy season. Hunting plays several roles in the lives of populations: it is the main source of animal protein, an important source of income (allowing farmers to obtain basic necessities such as soap, petroleum, salt, oil, rice, etc.) and a factor of social cohesion (through the sharing of captured game). The results of research in the study area show that 96% of households hunt to cover their animal protein needs and improve their income. The firearm is the main hunting tool in our research site and the types of ammunition used are Mac, Mirage, Fob, Missi and Nobel brands [10].

Fishing is practiced along the Dja River and its tributaries. Fishing is favored on the one hand by a fairly dense hydrographic network and on the other hand by the fishery richness of the waters. This activity also constitutes a source of protein supply. The fishing methods used are traps, lines, nets and dams.

Picking is widely practiced by the Baka and the Badjoué who get most of what they need from the forest. The products harvested are vines, bark, caterpillars, honey, fruits and leaves of certain trees, mushrooms and Marantaceae.

Breeding is almost non-existent. There are a few domestic animals (pigs, chickens, goats) that are left to wander and are not subject to any particular monitoring. They are intended for self-consumption.

Data collection

Secondary Data

Documents relating to the study area and the subject were used. To do this, documents from the library of the Higher Institute of Environmental Sciences and the forestry department of the Faculty of Agronomy and Agricultural Sciences (FASA) of the University of Dschang were consulted, as well as websites. These documents (scientific journals, dissertations, articles, various reports) allowed us to obtain relevant information on the study subject, particularly those related to the problem of the area.

Primary Data

After the literature review, data collection was carried out in the field through a socio-economic and ethnobotanical survey of households and a botanical inventory in forests and agroforests.

Household Surveys

The household survey aimed to assess the level of appropriation of agroforestry by the populations living near the Dja Biosphere Reserve, to characterize the agroforestry systems existing in the area and also to determine the preferences for the use of wild plants on the periphery of the reserve. Preparatory meetings were organized with local administrative representatives and the village chief to explain the purpose of our work and the activities we had to carry out in the village.

Sampling

The survey was conducted among 39 households in the village of Somalomo. A non-probabilistic convenience sampling was used. In fact, it was a question of interviewing the households that we met during our survey in the village and this was done according to the availability of the heads of households, who in some cases were busy with their field work. The resource persons were made up of the heads of households or their spouses where applicable. The question here was to interview one person per household.

Research Tools Used: the Questionnaire

A structured questionnaire was used to conduct household surveys. Two survey forms were used to collect data the first survey form allowed us to get an idea of the level of knowledge of the populations living near the Dja reserve on agroforestry, and also to characterize the different agroforestry systems implemented by these populations.

The second sheet allowed us to identify the species most used by households, their different uses (medicinal, food or other), the part of the plant used, the purpose of the exploitation, as well as the place of collection. These data allowed us to establish the preferences for plant uses and served as a basis for defining priority species for local populations according to the method of Bruschi et al. [4].

Conduct of Interviews

The interviews were conducted in French and the local language with the help of interpreters or field guides from the village, to facilitate communication and also to avoid respondents being reluctant to answer questions asked by a foreigner.

Botanical Inventories

The botanical inventory for this study was carried out in the forest and also in the agroforestry plots set up by the local populations. The inventory in the forest aimed to identify the structure, diversity and abundance of the different plant species found in the forests of this locality; while the inventory in the agroforestry plots mainly aimed to assess the specific diversity observed in these plots.

Forest Sampling Device

In the village, systematic random sampling was used to carry out the botanical inventory. It consisted of setting up two paths, namely, a basic path 2 km long comprising 5 plots placed every 500 m from each other. Then at the end of the basic path, a secondary path perpendicular to the basic path was marked out. On the secondary path, plots were marked out every 500 m and the length of the secondary path was 2.5 km, this ultimately resulted in the prospecting of 10 plots.

Preparing the Inventory

Before going into the field, the area to be sampled was identified in advance at the GEP Association office using a map, so as to have a good representation of the forest cover in the area. Prior discussions with community members allowed us to select the forests generally used by the community.

Inventory Team Formation

On the ground before the start of the inventories, a team composed partly of members of the locality was formed.
The inventory team consisted of 6 people, namely:

- A team leader who recorded data on the inventory sheets and checked the length and angle of the paths using GPS.
- A botanist who identified the different species, measured their diameters using a dendrometric tape and a caliper and estimated their heights.

- Two markers who were responsible for placing the markers every 50 m of the secondary paths and for marking out the plots using strings 25 and 50 m long.
- A compass maker whose role was to give the direction that the paths should take and who also played the role of machete.
- A second machete in charge of widening the line made by the compass maker.

Inventory Procedure

The plots used during these inventories were square in shape, 25 m on each side. Within each plot, in addition to the identification and measurements of diameter and height made on each tree, data on the type of vegetation, slope, geographic coordinates, visibility, and density of the undergrowth were also collected.

The inventory plots were subdivided into 3 different sections. A section of 25x25 m on each side, one of 4x4 m and one of 2x2 m. The 25x25 m sections were used for the identification and collection of dendrometric data on large trees. Thus, all trees with a Diameter at Breast Height (DBH) ≥ 10 cm were identified and their diameters and heights recorded.

Within the 25x25 m sections, a 4x4 m section was delimited for the identification of shrubs with DBH<10 cm and height>1 m.

Finally, within the 4x4 m sections, a 2x2 m section was delimited for the identification of shrubs ≤ 1 m high. In these sections, only the number of individuals per species was reported on the inventory sheet. Data concerning height or diameter were not recorded, unlike what was done for the 4x4 m and 25x25 m sections.

The basic path was oriented along an azimuth of 180° (North-South), and the secondary paths were placed perpendicular to the basic path (West-East). These paths were materialized so as to intersect the major elements of the relief (watercourses, ridges). This gives a more representative sample of all types of habitats [29].

