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Farmers' Perception of agroforestry in the Bambou–Mingali forest massif (Congo)

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Abstract— *Agroforestry offers an opportunity to enhance the value of poor ferralitic savannah soils in the Republic of Congo. The aim of the study was to analyze farmers' perceptions of agroforestry in the Bambou–Mingali artificial forest massif. A survey was conducted among 42 farmers who had signed an exploitation contract with the National Reforestation Service (SNR). The study revealed that most of the farmers involved in agroforestry on reforested state-owned plots were adults (83%) and had received education (100%). Agri-silviculture is practiced on these plots. The SNR is responsible for preparing the land for planting forest species (for example, Acacia, Eucalyptus, pines). Weeding was the only maintenance operation carried out by all farmers. Positive factors that may lead farmers to adopt agroforestry innovations in state reforested plots include free access to land, economies of scale in the establishment of food crops, and satisfaction with the yields obtained and income earned compared to savannah areas. Acacia was the most valued forest tree among farmers. Thus, the reforested plots are an opportunity to promote agroforestry for the benefit of smallholders.*

Keywords— ***Perception, agroforestry, socio-economic, forest massif, Congo***

I. INTRODUCTION

Congolese agriculture meets only 30% of the country's food needs (ECOM, 2005). The production system is based on shifting cultivation with cassava (*Manihot esculenta* Crantz) as the main crop. Cassava has a high capacity to adapt to different ecosystems and is the staple food of the Congolese (Massamba and Treche, 1995). The diagnostic assessment of this sector has shown that crop yields are low, averaging 11 t/ha (IFAD, 2008). These low yields can be attributed to low soil fertility, diseases caused by the spread of the African cassava mosaic virus, traditional low-input techniques, and the use of rudimentary tools, among other factors (Mabanza and Mahouka, 2001; Nzobadila Kindiela *et al.*, 2019).

Moreover, the soils of the Congo region are naturally poor, characterized by less exchangeable cations in the clay–humus complex and the acidity of the upper horizons (Djondo, 1994). Farmers cultivating food crops use slash-and-burn agriculture as the primary method of land preparation for cultivation. Slash-and-burn farming temporarily increases the availability of alkaline cations and, consequently the soil pH. Regardless of this positive impact, which is short-lived, this practice has many negative impacts on the soil, including volatilization of nutrients, destruction of organic matter, formation of a water repellent layer on the surface, and destruction of soil biology (Garcia-Oliva *et al.*, 1999; Okonkwo, 2010). In this context, agroforestry can be a sustainable alternative to slash-and-burn farming practices, and can be implemented with the aim of maintaining soil agricultural productivity at a

threshold deemed profitable. Agroforestry systems include both traditional and modern land use techniques where trees are associated with crops and/or livestock systems in agricultural settings. Trees contribute to several ecosystem processes, such as organic matter formation, nutrient recycling, erosion prevention, and water balance modification (Nasielski *et al.*, 2015; Carrier, 2018). Therefore, agroforestry systems offer forms of soil fertility improvement, food, and financial resources for local populations (Dupraz and Liagre, 2008; Jose, 2009).

In the Republic of Congo, the national reforestation policy is implemented by the National Afforestation and Reforestation Programme (ProNAR) and the National Reforestation Service (SNR). The SNR is a public service responsible for the establishment and management of state-owned plantations. In its prerogatives, this service has to its credit several state-owned areas at the national scale, including that of Bambou–Mingali located in the district of Igné, Department of Pool, 70 km north of Brazzaville. Within the framework of the management of the massifs, the national policy advocates partnerships between the public service and farmers/wood plantation industries. These partnerships aim to associate the cultivation of trees and food crops in plantations. The agroforestry initiative was launched by the SNR in the Bambou–Mingali forest massif in 2015. Several years after the launch of this initiative enhancing the value of state-owned plots through agroforestry, the results and effectiveness of this agroforestry system remain poorly understood. As a good understanding of farmers' perception is a prerequisite for sustainable land management initiatives, as reported by Valdivia *et al.* (2012) and Adedayo and Oluronke (2014), this study aimed to analyze farmers' perceptions of the socio-economic benefits of the agroforestry system under the socio-environmental conditions of Bambou–Mingali.

