

**CHARACTERIZATION OF AGROFORESTRY SYSTEMS AND THEIR  
IMPACT ON THE WELL-BEING OF THE POPULATION OF THE  
SUDANO-SAHELIAN ZONE OF CAMEROON**

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DOI: <https://doi.org/10.51193/IJAER.2025.11417>

Received: 22 Jul. 2025 / Accepted: 04 Aug. 2025 / Published: 11 Aug. 2025

**ABSTRACT**

The demographic explosion in developing countries leads to a loss of biodiversity and insufficient of arable land. One of the challenges facing these countries is to produce enough goods and services to meet the needs of their population. This study aims to: (i) characterize the structure and practices of agroforestry systems based on mango and cashew trees in the Sudano-Sahelian zone; (ii) study the floristic composition of agroforestry systems and (iii) assess their impact on agricultural production and the well-being of the population of the Sudano-Sahelian zone of Cameroon. To do this, a participatory and reiterative analysis using a semi-structured questionnaire conducted among 90 farmers spread across five villages and combined with an ecological study was conducted. The results showed that agroforestry systems have a small area and are more than 20 years old in the majority. A total of 37 species grouped in 35 genera and 22 families were identified. Individuals had a “J”-shaped vertical distribution with a strong dominance of individuals of the past. The annual production of agroforestry systems is estimated at 71.3 tons. The main products were fruits (27.5 tons), onions (19.4 tons) and cereals (12.5 tons). Food, construction and medicine were the main uses of these systems while microclimate moderation (95.2%), conservation and restoration of fertility (75.2%), biodiversity conservation (95.4%) were the most important services encountered. Agroforestry systems offered enormous potential to

increase production and to improve the goods and services and also provided a sustainable benefit to the population. It is therefore urgent to develop them in this study zone to not only counteract the degradation of forests but also improve the living conditions of the populations.

**Keywords:** Agroforestry systems, impact, well-being, Sudano-Sahelian zone, Cameroon

## 1. INTRODUCTION

In recent decades, African savannahs in general and those in the northern part of Cameroon in particular have undergone deep changes: a demographic explosion, an expansion of agricultural land, periods of drought or reduced rainfall. These different modifications have for consequences changes in agricultural practices. Thus, we are increasingly seeing excessive use of inputs, with mechanization creating new constraints (Pourtier, 2003). Each year, new farms are created, leading to the decline of the forest. Unfortunately, we are witnessing a decline in production of crop systems. The decline in the productivity of traditional agricultural systems associated with the strong growth of rural populations implies the need to find alternative or complementary sources of supply in order to meet the growing needs of rural areas (Tchatat and Ndoye, 2006). Several solutions have been proposed to solve these problems (Prevels, 2008). Unfortunately, these solutions have remained without results. Other alternative solutions including agroforestry are proposed in order to provide sustainable solutions not only to the problems of declining production but also to those related to the environment. Agroforestry refers to all agrosystems where trees, crops, and sometimes animals are associated simultaneously on the same plot and interact with each other (Nair *et al.*, 2008). This practice is considered promising to not only mitigate the effects of climate change, but also adapt to it while improving agricultural productivity, food security, and diversification of household income (Feliciano *et al.*, 2018). Agroforestry also provides ecosystem services such as the conservation and improvement of biodiversity (Zhang *et al.*, 2018). Agroforestry systems are widespread throughout the world; in humid tropical zones, there are agroforests based on cocoa and coffee trees (Ndonmou *et al.*, 2022); in temperate zones, we can cite pre-orchards, silvo-arable systems based on annual crops (Van Lerberghe, 2015); in the Sudano-Sahelian zone, the most prominent are orchards (Woin and Essang, 2003; Niabaly *et al.*, 2022). In this last zone, the mango tree (*Mangifera indica*) and the cashew tree (*Anacardium occidentale*) are cited among the most common and abundant agroforestry species and the intercrops are cereals, food legumes in rainy conditions or market gardening crops in irrigated conditions (Kekele *et al.*, 2023).

In Cameroon, agroforestry practices are part of traditional rural landscapes. They are present in the Sudano-Sahelian zones where farmers seek to maximize the profitability of agricultural land and increase the efficiency of resource use (Smektala *et al.*, 2005). Mango and cashew agroforestry systems are generally characterized by high tree density and high yields. However, the nature,

structure and performance of these systems are very diverse. Despite the importance of agroforestry in the Sudano-Sahelian zones of Cameroon, very little attention has been paid to these associations. Some studies have been carried out on carbon sequestration in agroforestry systems, the typology of agroforestry systems in the Guinean savannahs of Cameroon (Noiha *et al.*, 2017a; Boukeng *et al.*, 2023). In order to develop agroforestry in this area and to adapt traditional systems to new climatic and economic contexts, a better understanding of the diversity and functioning of existing systems is necessary. Thus, a characterization and evaluation of the performance of agroforestry systems focused on mango and cashew systems, with the aim of better understanding their functioning is proposed here. This work is also a prerequisite for controlled experiments on the most common associations. This study aims to: (i) characterize the structure and practices of agroforestry systems based on mango and cashew trees in the Sudano-Sahelian zone of Cameroon; (ii) study the floristic composition of mango and cashew agroforestry systems; and (iii) assess their impact on agricultural production and the well-being of the population of the Sudano-Sahelian zone of Cameroon.