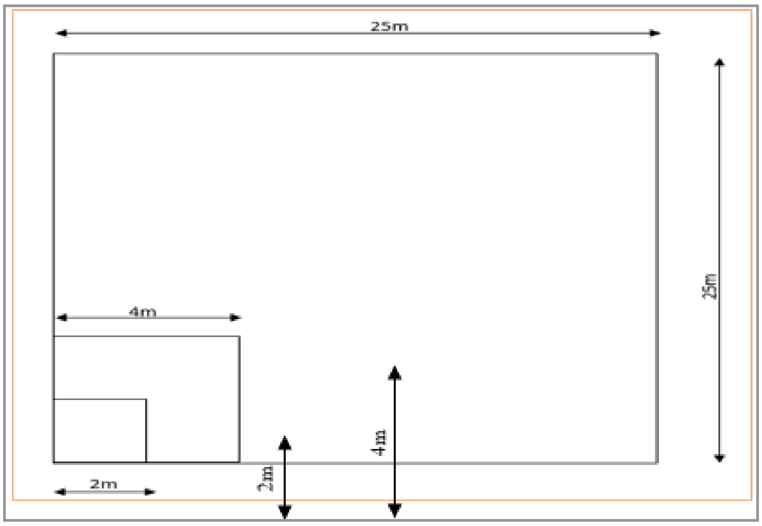


Figure2: Configuration of the sampling plot for the botanical inventory

Sampling Device in Agroforestry Systems

The inventory in agroforestry systems required the same team as in forests. However, here, given the distribution of agroforestry plotsand the fact that they are planted by man, there was no longer any question of tracing paths, under penalty of having a poor representation of the plots. Thus, with the help of a local guide, the different plots set up by the populations were identified and inventoried. The inventory plots in this case were rectangular in shape with sides of 50x40 m. Being cultivated areas, small individuals are generally cut down; consequently, the establishment of sub-plots for the inventory of trees with a diameter of less than 10 cm was no longer necessary. Thus, in this 50x40 m plot, all trees with a diameter greater than or equal to 10 cm were identified. In total, 10 agroforestry plots were inventoried, which gives a total area of approximately 2 ha.

Data Analysis

Microsoft Office 2016 software was used for data encoding and processing.

The analysis and interpretation of data from surveys on agroforestry practices aimed to establish comparison tables, graphs and percentages of respondents' responses based on the different questions asked.

Results

Practice of Agroforestry by the Populations of Somalomo

Agroforestry Systems used in Somalomo Village

The analysis of the data collected during the socio-economic survey conducted in the village of Somalomo shows us that 100% of households practicing agroforestry use a complex agroforestry system based on cocoa trees. The agroforestry systems implemented by these populations are 100% made up of two components: the agricultural component and the forestry component. The pastoral component is absent since they do not practice livestock breeding.

Agricultural Component

In addition to cocoa and banana trees, the agricultural crops most commonly represented in these agroforestry plots are cassava (present in 76% of the plots), peanuts (65%), corn (53%) and macabo (53%), as shown in Figure 3.

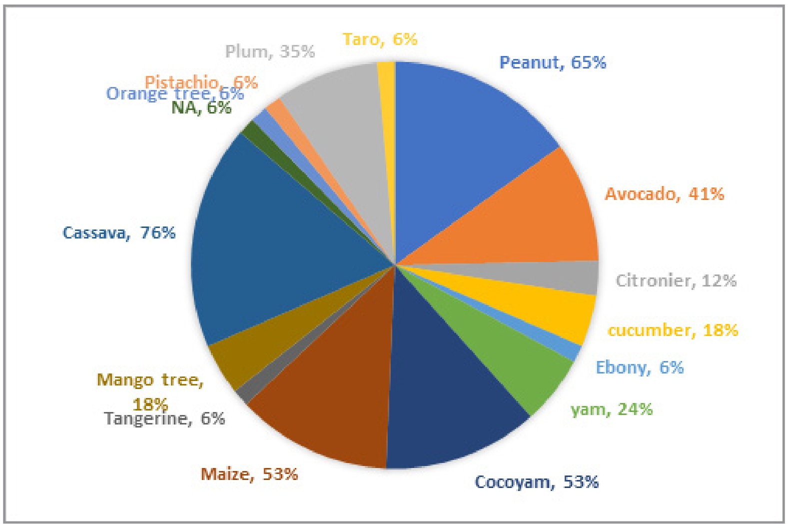


Figure3: agricultural speculations found in the agroforestry plots of Somalomo

Figure 3 clearly shows the importance of food crops for the people of Somalomo. Food crops are generally intended for self-consumption and cash crops, i.e. cocoa, for marketing. These results are similar to those of Nyaga , who found that in the peripheral zone to the DBR, the most cultivated food crops are generally cassava (Manihot spp.), macabo (Xanthosoma spp.), banana (Musa spp.), peanut (Arachis hypogea) [38].

Forest Component

The forest component is composed of trees left behind by the populations when establishing the agroforestry plots, these populations practicing very little domestication. The objective here is either to provide shade for cultivated plants; or to have available a fruit or medicinal tree that can be used later if necessary and in very rare cases in order to improve soil fertility. Figure 4 shows us the different forest trees left behind by the populations in the agroforestry plots.

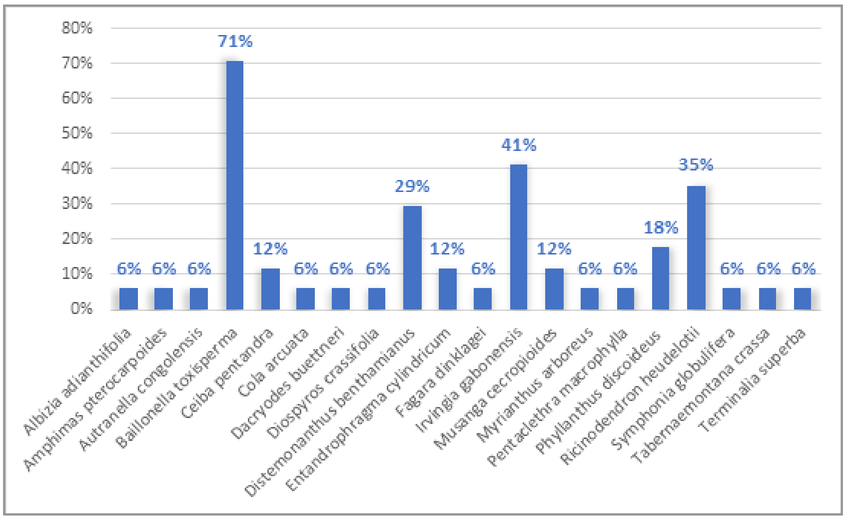


Figure 4: Forest trees left in the agroforestry plots of Somalomo

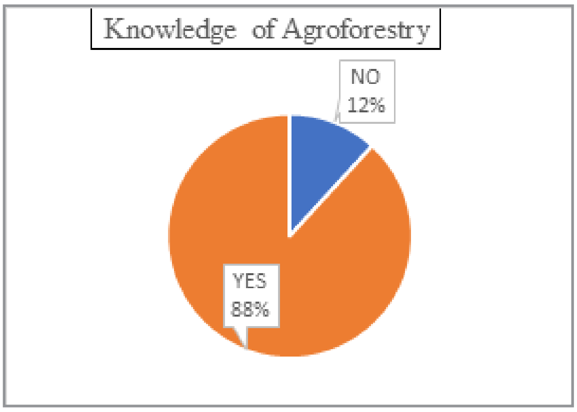
Figure 4 shows that a total of 20 tree species are left in agroforestry plots when they are established. The population survey shows that Baillonella toxisperma (present in 71% of plots), Irvingia gabonensis (41%), Ricinodendron heudelotii (35%), and Distemonanthus benthamianus (29%) are the forest trees most commonly left in agroforestry plots.

