

Contribution of Avenue Trees Planted Along Managed Roadways in the Provision of Ecosystem Services to the Population of the Municipality of Sèmè-Podji in Benin

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Abstract: The plant needs of city dwellers sometimes force them to make use of the local plant diversity of which the avenue trees are a part. In the municipality of Sèmè-Podji, avenue trees provide social and environmental advantages to residents in daily practices. However, they are poorly valued and subjected to anthropogenic pressures. The objective of this study is to analyze the contribution of avenue trees in the provision of ecosystem services to the populations along roadways of the municipality of Sèmè-Podji. The methodological approach used is based on counting the forms of harvesting from the different species of trees over 26 kilometers of developed streets. Then, semi-structured interviews are carried out with 260 peoples, divided into 4 socio-professional categories. The Pearson correlation test was used to assess the agreement between the opinions of the respondents, then the prioritization matrix and the factorial correspondence analysis were used to assess the involvement of species and organs in the availability of ecosystem services. The results obtained reveal 7 forms of use classified into 4 categories of ecosystem services, confirmed by the opinions of the socio-professional categories with high degree of consensus between traders and craftsmen ($r = 0.955$; $p = 0.001$). The usage values vary between 0.53 (regulation service) and 0.04 (support service). However, supply services are the most cited and come from the species *Coccoloba uvifera*, *Terminalia catappa*, *Cocos nucifera*, *Manguifera indica* and *Eleais guineensis*. Taking into account the information provided by the populations on ecosystem services could facilitate the integration of alignment plantations in the sustainable development of this city.

Keywords: Avenue Trees, Alignment Plantation, Ecosystem Services, Urban Planning, Sèmè-Podji

1. Introduction

Plants are an integral part of urban ecosystems which play a significant role in human life [1]. The forms of use of these plants are described through the removal of organs or the use of parts of plants in the form of goods and services that trees provide both to man and to nature and which represent the ecosystem services [2]. These benefits provided by plants contribute to the well-being of populations through carbon sequestration in the atmosphere [3], the renewal of oxygen in the air and hygrometric regulation [4, 5], the control of water erosion of soils [6] and the improvement of thermal comfort [7]. Thus, the tree is revealed as a multifunctional component of the urban environment and essential to maintaining the living environment of city dwellers [8]. It is therefore

appropriate for urban managers to make trees sustainable using appropriate management approaches to ensure the availability of ecosystem services to city dwellers [9].

However, the ecosystem services provided by urban trees vary depending on the city and the nature of the relationship between the tree and its environment, in particular the biotic and abiotic factors [10], which condition its viability. Indeed, the level of greening of cities, the availability of spaces for the establishment of green spaces, the status of the city and the socio-cultural value of the tree, influence the availability of ecosystem services [11]. In addition, it is established that the standard of living and knowledge of the populations improve their cohabitation with urban trees through maintenance, the increase in their number, the maintenance of biomass [12], and spare them from acts of vandalism. These interactions

between the tree and its environment show that the magnitude of the benefits provided by urban trees depends on their abundance, size and growth in the urban landscape [13]. Thus, green spaces, in addition to their aesthetic value, contribute to improving the sociological, psychological, economic and ecological conditions of life in urban areas [14]. In addition, with the current dual context of urban people growth and climate change, green spaces constitute an encouraging alternative to meeting the vital needs of local populations and resilience to the energy crisis in sight in cities [15].

This situation of interdependence between trees and populations also characterizes the main and secondary cities of Benin, where urban plant resources are often called upon in daily practices, but little known in the form of ecosystem services [16]. This is the case in the municipality of Sèmè-Podji, where urban trees are poorly valued and subjected to anthropogenic pressures. As a result, we are witnessing a degradation of urban phytodiversity [17] and a gradual decrease in the benefits of local plant resources to meet the needs for ecosystem services [18] of an increasingly growing population. In addition, the low priority given to landscaping in the city and the socio-cultural influence of the environment are all factors that influence the promotion and survival of urban trees. This situation does not provide reliable information for decision-making in urban forestry, making the assessment of the potential for ecosystem services uncertain [19]. Faced with this challenge, it is necessary to fall back on the knowledge of city dwellers to understand the interactions

between trees and the urban environment [20]. It is in this perspective that this study proposes to analyze the contribution of alignment trees in the provision of ecosystem services in the town of Sèmè-Podji.