## **2. MATERIALS AND METHODS**

### **2.1 Study area**

The study was conducted precisely in the Far North region of Cameroon located respectively between latitudes 10° 30' 00" N and 10° 57' 00" N and longitudes 14° 06' 00" E and 14° 33' 00" E (Fig. 1). The Far North region is subject to a Sudano-Sahelian climate characterized by a long dry season lasting from October to early June and a short rainy season lasting from late June to September, of which two months (July and August) alone account for 2/3 of the total annual precipitation (Ndongo *et al.*, 2015). At the height of the dry season, temperatures were situated then around 35° C. Its vegetation is dominated by the thorny steppes Sahel. The presence of plants such as *Terminalia leiocarpa* on loose and uncleared soil, *Boswellia dalzielii* on stony soil and *Balanites aegyptiaca* is most noted (Ndongo *et al.*, 2015; Jiagho *et al.*, 2016). The main activities are agriculture and animals' husbandry.

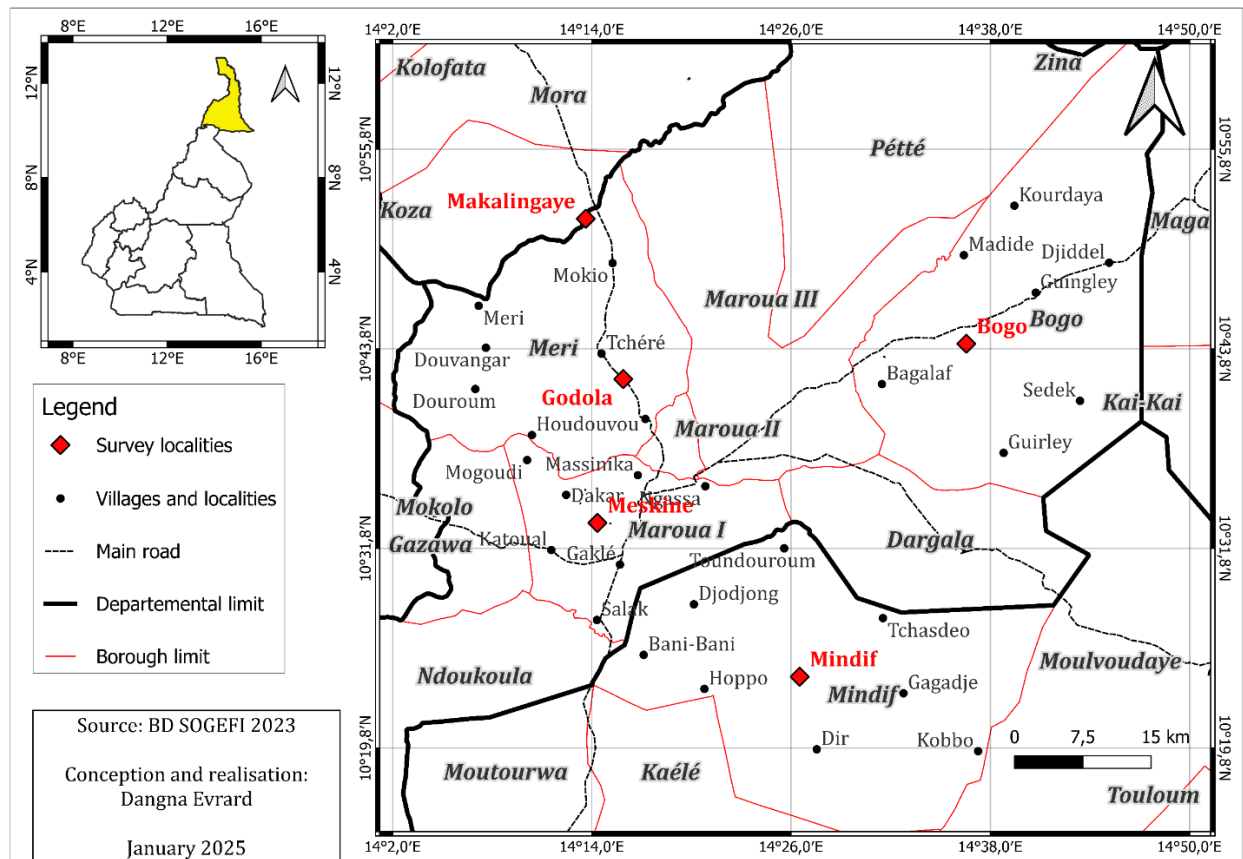


Figure 1: Map of study zone

## 2.2 Data collection and analysis

The study was carried out by combining both a semi-structured survey and an ecological study. The survey was carried out between April and July 2023 using a questionnaire applied to the owners of agroforestry systems in the selected villages. The questionnaire includes the following sections: -Practices and structures of agroforestry systems, -Biodiversity, -Production of agroforestry systems and its impact on the population lives. Regarding production, the owners of agroforestry systems gave an estimate of their production in 100 kg bags. The questionnaire consisted of closed questions where the answer is yes or no, open questions giving farmers the freedom to express their points of view at will and leading questions to which several answers have been proposed to the respondents who must choose one or two among them. A total of five villages were explored and 90 farmers were surveyed. The villages concerned are Meskine, Bogo, Godola, Makalingaye, Mindif considered as bastions of mango and cashew agroforestry systems in the study area. The choice of operators was made randomly among those having at least one agroforestry system and ready to receive us.

For the second phase of the study, the surface of the agroforestry systems was measured. Complete inventories were carried out to assess the total number and diversity of species, varieties and abundance of crops. Species identification was done on site. For species that were not identified, samples were collected, dried and sent to the National Herbarium of Cameroon for identification. Plants were recorded with local and/or scientific names. Then, the measurement of dendrometric parameters were taken on the different trees present in the systems. These parameters included the diameter at breast height (dbh), the height of the trees. The dbh was determined from the circumference measured at 1.30 m from the ground using a tape measure and deduced from the following formula:  $D=C/\pi$  with C: circumference (cm);  $\pi=3.14$ . Tree height was determined using a graduated pole. The data were subjected to descriptive statistical analysis such as frequency and percentage and SPSS 20.0 software was used.