Level of Integration of Agroforestry by the Populations of Somalomo

During the survey conducted in the village, it was also a question of collecting the opinions of the populations regarding the practice of agroforestry. The aim here was to determine their level of knowledge regarding agroforestry, and to assess their level of satisfaction regarding the practice of agroforestry. This was in order to make recommendations to improve the productivity of their systems.

Knowledge and Practice of Agroforestry

Figure 5 shows us the percentage of respondents who have some notion of agroforestry, as well as the percentage of those who actually practice agroforestry.



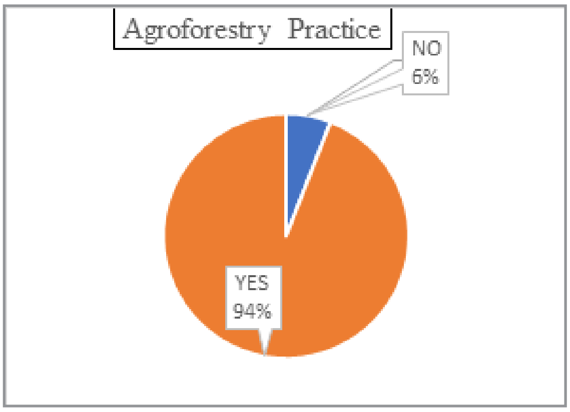


Figure 5: Knowledge and practice of agroforestry by the inhabitants of Somalomo

Figure 5 shows us that the majority of individuals interviewed know and practice agroforestry. This is certainly due to the extension activities carried out by the ECOFAC project and the multitude of NGOs and environmental associations working in the area.

In this figure, we can nevertheless see that the percentage of individuals with some notion of agroforestry (88%) is lower than that of individuals' actually practicing agroforestry (94%). This could be explained by the fact that some of the respondents, although not already having been made aware of agroforestry production techniques, already use methods often inherited from their parents. As described in Boffa, For generations, farmers in Africa have deliberately selected and protected valuable native trees in their fields [28]. These methods, which follow the basic principles of agroforestry, can therefore be considered agroforestry practices. This demonstrates the importance of traditional production techniques, which in some cases can be more efficient than modern techniques.

Satisfaction with the Practice of Agroforestry

In Somalomo village, 70% of respondents believe that the practice of agroforestry has a positive impact on production yields. Figure 6 shows the level of satisfaction of respondents with the practice of agroforestry.

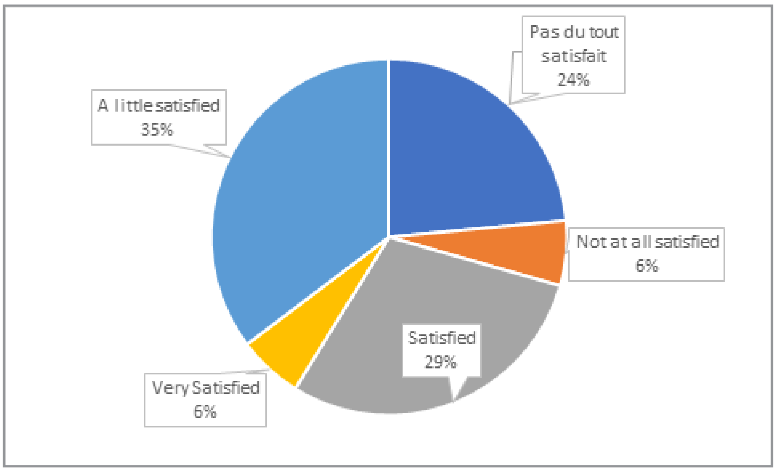


Figure 6: Satisfaction with the practice of agroforestry in the village of Somalomo

Figure 6 shows that out of the 70% of respondents who believe that agroforestry practices have a positive impact, approximately 64% are not entirely satisfied with its contributions (Somewhat satisfied [35%] and Satisfied [29%]). Added to this percentage are the 24% of respondents who are not at all satisfied with agroforestry practices. This clearly expresses the work that needs to be done to optimize agroforestry systems set up by local populations. This could be done by diversifying the trees present in the plots, thus providing a wide range of goods and services.

Domestication of Plants

The practice of agroforestry in the Eastern region of Cameroon is generally done by leaving trees standing when setting up the agroforestry plot. This method has the advantage of being simple to implement, but does not offer much leeway in terms of the choice of forest species to be left in the plot, as it depends essentially on the species already present on the site.This method is also limited in terms of the choice of the arrangement of trees in the plot, thus limiting the possibilities for optimization. This study therefore sought to determine whether the populations of the area, apart from leaving trees standing, also planted other tree species in their plot; and if so, what reproduction methods were used. Figure 7 shows the percentage of respondents who had already domesticated trees in their agroforestry plots.

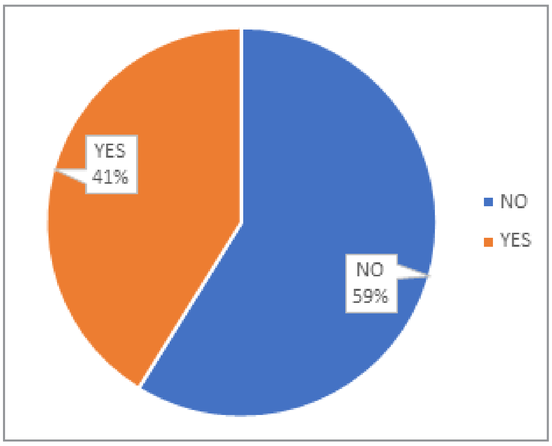


Figure 7: Percentage of respondents who have domesticated trees in Somalomo

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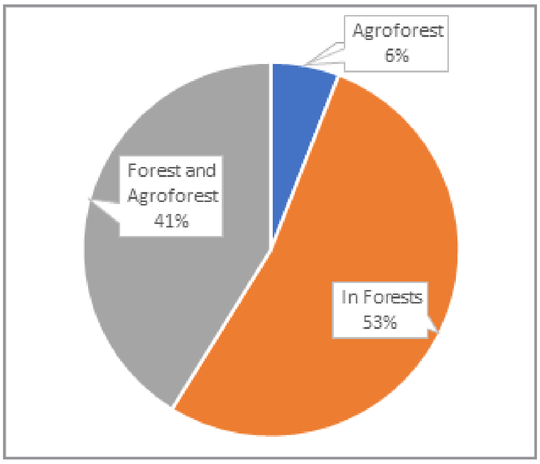

Figure 8: Place of collection of NTFP by the populations of Somalomo (AG: Agroforest)

Figure 8 shows that people harvest the majority of their NTFP in forests with 53% of harvests made only in forests, 41% made in both forests and Agroforests and finally 6% only in Agroforests. This figure shows that the people of Somalomo are still largely dependent on forests for the collection of NTFP necessary for their well-being. Hence the need to diversify the Agroforests set up by local communities, and thus limits their impact on forests. These results are slightly different from those of Kengue et al. which finds that although highly diverse, closed-canopy forests remain important sources of forest products, a large proportion of NTFPs are harvested from fallow land and agroforestry plantations [30].