2. Material and Methods

2.1. Study Area

Located in Ouémé department, in the south-east of the Republic of Benin and on the Atlantic coast, the Municipality of Sèmè-Podji is situated between 6°19'59" and 6°27'34" north latitude and between 2°27'42" and 2°42'34" east longitude (Figure 1). At the last population census, the Municipality of Sèmè-Podji had 222,701 inhabitants, including 113,107 women [21]. Due to its geographical location, the municipality of Sèmè-Podji enjoys a Sudano-Guinean type climate with two dry seasons and two rainy seasons. The average temperature is around 27°C with high relative humidity. The annual rainfall is 1,100 mm, this due to cyclical disturbances under the influence of the coastal wind, which also makes this town one of the wettest areas in southern Benin. The green landscape of the study area belongs to the Guinean coastal phytogeographic sector made up of shrubs and shrubs, but which are endangered due to the pressure exerted by the neighboring populations. The biophysical conditions thus described are favorable for the development of urban plants, including the avenue trees which were the subject of this study.

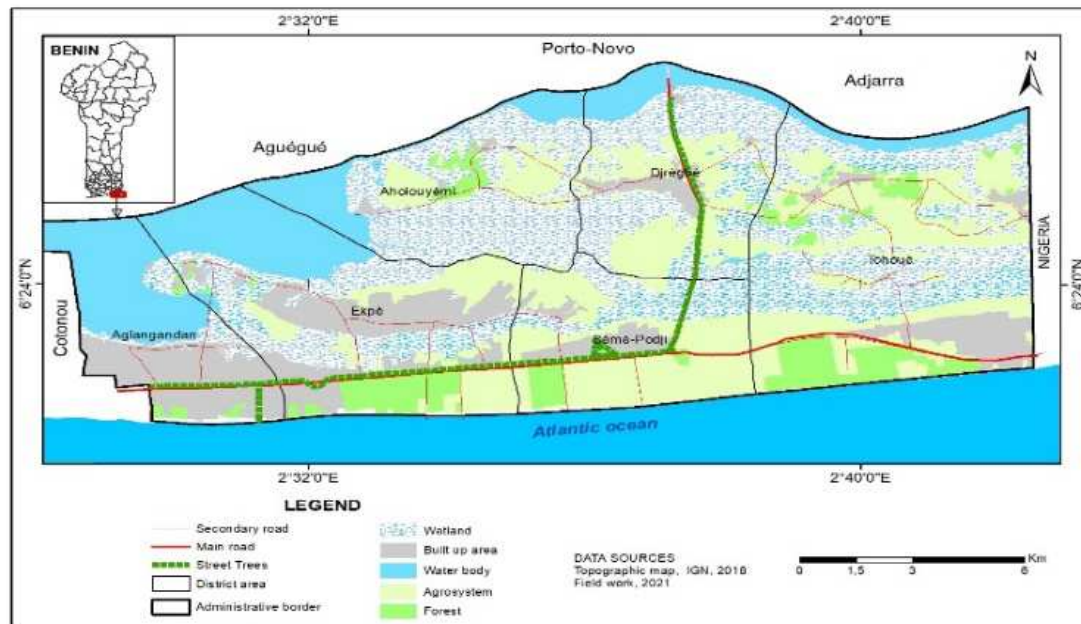


Figure 1. Geographical location of the municipality of Sèmè-Podji.

2.2. Sampling and Data Collection Methods

The avenue trees studied are those located along managed roadways (highroad or paved) and which are officially reforested by local or decentralized authorities. Thus, out of a total of 26 km of developed streets, tree species in alignment

are identified on both sides. Then, a questionnaire was sent to users of these roads to understand the benefits they derive from proximity alignment trees, as well as their perceptions of ecosystem services. Reasoned-choice sampling made it possible to select in an itinerant way, one individual for every 100 meters of street, that is to say a total of 260 individuals

subjected to the questionnaire. The number of respondents is proportional to the length of each plantation studied and the profile of the respondents is made up of an employee, a trader, an artisan and a housewife who is at least the age of majority.

2.3. Data Processing and Analysis Methods

The information collected from the populations is entered in the Excel spreadsheet and the relative frequencies are calculated for the various benefits reported by the categories of actors and coming from the avenue trees.

The relative frequency (RF) reflects the ratio of the number of responses (n) to the total number of responses obtained for a variable (N):

$$RF = \frac{(n \times 100)}{N} \quad (1)$$

Then, Pearson's correlation test was used to assess the concordance of responses between the categories of actors surveyed. Pearson's correlation is defined as the ratio of the covariance of two variables considered, normalized by the square root of their variance [22]. It is calculated by the formula:

$$r = \frac{\sum (x - \bar{x})(y - \bar{y})}{\sqrt{\sum (x - \bar{x})^2 \sum (y - \bar{y})^2}} \quad (2)$$

Where r is Pearson's correlation; x and y are the variables of the socio-professional categories considered; and \bar{x} and \bar{y} are the means of these variables. The probability associated with each correlation coefficient is also determined to assess the level of significance at the 5% threshold.