### **3. RESULTS**

#### **3.1 Socio-economic characteristics of agroforestry systems:**

Table 1 presented the socio-economic characteristics of agroforestry systems in the study area. The table 1 showed that 60.4 % of the respondents had no formal education while 28.2 % of the respondents had primary education. The percentages of those who had attained secondary and tertiary education were 8.2 % and 3.2 % respectively. Farmers belonged to different age categories. Owners aged between 45 and 60 years old constituted the majority (71.7 %). The youngest represented 3.3 %. The size of the family of farmers was often large. The largest category (5 to 10 persons) represented 61.7 % followed by the category of families of more than 10 persons (38.3 %). Producers whose family size was less than or equal to 5 persons were absent in the area.

Agroforestry systems with an area of more than 1.5 ha did not exist in the study area. Those with an area between 0.75 and 1.5 ha represented 45 % while those with less than 0.75 ha were the most numerous with 55 %. Regarding the age of the farms, the largest (48.3 %) were in the age category of over 20 years old followed by the age category of between 10 and 20 years old (46.7 %). The least represented belonged to the age group of less than or equal to 10 years old. In the study area, the most important activity was agriculture (65.3 %), while livestock breeders represented 18.6 % of the owners of agroforestry systems. In the area, Legacy and sharecropping were the most practiced modes of access to land with 44.6 % and 32.4 % respectively.

**Table 1: socio-economic characteristics of des owners**

Characteristics		Frequencies (%)
Owners age (year)	≤30	3,3
	[30-45]	16,7
	[45-60]	71,7
	>60	8,3
Family size	≤5	0
	[5-10]	61,7
	>10	38,3
Surface (ha)	<0,75	55
	[0,75-1,5]	45
	>1,5	0
Exploitation age (year)	≤10	5
	[10-20]	46,7
	>20	48,3
Accessibility to land	Owner	13,3
	Legacy	44,6
	Sharecropping	32,4
	Don	9,7
Main activities	Agriculture	65,3
	Livestock	18,6
	Trade	10,2
	Others	5,9
Education level	No formal education	60,4
	Primary education	28,2
	Secondary education	8,2
	Tertiary education	3,2

### 3.2 Biodiversity of agroforestry systems

Table 2 presented the different plant species found in agroforestry systems in the Sudano-Sahelian zone of Cameroon. The most important species were fruit species such as *Mangifera indica*, *Anacardium occidentale*, *Psidium guajava*, *Carica papaya*, *Citrus* spp. In the alleys, depending on the density and size of the trees, crops were grown either in the rainy season or in market gardening. The figure 2 shows the appearance of the agroforestry systems observed in the study site illustrating the richness of biodiversity. The most important crops are: *Arachis hypogea*, *Zea mays*, *Vigna unguiculata*, *Sorghum bicolor*, *Hibiscus sabdariffa*, *Solanum nigrum*, *Allium cepa*, *Ipomea*