II. METHODOLOGY

Study area

The study was conducted in the Bambou–Mingali forest massif, in the sub-prefecture of Igné, in the urban community of Igné as well as in the villages bordering this massif (Figure 1). The village of Bambou–Mingali is located at a distance of approximately 60 km from Brazzaville on the Mbé Plateau. An important forest massif that comprises approximately 1100 ha in the state land domain of 2100 ha is located nearby and secured by the P_{RO}NAR. Several forest species are planted in rows in this area, with variable densities for each species. These include clones of the hybrid *Eucalyptus urophylla* × *Eucalyptus grandis*, *Eucalyptus PF1*, *Pinus caribaea*), *Millettia laurentii*, *Acacia auriculiformis*, and *Acacia mangium*. Access to the site for farmers is subject to the signing of a memorandum of understanding between them and the SNR. All farmers are required to maintain the land in an acceptable state of cleanliness to enable proper growth of the trees at the site. The farmers conduct periodic maintenance of the young plants and crops and the public service or the industrialists are responsible for land preparation operations (ploughing, harrowing, squaring, staking, hole digging, and planting)

The climate of the study area is humid tropical (Samba-Kimbata, 1978). The average annual temperatures vary between 23 °C and 26 °C. Seasons alternate as follows: short dry season (January, rainfall decreases), first rainy season (February to mid-May, with a peak in April), long dry season (mid-May to mid-September) and second rainy season (October to December). The interannual rainfall variability between 1980 and 2014 was approximately 1,364 mm (Mengho, 2017). The soils in the study area are ferralitic, impoverished, and highly desaturated from the ochre sands of the Teke Plateau. They are characterized by sandy texture and low organic matter content, with a low reserve of exchangeable bases. The cation exchange complex is dominated by aluminum (46%), calcium (20%), and magnesium (9%) (Souchere and Bosseno, 1974; Djondo, 1994). The habitat comprises a herbaceous savannah with the following dominant species: *Hyparrhenia diplandra* Stapf., *Crotalaria retusa* L., *Hymenocardia acida* Tul., and *Annona senegalensis* Pers. (Descoing, 1975; Makany, 1976). Following land reclamation, the dominant species were *Digitaria horizontalis* Willd. and *Imperata cylindrica* (L.) P. Beauv.