To assess the importance of the forms of use of the organs of avenue trees, the use value formula, often used in ethnobotanical studies [23, 24] is used. This value is based on the number of organ uses and the number of people who cited a form of organ use. It is noted UV and varies from 0 to 1. Its formula is:

$$UV = \frac{\sum n_i}{N} \quad (3)$$

With n_i the number of people who cited a form of use for an organ and N the total number of respondents.

For the categorization of ecosystem services associated with the species diversity of streets, the forms of use of the organs of each tree are determined, then integrated into the matrix of the functional classification of ecosystem services proposed by Kosmus *et al.* [25]. Then, the table of the relative frequencies of citation of the forms of use by organ used by the populations on each species is subjected to a Chi square test (χ^2), then to a Factorial Correspondence Analysis to assess the map of the specific richness, depending on the organs or part

of the plants used.

3. Results

3.1. Characteristics and Consensus of Informants on Ecosystem Services

Respondents are made up of employees from the public or private sector, traders, craftsmen and housewives living or working along the streets lined with alignment trees. Characteristically, the employees are 90% men and 10% women, with an average age of 34 ± 5 years. Among them, 80% have a university level and 20% have reached the secondary level. As for the traders, they are made up of 60% men and 40% women, with an average age of 36 ± 10 years. Among them, 38% have a university level, 25% have reached secondary level and 37% have primary level. The craftsmen interviewed are all men, with an average age of 41 ± 9 years. Among them, 23% have a university level and 27% have reached secondary level and 50% have reached primary level. The housewives interviewed have an average age of 28 ± 9 years. Among them, 27% have a university level and 32% have reached the secondary level and 41% have the primary level. These characteristics testify to the relative maturity of respondents to provide reliable information.

Thus, 55% of respondents from these socio-professional categories benefit from supply services, compared to 27% of respondents for regulation services, 16% for support services and 2% for socio-cultural services (Figure 2).

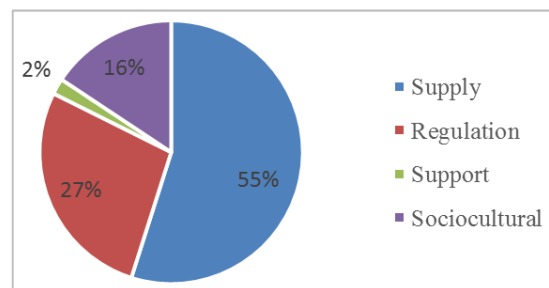


Figure 2. Proportion of responses on the categories of ecosystem services recognized by the populations on the alignment trees.

It should be noted that some respondents refer to two or more ecosystem services. The level of consensus between these socio-professional categories is presented in the correlation matrix in Table 1.

Table 1. Pearson's correlation on the categories of actors who gave their opinion on ecosystem services.

Couple of actors	Pearson's correlation (r)	Coefficient of determination (r ²)	Probability (p)
Employee / Trader	0,501	0,251	0,252
Employee / Craftsman	0,539	0,290	0,212
Employee/Housewife	0,051	0,003	0,913
Trader/Craftsman	0,955	0,911	0,001***
Trader/Housewife	0,823	0,677	0,023*
Craftsman/housewife	0,813	0,660	0,026*

The agreement of opinions is significant at the threshold of 0,05 (*); 0.01 (**) and 0.001 (***).

From this table, we retain that the degree of consensus on the use of goods and services from the alignment trees is correlated between Trader and housewife ($r = 0.823$; $p = 0.023$), craftsman and housewife ($r = 0.813$; $p = 0.026$), then very significant between trader and craftsman ($r = 0.955$; $p = 0.001$). The coefficient of determination calculated indicates that the rates of concordant responses from the opinions of these actors are respectively 91%, 67% and 66%. As a result, the exploitation of ecosystem services from line trees is real and of great importance to traders,

artisans and housewives along the landscaped streets of the town of Sèmè-Podji.

3.2. Prioritization of Ecosystem Services Associated with the Avenue Trees in the Municipality of Sèmè Podji

Several goods and services are obtained from the avenue trees by the residents of the main roads of the town of Sèmè-Podji. These goods and services come from the organs or parts of plants, and are used in several forms (Table 2).

Table 2. Classification of forms of use into ecosystem services.