*batata*, *Glycine max* etc. In the agroforestry systems of the Sudano-Sahelian zone, spontaneous species were also observed with varying success. These were *Piliostigma thonningii*, *Faidherbia albida*, *Sclerocarya birrea*, *Balanites aegyptiaca*, *Hyphaene thebaica*, *Borassus aethiopum*, *Tamarindus indica*, *Adansonia digitata*. These species were preserved in these systems for their important and diverse medicinal, food, fodder roles. They were also recognized for their other roles, namely the role in construction and even ecological.



**Figure 2: Appearance of some agroforestry systems showing biodiversity; A=corn cultivation under *Anacardium occidentale*; B=Home garden**

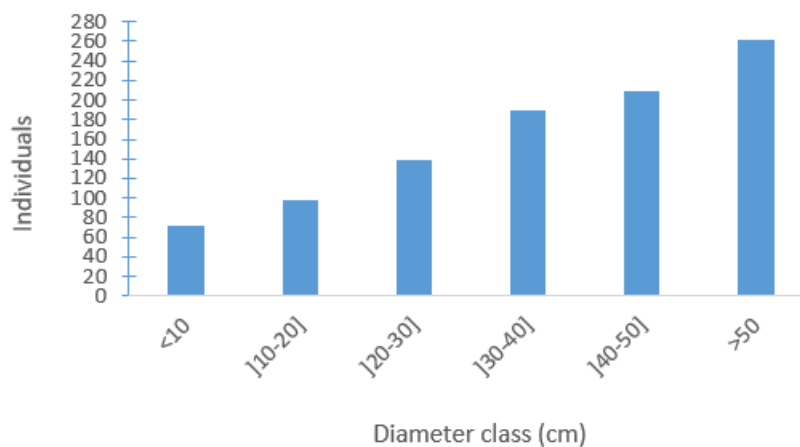
**Table 2: Plant species found in agroforestry systems (%)**

Species	Families	Localities				
		Meskine	Godola	Bogo	Mindif	Makalingaye
<i>Mangifera indica</i>	Anacardiaceae	58.6	59.2	612.	56.1	75.1
<i>Citrus lemon</i>	Rutaceae	12.2	8.4	13.1	14.2	31
<i>Piliostigma thonningii</i>	Fabaceae	0.8	0.2	0.1	0.3	0
<i>Anacardium occidentale</i>	Anacardiaceae	37	52.4	67.2	58.1	45.3
<i>Carica papaya</i>	Caricaceae	26	28.7	24.6	27.1	12.2
<i>Psidium guajava</i>	Myrtaceae	21.6	16.4	24.1	15.3	23.4
<i>Acacia nilotica</i>	Fabaceae	0.7	0.4	0.9	1	0.5
<i>Zea mays</i>	Poaceae	36.6	23	31.1	15.3	12.2
<i>Hibiscus sabdariffa</i>	Malvaceae	4	0	0.1	0.7	0
<i>Arachis hypogea</i>	Fabaceae	2.1	3.2	0	0	0.7
<i>Vigna unguiculata</i>	Fabaceae	3.6	1.1	2.6	2.4	4.7
<i>Sorghum bicolor</i>	Poaceae	11.2	31	6.1	5.2	17.3
<i>Solanum nigrum</i>	Solanaceae	1.1	2.9	0	1.2	0.1
<i>Faidherbia albida</i>	Fabaceae	1.2	0.5	0	0	45
<i>Sclerocaya birrea</i>	Anacardiaceae	0.3	2	0	0.3	0.1
<i>Azadirachta indica</i>	Meliaceae	0.8	0.1	0.8	0.1	0
<i>Balanites aegyptiaca</i>	Balantaceae	0.5	0	0.3	1.3	0