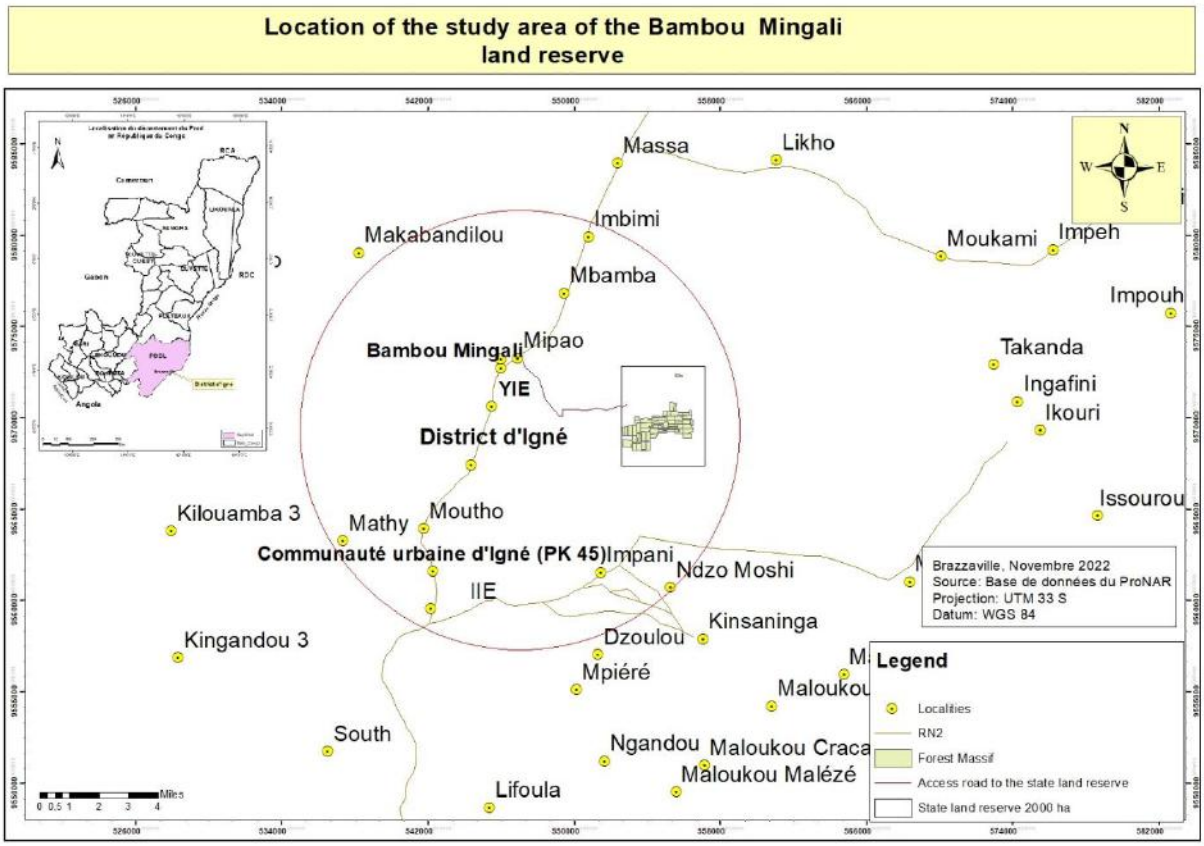

Fig.1. Location of the study area

Sampling and data collection

The study population consisted of farmers of the Bambou–Mingali forest massif. As the list of agroforestry farmers in this forest massif was available, the sample was constituted on the basis of probability sampling, by drawing lots. The selected farmers were contacted by telephone and an appointment was made to conduct the individual interview using a survey questionnaire. A total of 42 farmers were selected from the 50 farmers who had signed the contract with the SNR forestry station represented by its head of unit, resulting in a sampling rate of 84%. The interviews were supplemented with open discussions, individual interviews with resource persons via an interview guide, and documented information. The latter focused on documentation related to agroforestry and knowledge of the study area. The data collection tools (survey questionnaire and interview guide) included information on farmer profiles, the characterization of the production system, and perception of the benefits of agroforestry; these tools were validated during a pre-survey. The formal individual interviews were conducted either at the farmers' residence or at the farm site. However, free discussions were held in places where people could use the land, in this case in bars.

Data processing and analysis

Data were analyzed using Sphinx software version 5.1.0.7. The database constituted through data entry was checked for consistency and conformity between the data collected and those entered. The data collected in the field were subjected to descriptive statistical analysis, thus determining the numbers and frequencies (%) of the response modes of the variables studied. The chi-square test was used to test the significance of the responses for qualitative variables. Excel 2016 software was used to graphically represent the results.

The qualitative data from the open discussions, literature review, and resource person interviews were subjected to content analysis to extract the information essential to the study objectives.

III. RESULTS

Description of the Bambou–Mingali agroforestry system

Access to the inter-rows of forest plots in the massif for the cultivation of food crops is subject to the signing of a work protocol between the station chief and the farmer, who may be the farmer or a person belonging to another category. The terms of the contract stipulate that "the SNR authorizes the farmer to plant cassava cuttings or other food crops in the young plantations." However, the farmer is obliged not to destroy the young plants during the planting of cassava

cuttings or other food crops, and the same applies to weeding operations aimed at keeping the plots clean throughout the crop cycle. This is a "win-win" public-private partnership agreement, as the SNR is exempted from the cost of maintaining the plot and the farmers are given free access to an area of between 0.5 and 5 ha. If the plot is not maintained, the SNR conducts mechanical maintenance of the plot, which implies that it destroys everything in the rows using a machine, leaving only the forest species, and then withdraws the farmer's access to the plot.

Table 1 presents a description of the Bambou–Mingali agroforestry system. The results show that the agroforestry system practiced here was the only one practiced in these state plots. Cassava was the main crop cultivated by farmers, accounting for 79% ($P < 0.05$). It represents the staple food of this region as well as the main product marketed after processing (cassava pods, cassava bread, or chikwangue). Approximately half of the farmers (55%) managed agroforestry plantations of less than one hectare ($P < 0.05$). However, 31% of the farmers cultivated areas between 1 and 2 ha. Very few cultural maintenance operations were conducted within these agroforestry plots. Weeding was the main maintenance operation conducted by almost all farmers, 95% ($P < 0.05$). The use of basal and maintenance fertilization and the use of plant protection products for better crop protection was rare ($P < 0.05$). Moreover, very few farmers (7%) used crop rotation ($P < 0.05$).