Perception on the Domestication of NTFPs

During the study, respondents were asked to give their opinion on domesticating NTFPs from forests, in order to insert them into agroforestry plots. The results obtained are shown in Figure 9.

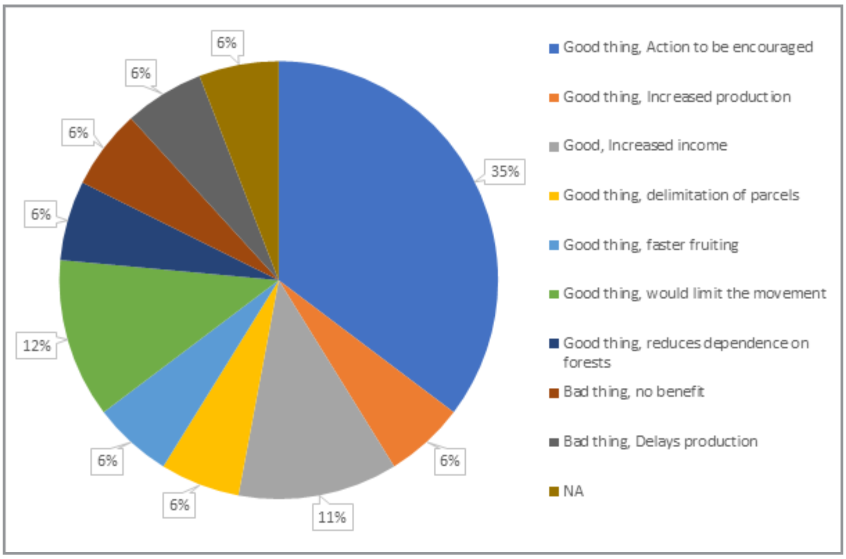

Figure 9: Perception of the populations of Somalomo on the domestication of NTFP

Overall, Figure 9 shows that 82% of respondents think that domesticating NTFPs and integrating them into agroforestry plots would be a good thing; 12% think it would be a bad thing and 6% have no opinion on the issue. Among those who think it would be a good thing, the notions of increasing income, improving production, limiting travel, and reducing dependence on forests were mentioned. Those for whom domestication would be a bad thing argue that it would have no benefit or that the trees placed in the plots would have the effect of delaying production. From these results, we can deduce that the populations of Somalomo are in the majority of cases in favor of setting up a domestication program aimed at diversifying the forest species already present in their plots.

Plants used by Local Populations

Different uses of Plants by Local Populations

Among the 92 species recorded during these surveys, the majority were used as food plants (with 46% of uses), and medicinal (30%), then came the other uses, as presented in Figure 10.

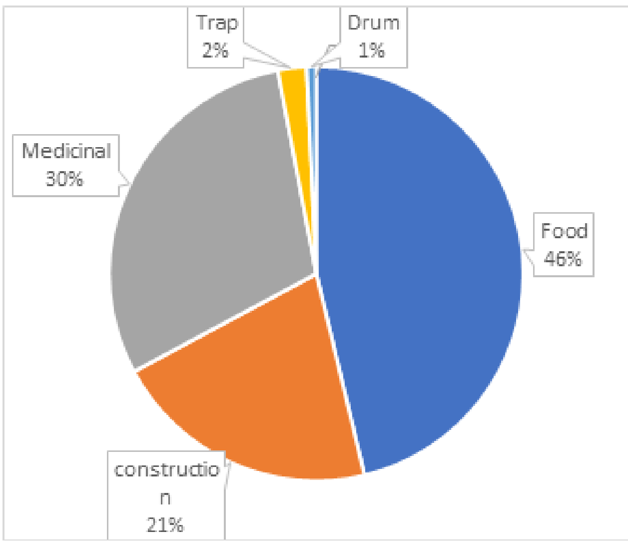

Figure 10: Different uses of NTFP in the village Somalomo

Figure 10 clearly shows the importance of the use of NTFPs within the community, to meet their basic needs. This result is consistent with those of Gaoue et al. who finds that rural populations living in forest areas are largely dependent on natural resources to meet their basic needs, needs which are mainly food and medicinal [31].

Community Plant Use Preferences

The species recorded in this study were ranked according to their use value and frequency of citation. These data are reported in Table 2 for the 15 species with the highest use value.

Table 2: Values of use and frequency of citation of the most used plants in the village in Somalomo

Scientific name of the plants listed	Use value (UV)	Frequency of citation (CF)	Use	Part used
Baillonella toxisperma	2.30	1.00	Fd; Med	Almond; Flesh; Bark
Irvingia gabonensis	2.00	1.00	Fd; Med	Almond; Flesh; Bark
Trichoscypha sp	1.00	0.89	Fd; Med	Bark; Fruit
Alstonia boonei	0.96	0.81	Med	Bark
Trichoscypha abut	0.78	0.78	Fd	Fruit
Trichoscypha acuminata	0.78	0.78	Fd	Fruit
Drypetes sp	0.67	0.44	Fd; Med; Tr	Fruit; Root; Stem
Anonidium mannii	0.63	0.44	Fd; Con; Med; Tr	Wood; Bark; Fruit; Stem
Lasianthera africana	0.59	0.56	Fd; Con; Tr	Wood; Fruit; Stem
Piptadeniastrum africanum	0.59	0.48	Med	Bark
Chrysophyllum lacortianum	0.59	0.44	Fd; Con; Med	Wood ; Bark; Fruit; Seed
Ricinodendron heudelotii	0.56	0.44	Fd; Med	Almond; Bark
Uapaca sp	0.48	0.48	Fd ; Con	Wood; Fruit
Massularia acuminata	0.48	0.48	Med; Part	Bark; Stem
Polyalthia suaveolens	0.44	0.41	Con; Med; Tr	Wood; Bark; Stem

Fd=Food; Med=Medicinal; Con=Construction; Tr=trap; Pir=pirogue; Fw=firewood

Table 2 shows that the most used plants are mainly food and medicinal plants. Baillonella toxisperma appears to be the most used plant in the village (UV=2.30) and is used by all the people interviewed (CF=1). Its very appetizing fruits are consumed by the population and oil is extracted from its almonds. This highly prized oil is used for food and is also associated with many therapeutic virtues. Its bark is also used for the treatment of many diseases such as rheumatism. Irvingia gabonensis is the second most used plant (UV=2; CF=1), followed by Trichoscypha sp (UV=1; CF=0.89), and Alstonia boonei (UV=0.96; CF=0.81). These results are similar to those found by Nguenang et al. (2010), who in the village Doumo Pièrre, located on the northern outskirts of the DBR find that the 4 plants most used by households are Baillonella toxisperma, Trichoscypha acuminata, Uapaca spp, and Irvingia gabonensis. This could be explained by the fact that these villages are located in similar ecological zones and are made up of individuals of the same ethnic group, namely the Badjoués.