<i>Hyphaene thebaica</i>	Arecaceae	0.1	0	0.1	0	0
<i>Borassus aethiopum</i>	Arecaceae	0.2	0	0	0.1	0
<i>Adansonia digitata</i>	Bombacaceae	0	0	0.3	0.6	0
<i>Tamarindus indica</i>	Fabaceae	0	0	12	17	0
<i>Moringa oleifera</i>	Moringaceae	45	35	19	16.3	12
<i>Gossypium hirsutum</i>	Malvaceae	0	13.3	18.2	0	0
<i>Sorghum bicolor</i>	Poaceae	35.2	62.1	13.6	16.2	27.2
<i>Ipomea batata</i>	Convolvulaceae	8.2	1.3	0	0	0
<i>Vigna subterranea</i>	Fabaceae	0	0.8	0	0	2.4
<i>Boswellia dalzielii</i>	Burseraceae	0	0.3	0	0	1.3
<i>Commiphora africana</i>	Burseraceae	0	2.4	0	1.2	3.1
<i>Citrus sinensis</i>	Rutaceae	12.3	0	0	0	8.2
<i>Cucumis melo</i>	Cucurbitaceae	8.1	12.6	4.1	6.3	14.1
<i>Ficus thonningii</i>	Fabaceae	0	0	1.1	0.2	0
<i>Diospyros mespiliformis</i>	Ebenaceae	0	0.1	0	0.7	0
<i>Glycine max</i>	Fabaceae	14.5	0.8	2.1	0.4	0.2
<i>Allium cepa</i>	Liliaceae	57	37.5	12.5	42.1	56.3
<i>Eucalyptus camaldulensis</i>	Myrtaceae	8.1	3.1	0.4	0.7	0.1
<i>Daniella oliveri</i>	Fabaceae	0	0.3	0	0.1	0.2

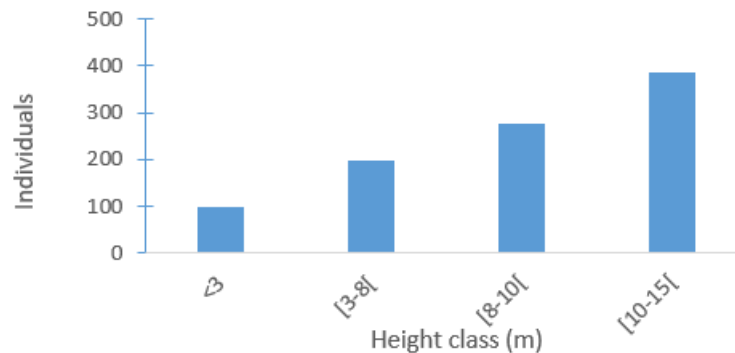
### 3.3 Woody plants structure in agroforestry systems

The diameter and height classes of individuals in agroforestry systems were a good reference for understanding the structure of plant populations in these systems. The distribution by diameter class (Fig. 3) allowed to understand the horizontal structure of individuals of all woody species in agroforestry systems. This distribution revealed a "J"-shaped that mainly grouped the plants in the class of old individuals with a strong representation of individuals of diameter over 50 cm (269 individuals). The individuals in this class were followed by those with a Dbh between 40-50 cm with 209 individuals or 21 % (Fig. 3). On the other hand, the least represented individuals belonged to the diameter class <10 cm and that between 10 and 20 cm with respectively 72 and 98 individuals or 7.4 % and 10.1 % of the woody plants of the agroforestry systems of the Sudano-Sahelian zone of Cameroon. These results would reflect a weak distribution of so-called relay plants in these systems.



**Figure 3: Tree diameter class distribution of Agroforestry systems**

The vertical distribution of individuals in agroforestry systems is illustrated in Figure 4. The analysis of this figure allowed to note that agroforestry systems in the Sudano-Sahelian zone was dominated by individuals with a height between 10 and 15 m (385 individuals or 40.3%) followed by trees with a height between 8 and 10 m (275 individuals or 28.7%). The low number of individuals was found in the <3 m class with 98 individuals or 10.3 % of the trees in agroforestry systems. These results showed a vertical distribution with a "J" shape which reflected a strong dominance of individuals from the past. The youngest trees and adult plants were less dominant. This "J" shaped showed clearly that in these systems, individuals were well distributed in strata.

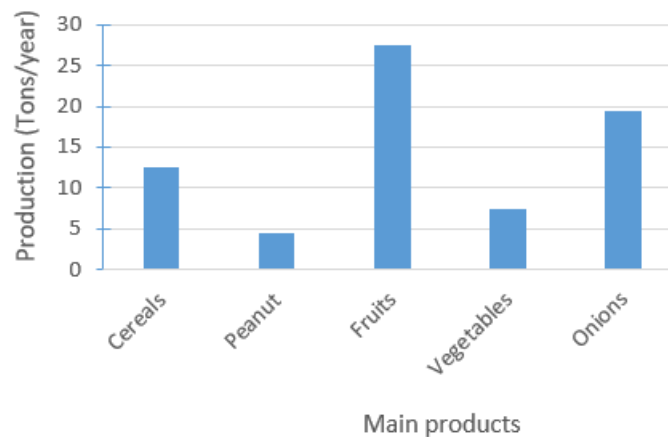


**Figure 4: Tree height class distribution of Agroforestry systems**

### 3.4 Impact of Agroforestry Systems

#### 3.4.1 Production

The production of agroforestry systems was illustrated in figure 5. It emerged from the analysis of this figure that fruits, onions and cereals were the main products from agroforestry systems respectively with 27.5 t, 19.4 t and 12.5 t annually. These results were explained by the fact that these crops were the most preferred in the area. Other products such as peanuts (4.4 t) and vegetables (7.5 t) were harvested. These crops were associated with the main crops in agroforestry systems to optimize their production.