Table 1. Characteristics of the Bambou–Mingali agroforestry system

Variables	Responses	Frequency (%)	Significance
Cultivation system used	Agri-silviculture	100	Constant
	Other	0	
Key crops of the farm	Cassava	79	P < 0.05
	Vegetables	15	
	Corn	6	
Area farmed (ha)	< 1 ha	55	P < 0.05
	1-2 ha	31	
	> 2 ha	14	
Cultivation operations conducted	Weeding	95	P < 0.05
	Weeding and fertilization	5	
	Other	0	
Use of fertilizers	No	95	P < 0.05
	Yes	5	
Use of plant protection products	No	100	P < 0.05
	Yes	0	
Practice of crop rotation	No	93	P < 0.05
	Yes	7	

Socio-economic importance of the Bambou–Mingali agroforestry system

The practice of agroforestry in the Bambou–Mingali forest massif mobilized both women and men, in proportions of 45% and 55%, respectively ($P > 0.05$). Young people (17%) were less involved compared to adults (83%). Thus, the proportion of adults that participated in the system was approximately five times greater than that of youth ($P < 0.05$). The schooling rate of farmers was 100%, with a predominance of farmers with a secondary level 2ème degree (31%) ($P < 0.05$). Agriculture and trade were the two main activities the surveyed farmers participated in, with proportions of 45% and 31%, respectively.

The survey results also showed that more than half of the farmers (60%) had less than 5 years of agroforestry experience ($P < 0.05$). However, 24% of the farmers surveyed claimed to have between 6 and 10 years of agroforestry experience (Table 2). In contrast, a marginal proportion of farmers had a rich agroforestry experience exceeding 11 years. Half of the respondents resided in the urban community of Igné ($P < 0.05$). Other respondents lived in the rural communities of Bambou–Mingali (19%), Yié (19%), and Moutoh (12%).

Table 2. Profile of farmers in the Bambou–Mingali forest massif

Variables	Responses	Frequency (%)	Significance
Type	Female	45	P > 0.05
	Male	55	
Age range (years)	Young ≤ 35	17	P < 0.05
	Adult ≥ 36	83	
Level of education	Primary	29	P > 0.05
	Secondary 1er degree (middle school)	24	
	Secondary 2ème degree (high school)	31	
	University	17	
Main activity	Agriculture	45	P < 0.05
	Trade	31	
	Other activities	21	
Length of time in agroforestry experience	≤ 5 years	60	P < 0.05
	6-10	24	
	≥ 11 years	17	
Location of respondent's residence	Urban Community of Igné	50	P < 0.05
	Bambou–Mingali	19	
	Yié	19	
	Moutoh	12	

The results of the survey showed that marketing and self-consumption were the two objectives of establishing farms in the Bambou–Mingali forest massif. Notably, a large majority of farmers (86%) were involved in commercial, market-oriented farming (P < 0.05). Free access to land within the forest massif was the main determinant of the establishment of agricultural plantations in this massif (72%) (P < 0.05). However, proximity to the place of residence (19%) and the search for fertile land (9%) were also among the other factors contributing to the cultivation of food crops within the forest plots (Table 3).

Table 3. Motivations for agroforestry practice in the artificial forest

Variables	Responses	Frequency (%)	Significance
Objectives of the operation	Auto consumption	14	P < 0.05
	Marketing	86	
Motivations for the establishment of plantations in the forest	Free access to land	72	P < 0.05
	Soil fertility	9	
	Proximity of the place of residence	19	

Analysis of the consolidated operating cost for the cultivation of one hectare of cassava in plots located inside and outside the forest under SNR management showed that the SNR's contributed approximately 45% to the production cost of cassava cultivation. Indeed, farmers who cultivated cassava on plots prepared by the SNR minimized expenses related to access to land and soil preparation operations (stump removal, stump collection, ploughing, and harrowing). These costs amount to 180,000 FCFA for one hectare of cassava (Table 4). This category of farmer incurred a production cost of 216,500 FCFA and made a turnover of 500,000 FCFA after selling 60 bags of cassava. At the end of the production cycle, they had a net commercial margin of 283,500 FCFA. However, farmers

who cultivated cassava outside the forest massif incurred higher production costs. These production costs amounted to 396,500 FCFA, i.e., a difference of 180,000 FCFA, thus reflecting the satisfaction of the farmers in partnership with the SNR.