Composition, Structure and Diversity of the Forest Stand

Composition of the Forest Stand

Thanks to the botanical inventory carried out during this study, it was possible to study the structure, composition and distribution of plants of ethnobotanical interest in the forest surrounding the village.

Of the 10 plots inventoried in this forest, there are a total of 45 families divided into 138 tree species. Figure 11 shows these different families classified according to their number of species.

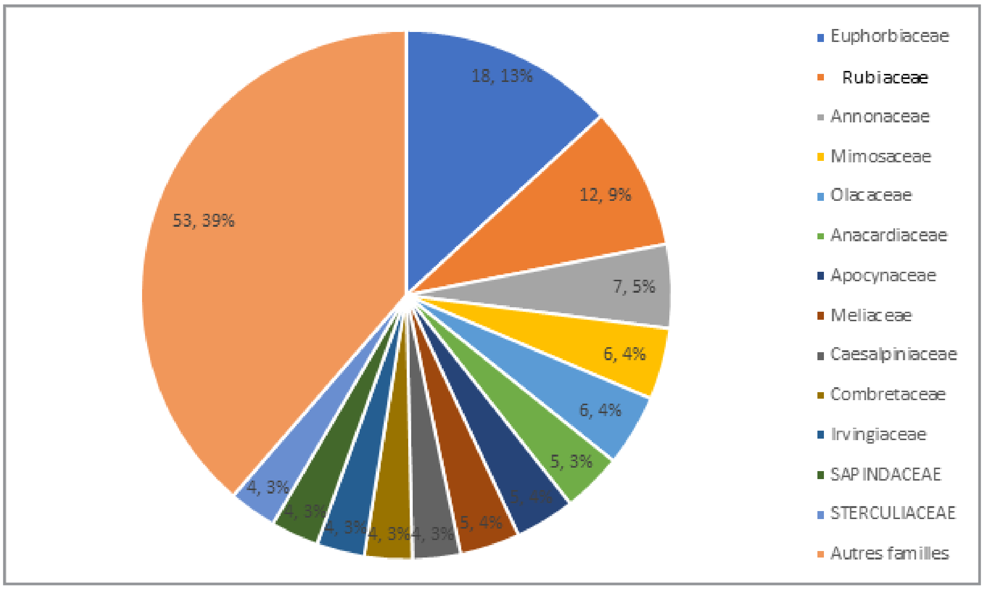

Figure 11: Proportion of species from different plant families found in Somalomo

Figure 11 illustrates a predominance of the Euphorbiaceae family in this forest. This family has a total of 18 species representing 13% of all species identified in the field. The results from this inventory are similar to those of Sonke and Lejoly , who found that the Dja wildlife reserve is a forest marked by a relative predominance of Euphorbiaceae, followed by Annonaceae, Rubiaceae, Meliaceae, Caesalpiniaceae and Mimosaceae [21]. There is also a similarity between these data and the results of the ethnobotanical survey conducted in the area where in both cases there is a predominance of the Euphorbiaceae family, and a strong representation of the main families cited by the respondents in this forest. This similarity can be explained by the results of Gonçalves et al. which shows that the most commonly available woody plant species are the most used by human populations [32].

Of the 92 species of trees and shrubs recorded during the ethnobotanical surveys, 70% were found in forest plots. The woody species used by local communities and not found in the inventoried plots (30%) may consist of plants collected outside the inventoried area (meadows or near houses). They may also consist of rare species or species located in forest areas not covered by the inventory, species for which an increase in the inventoried surface area could have allowed their identification; or the absence in the plots may suggest that the collection of plants carried out in the past by the communities could have contributed to a local rarefaction or even their extinction.

Table 3 presents the 15 most represented species in the forest classified according to their ecological importance value index.

Tableg 3: List of the most represented useful species in the inventory plots

Scientific name	Family	EVI	UV
Petersianthus macrocarpus*	Lecythidaceae	22.25	0.33
Heisteria parvifolia*	Olacaceae	16.27	0.04
Plagiostyles africana	Euphorbiaceae	14.00	0
Uapaca paludosa	Euphorbiaceae	12.61	0
Pentaclethra macrophylla*	Mimosaceae	11.11	0.41
Trichilia sp.	Meliaceae	10.59	0
Uapaca acuminata	Euphorbiaceae	10.06	0
Tabernaemontana crassa*	Apocynaceae	8.51	0.11
Celtis mildbraedii	Ulmaceae	7.28	0
Distemonanthus benthamianus	Caesalpiniaceae	6.68	0
Coelocaryon preussii	Myristicaceae	6.32	0
Uapaca vanhoutei	Euphorbiaceae	6.31	0
Anonidium mannii*	Annonaceae	6.09	0.63
Musanga cecropioides*	Urticaceae	5.95	0.19
Carapa procera*	Meliaceae	5.85	0.04

(EVI= Ecologically Significant Value Index; UV = use value; * = species recorded during ethnobotanical surveys)

Table 3 shows that the most represented species in this forest is Petersianthus macrocarpus of the Lecythidaceae family (IVI=22.25; UV=0.33), which is also a plant that has been cited in ethnobotanical surveys. It is followed by Heisteria parvifolia (Olacaceae;EVI=16.27; UV=0.04), Plagiostyles africana (Euphorbiaceae;EVI=14.00), Uapaca paludosa (Euphorbiaceae;EVI=12.61), and Pentaclethra macrophylla (Mimosaceae;EVI=11.11; UV=0.41). It is also noted from Table 4 that the species recorded in ethnobotanical surveys and which are highly represented in the forest have a relatively low use value; while among the species recorded and poorly represented in the forest, high utilization values are noted, such as Trichoscypha abut (Anacardiaceae;EVI=0.34; UV=0.78), Irvingia gabonensis (Irvingiaceae;EVI=0.56; UV=2.00), Ricinodendron heudelotii (Euphorbiaceae;EVI=0.67; UV= 0.56) and Chrysophyllum lacortianum (Sapotaceae;EVI=0.59; UV=0.59). This could be explained by the fact that plants with a high use value, and therefore more exploited, consequently become less abundant in forests. This clearly shows the influence of the use of plants by communities on plant populations.

Forest Stand Structure

Forest Structure

The diameter structure of the forests in the study area is illustrated in Figure 12 which shows the distribution of the density of individuals present in this forest according to their diameter class.