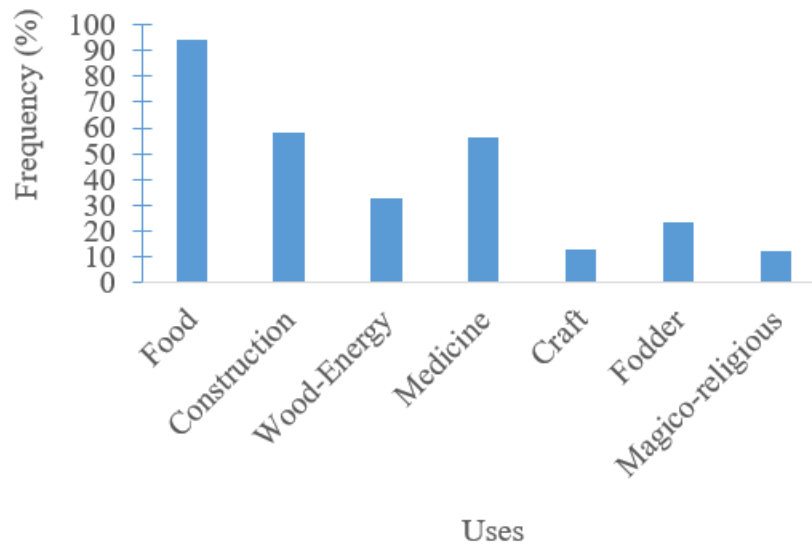
**Figure 5: Products quantities of main cultures in agroforestry systems of Sudano-Sahelian zone of Cameroon**

#### 3.4.2 Goods and services of the needs of rural populations

The direct or indirect benefits for the satisfaction of the needs of rural populations were deduced from the goods and services provided by each of the plant components (15 woody plants, 6 annual

crops) of the agroforestry systems studied. The most common trees in these systems were *Anacardium occidentale*, *Mangifera indica*, *Psidium guajava*, *Carica papaya*, *Citrus spp.*, *Moringa oleifera*. As for annual crops, the most common were Maize, Sorghum, Cotton, Peanut, Cowpea, Potato. Market gardening were onions, vegetables such as Carrot, Sorrel, Black Nightshade, Eggplant, Cucumber, Pepper etc.

Seven different uses of the products (Fig. 6) were identified in the agroforestry systems of the Sudano-Sahelian zone of Cameroon. Some uses or services varied relatively in the different localities of the study area. Uses such as food (94.4 %), construction (58.3 %) and medicine (56 %) were the most important and common in all localities. Other areas of use such as the magico-religious domain, fodder production and the craft field were noted in the study area.



**Figure 6: Main uses of agroforestry systems in Sudano-Sahelian zone of Cameroon**

Regarding the services provided by agroforestry systems in the Sudano-Sahelian zone of Cameroon (Fig. 7), microclimate moderation (95.2%), conservation and restoration of fertility (75.2%), and biodiversity conservation (95.4%) were the most important services encountered. Other services, and not the least, had been identified in these systems. These were the protection of water quality, recycling of matter, landscape beauty and aesthetics. These results were different from those of Biaoutal et al. (2016) who reported about ten services in agroforestry systems in Benin.



**Figure 7: Services encountered in the Sudano-Sahelian zone of Cameroon. MMC: Moderation of Microclimate, CRF: Conservation and restoration of fertility, PQE: Protection of water quality, RCM: Recycling of matter; CAGD: Conservation of agrodiversity.**

### 3.4.3 Financial contribution of agroforestry systems

On the local market, commodity prices vary depending on the season. At harvest, a 100 kg bag of cereals (corn, sorghum) costs approximately 26.65 US\$, while during the lean season it is sold at 44.42 US\$. As for onions, at harvest, a 100 kg bag is sold at 21.32 US\$, while during periods of scarcity, this same bag is sold at approximately 159.93 US\$. For other crops, mainly found in agroforestry systems, peanuts, beans and vegetables from agroforestry systems, the price is set by the highest bidder depending on the quality of the product.