Table 4. Consolidated operating cost for cassava cultivation in Bambou–Mingali

Operation	Bambou–Mingali Forest Massif		Outside the forest massif - Savannah	
	Expenses (FCFA)	Product (FCFA)	Expenses (FCFA)	Product (FCFA)
Expenses (A)				
Purchase of the machete	4 000		4 000	
Purchase of the hoe	3 500		3 500	
Purchase of the peel	4 000		4 000	
Land rental	0		30 000	
Stump removal	0		50 000	
Pickup	0		10 000	
Ploughing	0		45 000	
Spraying	0		45 000	
Buy cuttings	10 000		10 000	
Cutting of cuttings	5 000		5 000	
Transport	10 000		10 000	
Planting	30 000		30 000	
Weeding	120 000		120 000	
Harvest	30 000		30 000	
Total load	**216 500**		**396 500**	
Turnover - Cassava sales (B)		500 000		500 000
Net sales margin (B-A)		**283 500**		**103 500**

The socio-economic importance of agroforestry within this massif is justified by the satisfaction of the majority of farmers surveyed (88%). Indeed, 81% of the respondents were satisfied with the income generated through agroforestry within this forest massif ($P < 0.05$). A marginal proportion of farmers (7%) were highly satisfied with the income generated. However, 12% of farmers remain dissatisfied with the income generated; these mostly included farmers cultivating in *Eucalyptus* plots.

Perception of the benefits of the state agroforestry system and the most suitable forest species

Table 5 shows the perception of farmers in Bambou–Mingali forest massif regarding the benefits of trees within the farm and the most suitable forest species for cultivation in association with food crops. The analysis of Table 5 shows that leaf collection was the main benefit perceived by the farmers (57%) ($P < 0.05$). These leaves are used to fertilize the soil and also serve as natural remedies. For example, *Eucalyptus* leaves are harvested for the treatment of respiratory tract diseases (bronchitis, flu) and ENT diseases (sinusitis). The ecosystem services provided by trees integrated into farming also concern the improvement of soil fertility for certain forest species of the family Fabaceae (*Acacia* spp.), which affects crop yields and farmers' income. Harvesting of wood, caterpillars and mushrooms are also ecosystem services provided by the agroforestry system through the trees. During September and October, when the rains begin, some farmers reported harvesting mushrooms from their agroforestry farms.

The results also indicate that *Acacia* is the most preferred tree in agroforestry in the study area. More than half of the farmers included in the survey held this view (69%) ($P < 0.05$). In terms of preference, *Acacia* was followed by pine and *Millettia*, at 14% and 12%, respectively. *Eucalyptus*

was the least preferred tree in agroforestry, with 5% of the respondents showing a preference for it.

Of the farmers interviewed, 79% thought that cassava yields in the Bambou–Mingali massif were higher than those in the savannah zone ($P < 0.05$). Only 21% disagreed with this view. This category of farmers cultivated food crops in the *Eucalyptus* plots.

Table 5. Perceived benefits of the agroforestry system in state-owned plots

Variables	Responses	Frequency (%)	Significance
Advantage of trees in the farm	Collection of leaves	57	$P < 0.05$
	Improvement of soil fertility	19	
	Firewood	18	
	Mushroom harvesting	6	
Best woody species for agroforestry	*Acacia mangium* Willd./*Acacia auriculiformis* A. Cunn. ex Benth.	69	$P < 0.05$
	Pinus spp.	14	
	Millettia laurentii De Wild.	12	
	Eucalyptus spp.	5	

Acacia and pine were the two most preferred forest trees in the agroforestry system. Most farmers (90%) preferred to grow cassava with *Acacia* ($P < 0.05$). The same was true for maize (*Zea mays* L.) cultivation; 70% of the farmers preferred to cultivate with *Acacia* (Figure 2). However, for groundnut (*Arachis hypogaea* L.) cultivation, more than half of the farmers preferred to cultivate it in association with young pine trees ($P < 0.05$). Therefore, the promotion of agroforestry should focus more on *Acacia* to enhance the value of the savannah areas, which are less appreciated by farmers.