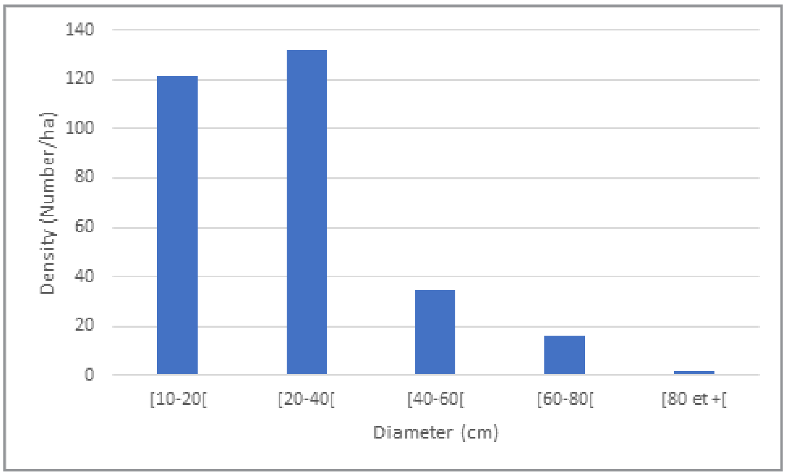

Figure 12: Diametric structure of the stand in the Somalomo forests

Figure 12 shows an inverted J-shaped distribution or decreasing exponential function which according to Pascal (2003) is characteristic of tropical dense forests in balance. There is a slight increase in density between classes [10-20[and [20-40[, which goes from 122 individuals/ha to 132 individuals/ha. This slight increase may be due to the fact that it is in the diameter class [10-20[that populations harvest the wood that is used for building houses. As the houses are aging, there is a general tendency to renew them in the village; which would have increased the pressure exerted on this diameter class in recent years. This disturbance will spread to the larger diameter classes, leading to a decrease in tree density in the years to come.

Structure of Agroforestry Systems

The diameter structure of the agroforestry systems inventoried in the study area is illustrated by Figure 13 which presents the distribution of the density of individuals present in the agroforests according to their diameter class.

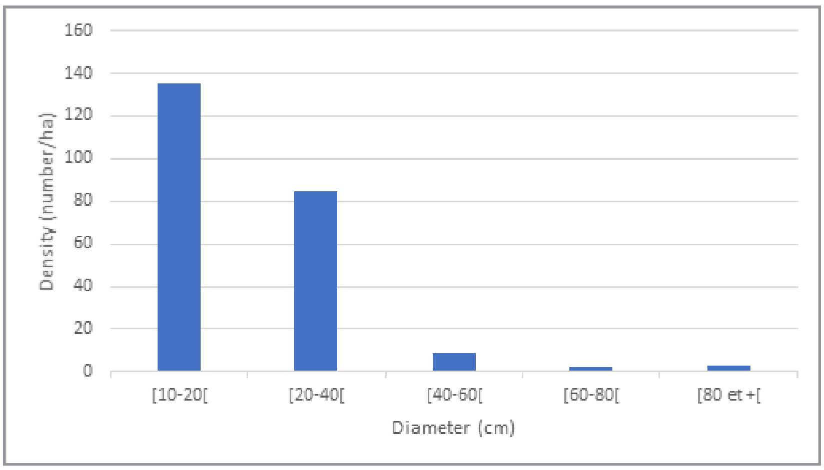

Figure 13: Diametric structure of the stand in the Somalomo Agroforests

Figure 13 also shows an inverted J-shaped distribution, as found in the forest area. This could be explained by the fact that these agroforestry plots are made up of trees initially present in the environment and which were left standing when the agroforestry plots were materialized. Therefore, the populations caused little disturbance in the structure of the initial forest stand. However, we note lower densities than those found in the forest plot, from the diameter classes [20-40[to the highest diameter classes. This could be explained by the fact that the populations cut down most of the trees with a diameter of [20-40[and above, in order to limit competition for light, and thus facilitate the growth of the agricultural crops planted.

Diversity of Forests and Agroforests

The diversity of the forest stand was assessed using the Shannon-Weaver diversity index and the Shannon evenness index. For the forest area, the value of the diversity index is 2.6 and that of the evenness index is 0.95. The value of the evenness index being very close to 1, we can conclude that the species are present in the forest in relatively equal proportions. These values reflect a high diversity in the site as generally found in natural tropical forests. This high diversity makes this forest less sensitive to the various disturbances, both natural and anthropogenic, that could affect it. According to Pascal, the advantage of the great diversity of tropical forests would be in terms of improving the resilience of the ecosystem and its adaptability to global climatic variations [33].

The Shannon-Weaver diversity index and Shannon evenness index for different vegetation types namely forests and agroforests are presented in Table 4.

Table 4: Shannon Diversity and Equitability Index for Forests and Agroforests

Type of vegetation	Shannon-Weaver Diversity	Shannon Fairness
Forest	2.6	0.95
Agroforest	2	0.92

Table 4 shows that for both vegetation types, the equitability index is greater than 0.92; the species are therefore more or less equitably distributed. This table shows that the diversity of forests is close to that of agroforests. The agroforests present in the village of Somalomo have a very high diversity. This result is similar to that of Temgoua et al which found in the agroforestry systems of the teaching and research forest of the University of Dschang diversity index values of more than 3.10 [47]. These results clearly show that agroforestry systems can be just as diverse as natural forests as also demonstrated Schroth et al. (2004) who find high levels of tree diversity for complex cocoa systems found in West Africa and Central America.

Priority Species whose Domestication would Contribute to the Conservation of Biodiversity

The list of priority plants for local populations, estimated using the domestication priority index (PI) is presented in Table 5:

Tableg5: Priority species for domestication in Somalomo village

Scientific name	HI score	EVI score	RSD score	PI
Alstonia boonei	35	27	10	72
Dichapetalum sp	28	30	10	68
Strombosia pustulata	28	30	10	68
Baillonella toxisperma	26.68	30	10	66.68
Massularia acuminata	22	30	10	62
Uapaca sp	22	30	10	62
Trichoscypha sp	20	30	10	60
Enantia chlorantha	17.5	30	10	57.5
Guarea cedrata	17.5	30	10	57.5
Picralima nitida	17.5	30	10	57.5
Piptadeniastrum africanum	17.5	30	10	57.5
Irvingia gabonensis	17	30	10	57
Brenania brieyi	16	30	10	56
Ricinodendron heudelotii	15	30	10	55
Bridelia grandis	14	30	10	54
Polyalthia suaveolens	21	24	7	52
Drypetes sp	11.89	30	10	51.89
Nauclea pobeguinii	10.94	30	10	50.94

Barteria fistulosa	10	30	10	50
Entandrophragma candollei	10	30	10	50
Entandrophragma cylindricum	10	30	10	50
Rhabdophyllum calophyllum	10	30	10	50

HI= harvest intensity; EVI= Ecologically Significant Value Index; RSD= Relative density of regeneration; PI= Priority index for domestication