To measure economic profitability, the market value of inputs and outputs must be taken into account, including subsistence goods or those that are reinvested in the system and which must be quantified in terms of monetary value (Torquebiau 1990). Thus, the net income calculations carried out took into account the current market price of products for a growing season. However, in the context of this study, the prices of inputs (plant protection products) are not taken into account because in most agroforestry systems, amendment is most often done with crop residues, anything that contributes to improving environmental conditions.

Table 3 shows the distribution of income generated by agroforestry systems for farmers. Fruits and onions are the products that provide the most income, with 3,664,998.02 US\$ and 2,278,073.93 US\$ respectively. This contribution varies depending on the location. However, it should be noted that fruits and onions are the main source of income in all locations. Farmers use this income to

solve their problems, including children's schooling, clothing for family members, purchasing soap, oil, and construction.

**Table 3: Financial contribution of agroforestry systems (US\$)**

Localities	Main products				
	Cereals	Peanuts	Fruits	Vegetables	Onions
Meskine	133272,66	71078,75	1132817,57	74632,69	952455,24
Godola	111060,55	177696,87	812963,2	49755,12	597061,5
Bogo	88848,44	142157,5	439799,76	60416,94	241667,75
Mindif	133272,66	177696,87	599726,95	28431,5	326962,25
Makilingaye	88848,44	213236,25	679690,54	53309,06	159927,19
<b>Total</b>	<b>555302,75</b>	<b>781866,24</b>	<b>3664998,02</b>	<b>266545,31</b>	<b>2278073,93</b>

## 4. DISCUSSION

### 4.1 Structural characteristics of agroforestry systems

Agroforestry systems in the Sudano-Sahelian zone of Cameroon had diverse structural characteristics. The results of this study were contrary to those obtained in the agroforests of the peri-urban area of the Bafia city in the Central region of Cameroon by Mapongmetsem et al. (2018). In the majority, agroforestry systems in the Sudano-Sahelian zone of Cameroon were younger than those in the Central region. This could be explained by the fact that in the Sudano-Sahelian zone of Cameroon, the population had recently integrated agroforestry systems into their customs, even as agroforestry was an old practice throughout the tropical part of Africa according to Boffa (1999).

In the Sudano-Sahelian zone of Cameroon, contrary to the results of Amoa Amoa et al. (2021) who worked on the same issue in the semi-mountainous western region of Côte d'Ivoire, the agroforestry systems studied in this study had a smaller area. These results could be explained firstly by the fact that farmers, most of whom were poor and elderly, were unable to manage vast areas of crops, sometimes left fallow, and secondly by the fact that the demographic explosion known in these regions (Zieba, 2014) made that there was not enough space to create large farms.

### 4.2 Biodiversity and production

In the agroforestry systems of the Sudano-Sahelian zones of Cameroon, various exotic and local plant species (food crops, market gardening and fruit crops, spices, medicinal plants, etc.) were identified to meet the various needs of households. This result was similar to that of Mariel et al. (2021) in Madagascar. The management of this diversity of plant groups found in this traditional

system allowed farmers to feed themselves, heal themselves, warm themselves, beautify their surroundings and at the same time maintained their environment (Mapongmetsem et al., 2009). Many NTFPs were harvested in these agroforestry systems and significantly strengthen household food security, as also mentioned by Mbolu (1998) in Edea in Cameroon. That was what explained the diversity of products identified in the agroforestry systems of the Sudano-Sahelian zone of Cameroon, which the most important were fruits, cereals and onions. The predominance of these products was justified by the fact that not only they were used in family consumption but they could also bring income to farmers. In addition, other products were harvested to complement the first.

The number of species identified in the agroforestry systems of the study zone was estimated at 37 species grouped into 35 genera and 22 families. Contrary to the results of Ndonmou et al. (2022) who worked in the humid savannah of Cameroon, this number was low. This was explained by the geographical location of the study zone. Indeed, it should be noted that the climatic conditions in this zone were harsher than those observed in the humid savannah of Cameroon. Compared to what was observed in other regions belonging to the same ecological zone, the agroforestry systems of the study zone presented a greater diversity. In the Sudano-Sahelian zone of Burkina Faso, Kafango et al. (2023) found 29 species. This diversity was dominated by fruit species. The significant biological richness in terms of exotic and local fruit trees and useful species included species such as *Mangifera indica*, *Anacardium occidentale*, *Psidium guajava*, *Citrus* spp, *Balanites aegyptiaca*, *Borassus aethiopum*, *Hyphaene thebaica*, *Adansonia digitata*, *Carica papaya*. These results were similar to those of Jagoret et al. (2012) and Jiofack et al. (2013). The local species preserved in these systems by the producers themselves showed that not only did they generally existed before the installation of the systems, grew spontaneously and the producers were just busy maintaining them, but above all, the existence of each species in the plots depended on the selection criteria of the producers who generally selected only those that were able to meet their social, economic, cultural needs, etc. including biofertilization, timber, firewood and food. These assertions suggested that the presence of trees was the most important factor to be considered in agroforestry practices (Alao and Shuaibu, 2011). In this study, 21 exotic and local woody plants were identified. This number was lower than that identified in Chad by Mbaiyetom et al. (2021). Among these woody plants, five fruit species were present in almost all agroforestry systems in the study zone. These were *Mangifera indica*, *Anacardium occidentale*, *Citrus* spp, *Carica papaya*, *Psidium guajava* and four local species (*Borassus aethiopum*, *Adansonia digitata*, *Tamarindus indica*, *Balanites aegyptiaca*) were also present in agroforestry systems. These different groups and many other species were conserved in these systems for their different economic, ecological, medicinal, stakes and construction materials and other roles. These results showed as much as exotic species were introduced by the owners, local species were preferred and