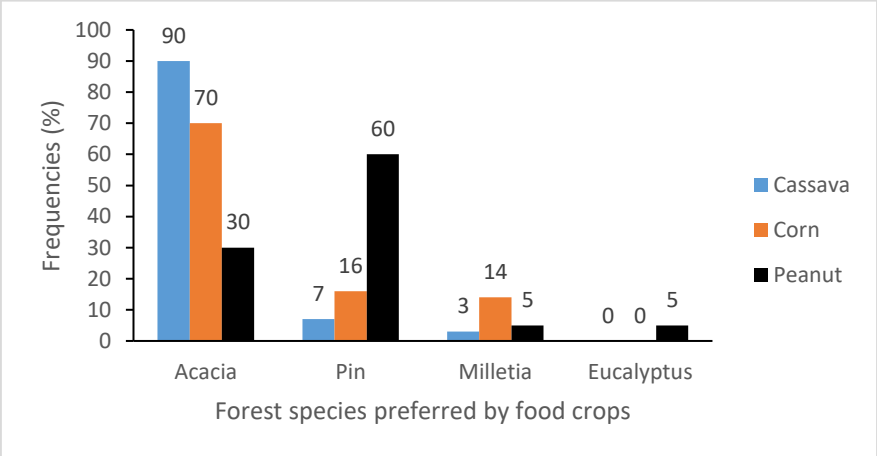

Fig.2. Farmers' perception of the preference for forest species cultivated in association with food crops

IV. DISCUSSION

Characteristics of the Bambou–Mingali agroforestry system

Only one agroforestry system, the agri-silviculture cultivation system, was practiced by farmers in the plots located in the Bambou–Mingali forest massif. Agricultural production was achieved using technical itineraries and archaic means of production that were not very efficient. With respect to crop maintenance operations, few interventions were conducted, and weeding was the most common intervention. The cut weeds were stirred up and left on the ground to restore exported nutritive elements through decomposition.

In the Bambou–Mingali forest massif, cassava was the preferred crop, and was planted both as a monoculture and in association with trees. Previous studies have shown that the traditional agricultural system integrates a range of crops with differing phonologies to ensure optimal production that is staggered in time. Crop association provides production security by minimizing risks and

maximizing land and labor use (Jayne *et al.*, 2010). National agricultural production basins are characterized by low crop diversity, including cassava cultivation areas. Furthermore, several studies in rural areas note that crops are often grown in association with others (maize, vegetables, groundnuts, etc.), but rarely as monocultures (ECOM, 2005). Only cassava is cultivated through monoculture; however, this is often observed in areas where cultivation of other crops is challenging owing to extremely poor soils.

The area utilized for agricultural purposes in the Bambou–Mingali Forest is mostly less than one hectare. Very few farmers practice cultivation in >2 ha of land; this can be explained by a various factors, including the difficulty in obtaining quality cuttings and tractors for land preparation and low soil fertility. Congolese agriculture is poorly mechanized and therefore highly dependent on labor. Moreover, cassava cultivation benefits from little investment, despite constraints such as field maintenance. In many agricultural production basins in Congo, family farms range between 0.5 and 1 ha (ECOM, 2005; CERAPE-SOFRECO, 2012). Larger areas are sown by producers with greater financial and human resources, as they can bear the higher production and marketing costs.

Mineral fertilization of cassava is significantly rare, and only 2 respondents out of the 42 surveyed applied NPK fertilizer for food crops. The distribution circuit for agricultural inputs is disorganized, resulting in low availability and high cost. In addition, the agricultural extension services responsible for disseminating good agricultural practices are deficient. It has been observed that the supply of organic matter is also non-existent in the area. This observation is shared by CERAPE-SOFRECO (2012) who found that the use of fertilizers remains marginal, and is limited to peri-urban areas. As cassava is a hardy crop, its cultivation requires only basic land preparation and few maintenance cultivation operations (El-Sharkawy, 2004). Several studies have shown the importance of fertilizers in maintaining soil quality. Schroth *et al.* (2001) also showed that fertilization is less frequent in agroforestry.