Trema orientalis	10	30	10	50
Trichoscypha abut	10	30	10	50
Vitex rivularis	10	30	10	50
Croton sylvaticus	9.25	30	10	49.25
Lasianthera africana	15	30	4	49
Excellent Militia	8.5	30	10	48.5
Chrysophyllum lacortianum	8.25	30	10	48.25
Cylicodiscus gabunensis	11.2	27	10	48.2
Garcinia cola	8	30	10	48
Bridelia micranta	7	30	10	47
Canarium wenzelii	7	30	10	47
Cola rostrata	7	30	10	47
Desbordesia glaucescens	7	30	10	47
Diospyros holeana	7	30	10	47
Erythrophleum suaveolens	7	30	10	47
Ficus mucuso	7	30	10	47
Irvingia grandifolia	7	30	10	47
Klainedoxa gabonensis	10	27	10	47
Myrianthus arboreus	10	30	7	47
Pycnanthus angolensis	7	30	10	47
Rauvolfia woodsoniana	7	30	10	47
Uvariopsis le-testui	7	30	10	47
Anonidium mannii	12	24	10	46
Xylopia hypolampra	6	30	10	46
Albizia glaberima	5.5	30	10	45.5
Mammea africana	5.5	30	10	45.5
Aidia micrantha	4	30	10	44
Antidesma lacinata	4	30	10	44
Chytranthus mortehanii	4	30	10	44
Cola arcuata	4	30	10	44
Dacryodes buettneri	4	30	10	44
Diospyros mannii	4	30	10	44
Eribroma oblongum	4	30	10	44

HI= harvest intensity; EVI= Ecologically Significant Value Index; RSD= Relative density of regeneration; PI= Priority index for domestication

Irvingia wombolu	4	30	10	44
Trichoscypha acuminata	10	24	10	44
Parkia bicolor	6	27	10	43
Funtumia elastica	5.5	30	7	42.5
Solanum torvum	2.5	30	10	42.5
Hylodendron gabunense	14	21	7	42
Antrocaryon Klaneanum	1	30	10	41
Chytranthus talbotii	1	30	10	41

Markhamia tomentosa	1	30	10	41
Pausinystalia lane-poolei	1	30	10	41
Pseudospondias microcarpa	1	30	10	41
Staudtia kamerunensis	1	30	10	41
Alchornea floribunda	8.5	30	1	39.5
Musanga cecropioides	7.75	21	10	38.75
Pterocarpus soyauxii	7	21	10	38
Rinorea longifolia	7	30	1	38
Pseuderanthemum ludovicianum	4	30	1	35
Santiria trimera	4	24	7	35
Sorindeia grandifolia	1	24	10	35
Symphonia globulifera	4	21	10	35
Petersianthus macrocarpus	19.38	6	7	32.38
Carapa procera	1	21	10	32
Tabernaemontana dirty	7	18	7	32
Heisteria parvifolia	7	12	10	29
Pentaclethra macrophylla	6	12	10	28

HI= harvest intensity; EVI= Ecologically Significant Value Index; RSD= Relative density of regeneration; PI= Priority index for domestication

In general, a high PI for these plants is mainly due to their low presence or total absence in the area inventoried. An increase in the sampled area will allow for a better understanding of the priority index of these plants in the area.

According to the priority index adopted in this study (PI), the priority woody species, whose domestication would contribute to the conservation of biodiversity in the study area are the following: Alstonia boonei (PI: 72), Dichapetalum sp (PI: 68), Strombosia pustulata (PI: 68), Baillonella toxisperma (PI: 66,68), Massularia acuminata (PI: 62).

The very high priority index of Alstonia boonei (Emien) would be linked not only to the fact that this plant is widely used in the village (UV=0.96; CF=0.81); which reflects a very high anthropogenic pressure on this plant, but also to the destructive harvesting method recorded for this plant, consisting of the removal of the bark. The bark of Alstonia boonei is used mainly for the treatment of malaria and is considered very effective by the village populations. The harvesting of the bark would have led to a reduction in the number of individuals of the species, as well as a drop in the reproduction rate; no individual of the species with a diameter < 10 cm having been found on the inventoried plots.

Baillonella toxisperma(moabi) is the most used species in the village (UV=2.30; CF=1.00). It is used by all the inhabitants of the village as both a food and medicinal plant. Its fruits are consumed by the populations, oil is extracted from its almonds and its bark is used mainly for the treatment of back pain. The relatively low natural regeneration rate of this plant, associated with the strong anthropogenic pressure exerted mainly on its fruits would have led to a decrease in the natural population of this plant, it being no longer able to reproduce; this could then explain the high priority index attributed to this species. This corroborates the results of Bruschi et al. (2014)who finds that high use of fruits or seeds can influence the regeneration capacity of a species population and, therefore, be potentially dangerous.

Dichapetalum sp, Strombosia pustulata Massularia acuminata, Uapaca sp havinglow rates of use value (UV = 0.4-0.5), their high priority indices are mainly related to their low occurrence in the area and the frequency of destructive harvesting methods recorded for most uses. In fact, all these species were mainly cited as a source of woody materials for construction and trap making, and all these uses involve the felling of trees, their branches or main stems.

Two flagship species in domestication projects in Cameroon and widely used by local populations were found with a high priority index. These are Irvingia gabonensis (Mango) (UV= 2) and Ricinodendron heudelotii (Djangsang) (UV= 0.56).

Among these priority plants, some are already subject to some domestication by local populations. These are Baillonella toxisperma and Irvingia gabonensis, however, the technique used is limited to sowing. However, the techniques of layering, cutting and even grafting of Irvingia gabonensis have given very good yields [35]. Also, for many of the plants appearing in Table 5, various methods of domestication have already been developed, these methods being able to be consulted in the book put together by FAO , entitled living and feeding on the forest in Central Africa. It will therefore be a question for these species of implementing these methods in the study area and evaluating their productivity [35]. For other plants, it will be a question of developing domestication techniques using processes standardized by FAO or ICRAF.

Among the species listed in Table 5, those with commercial value will be domesticated in priority over those without. Thus, a plant with a higher PI but which cannot be marketed will be left in place of one with a lower PI but which can be marketed. Farmers will be encouraged to protect existing vegetation and invest in new agroforestry systems when they have secure rights to the products generated by the trees, when there is a market for these products, and when they benefit from the positive environmental services produced by their trees.

Discussion

Agroforestry Systems and their Role in Sustainability

The study's results indicate that 100% of agroforestry households employ complex systems, predominantly based on cocoa and banana cultivation. This finding aligns with the broader understanding of agroforestry as an important strategy for achieving sustainable land use in tropical regions. Agroforestry systems, which integrate trees with agricultural crops, provide multiple ecosystem services. These systems enhance soil fertility, increase biodiversity, and improve water retention, all of which contribute to more sustainable farming practices [36]. The use of cocoa and banana in agroforestry systems also reflects a broader trend in tropical regions where cash crops are integrated with trees to maximize land use and improve farmer income.