conserved in agroforestry systems for their different roles: food, ecological, magico-religious etc. This assertion was confirmed by the work of Adewusi (2006) in eastern Nigeria.

The structural distribution of individuals by height or diameter class shows a J-shape suggesting a dominance of old individuals in agroforestry systems. This is explained by the fact that in these systems, regeneration is neglected by the owners. Indeed, these systems are created for fruit production. Once the plantation is established, new trees are rarely adopted. This low representation of young individuals in agroforestry systems could lead to a loss of fruit production in the long term. To solve this problem, strategies can be developed by owners who have noticed the phenomenon. It is urgent to replace old plants

### **4.3 Goods and services of agroforestry systems**

Seven groups of uses of goods and five services of trees and annual crops were identified through this study. In fact, in most countries of the Sudano-Sahelian zone, agroforestry practices were very old (Brookfield and Padoch, 1994) and directly provide to several million inhabitants various goods and services (Leakey et al., 1996; Nair et al., 2009). The goods and services of agroforestry systems useful to producers in tropical Africa had been documented by various authors (Libert and Eyog-Matig, 1996; Bayala et al., 2002; Barnes and Fagg, 2003; Traoré, 2003; ICRAF, 2009). However, these results were contrary to the work of Diata et al. (2016) who reported six different services in the agroforestry systems of the peanut basin of Senegal. This difference could be explained by the fact that the agroforestry systems of the present study were orchards created for very specific reasons. The categories of goods and services encountered in agroforestry systems of the Sudano-Sahelian zone were almost the same as those of their counterparts of other zones of tropical Africa. Trees and annual food crops were important sources of income for producers through the sale of products. But, it should be noted that unlike products or goods, the services often implicit were little or not quantified; which led some owners to neglect them when it came to keeping accounts of their farms. Many authors had documented the contribution of different agroforestry systems, as providers of ecosystem services (Place et al., 2012; Diatta et al. 2016; Seghieri and Harmand, 2019) including the sustainability of the agrosystem (Traoré, 2003), the conservation of (agro)biodiversity (Pewili, 2006, Dawson et al., 2013), nutrient recycling (Phombeya, 1999), for carbon sequestration (Nair et al., 2009), the mitigation of the perverse effects of climate variations (Luedeling et al., 2014), environmental resilience (ICRAF, 2009; Nguyen et al., 2013).

## **5. CONCLUSION**

The agroforestry systems of the Sudano-Sahelian zones of Cameroon had a small area and were more than 20 years old in the majority. They were quite diverse in terms of associated species. In total, 37 species grouped in 35 genera and 22 families were identified. *Mangifera indica*,

*Anacardium occidentale*, *Psidium guajava*, *Citrus* spp, *Balanites aegyptiaca*, *Borassus aethiopum*, *Hyphaene thebaica*, *Adansonia digitata*, *Carica papaya* were the most abundant and dominant woody species. The most frequent annual crops were Maize, Sorghum, Cotton, Peanut, Cowpea, Potato while the most dominant market garden crops were onions, vegetables such as Carrot, Sorrel, Black Nightshade, Eggplant, Cucumber, Pepper. Agroforestry systems in the Sudano-Sahelian zones of Cameroon contributed greatly to biodiversity conservation and environmental preservation. The horizontal distribution revealed a “J” shape suggesting the dominance of old individuals in agroforestry systems. Fruits, onions and cereals were the main products from agroforestry systems. Uses or services varied relatively in the different localities of the study area. Uses such as food, construction and medicine were the most important and most common of all localities. Climate moderation, conservation and restoration of fertility, biodiversity conservation were the most important services encountered in agroforestry systems. The study of their functioning and the density of plant species could be a means of combating desertification.

#### **ACKNOWLEDGEMENT**

The authors are in dept to anonymous reviewers who improve the manuscript with their valuable comments.

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