The use of phytosanitary treatments was non-existent in the study area. For the farmers surveyed, cassava plants in the field were rarely affected by crop diseases and pests. However, it should be noted that cassava is a hardy crop, growing quite well in most environments, and farmers are generally unaware of the symptoms of cassava diseases. Moreover, several farmers perceive that cassava that is attacked by pests or diseased is still productive. Thus, the model of agriculture practiced in the Bambou–Mingali forest massif is the same as that of almost all Congolese food production basins, strongly dominated by the individual or family village agricultural model, using rudimentary tools and techniques and not resorting to chemical inputs, especially fertilizers and pesticides (CERAPE-SOFRECO, 2012).

To a certain extent, farmers tend to grow varieties that are adapted to the environment (Elias *et al.*, 2004). This observation was also shared by CERAPE-SOFRECO (2012) who found that the use of pesticides in the Congolese rural environment remains marginal, and is limited to the peri-urban areas of the country, where market gardening activity remains important. Very few farmers in the agroforestry massif exploit the entire domain granted by the SNR by implementing crop rotations. However, fallowing is a constant feature of production systems in rural areas (Floret *et al.*, 1993).

Socio-economic importance of the Bambou–Mingali agroforestry system

The farmers of the Bambou–Mingali forest massif comprised both men (55%) and women (45%). Farmers in the age range of 36–44 years (45%) were the most involved in the agroforestry plantations of Bambou–Mingali. Almost similar results were also reported by the RGA (2017), wherein 74% of the heads of adult agricultural households and those in this category in the age range of 36–49 years were the most dynamic in the Congolese agricultural sector (38%). The high level of participation of this category of farmers remains an asset for the extension of agroforestry practices. Many studies report that age can be a determining factor in the adoption of a new technique (Adedayo and Oluronke, 2014). Regarding the age of agroforestry implementation, a majority of the farmers interviewed claimed to have practiced agroforestry for less than 5 years. The high proportion of farmers with less than 5 years of experience is owing to the fact that the SNR has only allowed farmers to cultivate in the massif for 5 years. However, those with more than 5 years' experience had already practiced the system elsewhere, in the surrounding forest blocks or in other localities.

All farmers included in the survey were educated. However, over half (55%) of them received secondary education, with a predominance of those with a secondary 2ème degree (31%). Nearly one-fifth of the respondents (17%) had a university degree. This can be explained by the proximity of the surrounding localities to the city of Brazzaville, the political capital, where the education offered is highly diverse. Moreover, the urban community of Igné includes school infrastructure, including a public high school. It is obvious that the development of agroforestry techniques and innovations requires a minimum of training and technical supervision. Results of previous studies have shown that the level of education plays a role in learning

new agricultural techniques and facilitates their adoption (Valdivia *et al.*, 2012; Adedayo and Oluronke, 2014).

The main activity of 45% of the farmers in the Bambou–Mingali Forest was agriculture. Other farmers used agriculture as a secondary or tertiary activity. This second category of farmers were primarily engaged in trade, vehicle driving, and handicrafts; this category also included government officials. The high involvement of farmers who do not farm as their main activity can be explained by the fact that households are highly dynamic in rural areas and can implement several monetization strategies simultaneously (Jayne *et al.*, 2010).

Most of the farmers (86%) surveyed conducted agricultural activities with the aim of marketing their products; a small portion of the production was devoted for self-consumption. As agriculture is the main income-generating activity for the inhabitants of this area, the cultivation of food crops is not only for self-consumption but also has serious economic importance. The integration of the local economy into a wider trade zone has been achieved through the National Road No. 2, which provides trade opportunities between the surrounding localities and the city of Brazzaville, where the demand for food products remains very high.