The socio-economic surveys conducted in the study reveal that 70% of respondents perceive agroforestry as having a positive impact on production yields. This aligns with existing literature on the benefits of agroforestry systems, which suggests that such practices can lead to enhanced agricultural productivity compared to monoculture systems [37]. Agroforestry allows for the diversification of income streams, where farmers benefit from both agricultural crops and NTFPs. Furthermore, agroforestry systems can make agricultural landscapes more resilient to climate change by improving biodiversity and ecosystem stability [38].

Non-Timber Forest Products (NTFPs) and their Role in Community Well-being

NTFPs play a critical role in supporting rural livelihoods, particularly in regions with high biodiversity like tropical forests. The study's findings show that 53% of NTFP harvests occur exclusively in forests, while 41% are harvested in both forests and agroforests. This division illustrates that, while agroforestry systems contribute significantly to NTFP production, natural forests remain an essential source of these products. NTFPs provide food, medicinal resources, and materials for local communities, making them integral to both cultural and economic well-being [39].

Interestingly, 82% of respondents believe that the domestication of NTFPs and their integration into agroforestry plots would be essential for their well-being. Domestication of NTFPs could lead to more sustainable harvesting practices by reducing the pressure on natural forests, which are often overexploited for their resources. Domesticated NTFPs would also provide a more reliable and accessible resource base for local communities, which is crucial for food security and medicinal needs [40]. The findings suggest that domestication is not only an ecological necessity but also a socio-economic imperative.

Ethnobotanical and Ecological Importance of Plant Species

The ethnobotanical surveys conducted as part of the study reveal that plants are primarily used for food (46%) and medicinal purposes (30%). This underscores the cultural significance of plant resources in local communities. One of the key species identified is Baillonella toxisperma, the most used plant in the village, which reflects its importance for both food and medicinal applications. Baillonella toxisperma, commonly known as African mahogany, is valued for its high-quality oil and durable wood, making it a crucial resource for local communities [41].

The study also highlights the most common species in the forests: Petersianthus macrocarpus, Heisteria pavifolia, and Plagiostyles africana. These species form part of the diverse tropical forest ecosystems that provide vital ecosystem services. The forest structure, as described in the abstract, follows a decreasing exponential function characteristic of dense tropical forests. Such structures are essential for maintaining biodiversity and ecological processes [42]. However, these forests face pressures from human activities, including logging and overharvesting of NTFPs, necessitating the domestication of key species to alleviate the burden on natural ecosystems.

Prioritization of Species for Domestication

One of the significant contributions of the study is the calculation of the Priority Index (PI) for the domestication of specific plant species, considering both ethnobotanical and ecological data. The species identified include Alstonia boonei (PI=72), Dichapetalum sp. (PI=68), Strombosia pustulata (PI=68), and Baillonella toxisperma (PI=66.68). These species have been prioritized for domestication due to their ecological importance and socio-economic value.

For example, Alstonia boonei, commonly known as stool wood, is valued for its medicinal properties, especially in treating fever and other ailments [43]. Its domestication could enhance access to important medicinal resources while reducing pressure on wild populations. Similarly, Baillonella toxisperma is critical for both its ecological and economic contributions, as it provides oil, timber, and medicinal compounds. The integration of such species into agroforestry systems would contribute to biodiversity conservation while simultaneously supporting local livelihoods (Leakey, 2017).

Implications for Biodiversity Conservation and Sustainable Resource Management

The study's results indicate that the Shannon index for biodiversity in the Somalomo forests is comparable to that of the agroforests. This is a significant finding as it suggests that agroforestry systems in the region maintain a high level of biodiversity, which is essential for ecological stability and resilience (Perfecto & Vandermeer, 2010). However, it is important to note that agroforestry systems, while beneficial, cannot fully replicate the complexity of natural forests. Therefore, a combined approach is needed: promoting agroforestry and domestication of key species, alongside the conservation of primary forests.

In conclusion, this study highlights the potential of domestication and agroforestry to contribute to sustainable natural resource management and improve the well-being of local communities. By prioritizing species with both ecological and socio-economic value, such as Alstonia boonei and Baillonella toxisperma, it is possible to enhance biodiversity conservation while promoting sustainable livelihoods. Agroforestry, coupled with the domestication of NTFPs, represents a promising strategy for achieving these dual goals in tropical forest landscapes.

Conclusion

The objective of this study was the sustainable management of wood resources and the improvement of the standard of living of populations located on the periphery of the Dja biosphere reserve, through the identification of priority NTFPs for domestication. Hypothesis 1 according to which "The majority of households located on the periphery of the Dja biosphere reserve practice agroforestry and use a complex agroforestry system based on cocoa trees" is accepted, because our results show that 94% of households in Somalomo practice agroforestry and among these households, 100% use a complex agroforestry system based on cocoa associated with different forest plants such as Baillonella toxisperma (present in 71% of plots), Irvingia gabonensis (41%), Ricinodendron heudelotii (35%), and Distemonanthus benthamianus (29%) [44, 19]. Hypothesis 2 according to which "Baillonnella Toxisperma is the plant most used by the riverside populations on the periphery of the Dja Biosphere Reserve" is accepted, because it appears from this study that Baillonnella Toxisperma is the most used plant in the Somalomo village, with a use value (UV) of 2.3 and a citation frequency (CF) of 1.00, followed by Irvingia gabonensis (UV=2; CF=1), Trichoscypha sp (UV=1; CF=0.89), and Alstonia boonei (UV=0.96; CF=0.81) [20]. Hypothesis 3 according to which "the periphery of the Dja Biosphere Reserve is marked by a relative predominance of Euphorbiaceae representing more than 10% of all species identified in the field» is accepted. Indeed, the results obtained during this study show a predominance of the Euphorbiaceae family in the forest, this family having a total of 18 species representing 13% of all the species identified in the field [21]. Hypothesis 4 according to which "the priority species for local populations are mainly plants for food use" is rejected. Indeed, among the 15 species with the highest priority index, only 5 are for food use, 7 for medicinal use and 3 used for construction. Therefore, the main use of the priority species for domestication is medicinal. Among the priority species, those with a commercial value will be domesticated in priority compared to those without it. Farmers will be encouraged to protect existing vegetation and invest in new agroforestry systems when they have guaranteed rights to the products generated by the trees, when there is a market for these products and when they benefit from the positive environmental services produced by their trees [45-52].

Acknowledgements

We would like to express our gratefulness to the International Foundation for Sciences (IFS) grant for providing funding. Thanks to this funding, we collected important data and produce quality results that will improve local living standards and conserve biodiversity on the northern periphery of the Dja Biosphere Reserve.

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