Farmers were highly satisfied with the income generated from agroforestry production compared to that generated from farms in the savannah zone. This satisfaction of the respondents was owing to the fact that farmers growing cassava on SNR plots saved expenses related to access to land and soil preparation operations. Increasing productivity within production systems is a requirement for economic development and poverty alleviation. This positive perception of farmers in Bambou–-Mingali forest range corroborates the work of Mercer (2004) and Bengali (2018), who argue that endogenous determinants affect farmers' perception. A majority of the respondents believed that this SNR initiative of agroforestry could enhance the value of wasteland and reduce the distances traveled in search of forest patches. In this context, the Société des Plantations Forestières Batéké Brazzaville (SPF2B), whose main objective is charcoal production, has integrated agroforestry into its production model by setting up a community development program. This program aims to encourage local communities to grow food crops (such as cassava, groundnuts, and maize) in the spaces between the *Acacia auriculiformis* A. Cunn. Ex Benth trees planted. All land preparation operations in the areas allocated to local communities in the Igné district of Congo are carried out by the SPF2B company prior to the allocation of land portions.

Benefits of the state agroforestry system and perception of the most suitable forest species

Free access to land was the main driving farmers' preference for the Bambou–Mingali state forest for conducting farming activities. To a lesser extent, they also cited the proximity of the site to their place of residence. The benefits cited by farmers owing to the presence of trees on their farms were soil fertilization and the availability of plant materials for traditional medicine. Collection of firewood and mushroom harvesting were among the less cited reasons. Similar to our findings, Jose (2009) showed that agroforestry parks are significant sources of wood and non-wood products that are indispensable to the population.

Most farmers found that crop yields were higher in the SNR agroforestry site than those outside the site. They also found that crop yields obtained in the *Acacia* plots were significantly better compared to plots with other forest species. *Eucalyptus* was the least preferred forest tree in association with crops. The relatively high crop yields in the *Acacia* plots can be explained by the fact that *Acacia* is genus belonging to the legume family Fabaceae and thus restores soil fertility. Indeed, leguminous plants are atmospheric nitrogen-fixing plants that transform nitrogen from the air into nitrogenous compounds in symbiosis with certain types of bacteria, thus improving soil fertility.

The consequences of a tree-crop association are variable depending on the associated species and the site studied (pedoclimatic conditions). Nevertheless, it would positively affect agricultural production owing to the discontinuous arrangement of trees, which would result in an increase in soil and air humidity, soil fertility, as well as a slowing of winds (Jose, 2009; Schroth *et al.*, 2001; Nasielski *et al.*, 2015). In contrast, the presence of trees sometimes adversely affects crop development (Carrier, 2018). The study by Akouehou *et al.* (2011) in Benin showed that the Taungya agroforestry system based on *Acacia auriculiformis* restored agricultural land and allowed farmers to have an additional and diversified gain of food products to support their needs. Dupraz and Liagre (2008) reported several advantages of agroforestry, including agronomic advantages (such as creation of microclimates in the plots, vertical development of the root system, nitrogen fixation for legumes) and economic advantages through income diversification. Consequently, the promotion of agroforestry based on forest species in state-owned plots provides an opportunity to enhance the value of savannah areas and a strategy for sustainable agricultural development that benefits family and commercial farming.

V. CONCLUSION

This study contributes towards a better understanding of farmers' perception of agroforestry in the Bambou–Mingali forest massif. The study revealed that the farmers in this

forest massif included both men (55%) and women (45%), 83% of whom were adults; the youth did not participate in farming to a considerable extent. The agri-silviculture system was the main cropping system practiced in this region. Cassava was the main crop grown in these forest plots, and other food crops (for example, maize and groundnuts) were sometimes cultivated along with cassava. Overall, the areas cultivated covered <2 ha (86%). Land preparation operations were generally managed by the SNR when the forest species were installed, which constituted an economy of scale for the farmers. Weeding was the main crop maintenance operation, and it also remained one of the "sine qua non" conditions for the utilization of state-owned plots of this forest massif by farmers. Very few farmers used fertilization (organic and mineral) and phytosanitary products. The survey also revealed that farmers perceived several advantages of agroforestry, including free access to land, economy of scale in setting up the farm, and satisfaction with crop yields and income compared to savannah areas. *Acacia* was the most valued forest tree.

The agroforestry experience of the Bambou–Mingali forest can serve as an example for the development of other forest areas. It enables the reconciliation of environmental and food concerns by developing uncultivated land for agriculture while reducing the distances traveled in search of forest patches. Promotion of forest species of the Fabaceae family, such as *Acacia*, is therefore necessary in the reforestation policy of state-owned plots. Future research should examine the sustainability of the agroforestry systems implemented and conduct in-depth studies of tree and food crop interactions to determine the best innovations to be popularized.

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