Categories of ecosystem services	Form of uses	Organes and parts of plants	Number of species	Number of citation	Use value
Supply	Feeding	1	5	5	0,26
	Energy wood	1	8	8	0,24
	Pharma- copoeia	4	9	13	0,47
	Palisade	1	2	2	0,15
Regulation	Shady	1	14	14	0,53
Support	Ecological Habitat	1	1	1	0,04
Socio- cultural	Aesthetic	2	6	8	0,24

We note in table 2 that seven forms of use are reported by the informants and can be classified into four categories of ecosystem services. These are supply services, with four forms of use including food, energy wood, pharmacopoeia and use in the form of palisade. These forms of use come from 1 to 4 organs and 2 to 9 species depending on the case. Regulation services come from a single form of use, which is shading. It is the crown of the trees that is used to provide this service to the populations and 14 species are reported to provide shade. As for the support service, it is exclusively provided by a single organ and comes from a single species. From the point of view of socio-cultural services, a form of use is also recorded, which is the aesthetic value of the landscape. Two bodies are involved in the provision of this service for which 8 species are requested. In terms of importance, it appears that the highest usage value is observed on shading ($UV = 0.53$) which is a regulation service. The other highest usage values are 0.47; 0.26 and 0.24 attributed respectively to pharmacopoeia, food and energy wood. This observation can be explained by the fact that these forms of use are frequently requested in the domestic habits of residents. For landscape attractiveness, some flowering plants are used with a value of 0.24. However, the lowest use values are 0.04 for ecological habitat and 0.15 for the use of branches as a fence.

The different species that provide ecosystem services, and their forms of use and the organs involved are detailed in Table 3. We retain from this table that *Eleais guineensis* and *Cocos nucifera* are the species which provide the most benefits to the townspeople of the municipality of Sèmè-Podji, with five forms of use, four of which are common: food, pharmacopoeia, feeding and shading, daily requested by the populations. Specifically, the use of organs in food form comes from fruit trees such as *Coccoloba uvifera*, *Terminalia catappa*, *Cocos nucifera*, *Mangifera indica*, *Eleais guineensis*. The medicinal use or pharmacopoeia is derived from species such

as *Cocos nucifera*, *Azadirachta indica*, *Coccoloba uvifera*, *Mangifera indica*, *Eucalyptus camaldulensis* and *Calotropis procea*. Shading is a common advantage that most trees provide when planted, depending on their size and crown shape. The use in the form of energy wood is not systematic, but constitutes an opportunity offered to residents as soon as an avenue trees is felled or pruned. According to the populations surveyed, this opportunity is periodic and depends on the need for maintenance of overhead or buried networks located in the grip of trees. Aesthetic value is provided by attractive flowering or crown species such as *Cordia sebestena*, *Delonix regia*, *Polyalthia longifolia*, *Haematoxylon campechianum* and *Roystonea regia*.

The quantitative analysis of this information indicates that the probability associated with the Chi-square test between the organs used and the species enumerated is below the significance level ($ddl = 108$; $p < 0.0001$). This suggests a dependence between these two variables and which is illustrated through the factorial correspondence analysis presented in figure 3.

This figure shows the factorial map of the organs used on the alignment trees according to the floristic diversity of the streets developed in the municipality of Sèmè-Podji. The eigenvalues extracted from the first two factorial axes are respectively 46% and 24.54%, corresponding to a total inertia of 70.54%. It is then possible to interpret this figure to draw valid conclusions. Thus, we note on the factorial axis 1 (F1) a strong contribution of leaves and flowers as organs used by populations. On factorial axis 2 (F2), we note a strong contribution of the crown, fruits, roots and trunk as organs and parts of plants that provide goods and services to populations as opposed to the use of the bark. The projection of coordinates in the factorial axis system highlights four groups of specific uses of alignment tree organs. Among the specific use groups, there is the exploitation of the bark,

mainly solicited on *Khaya senegalensis* on the one hand, and the leaves solicited on *Eucalyptus camaldulensis* and *Calotropis procera* on the other hand in the field of pharmacopoeia. Then there is the use of flowers from species such as *Haematoxylon campechianum*, *Cordia sebestena*, *Parkia bicolor*, *Delonix regia*, and *Roystonea regia* to

enhance the aesthetic appeal of the landscape. In addition, species with strong crowns such as *Terminalia catappa*, *Terminalia mantaly*, *Terminalia superba* and *Gmelina arborea* are used for shade. Apart from these peculiarities, two or more organs can be solicited on certain species according to the needs of the populations.

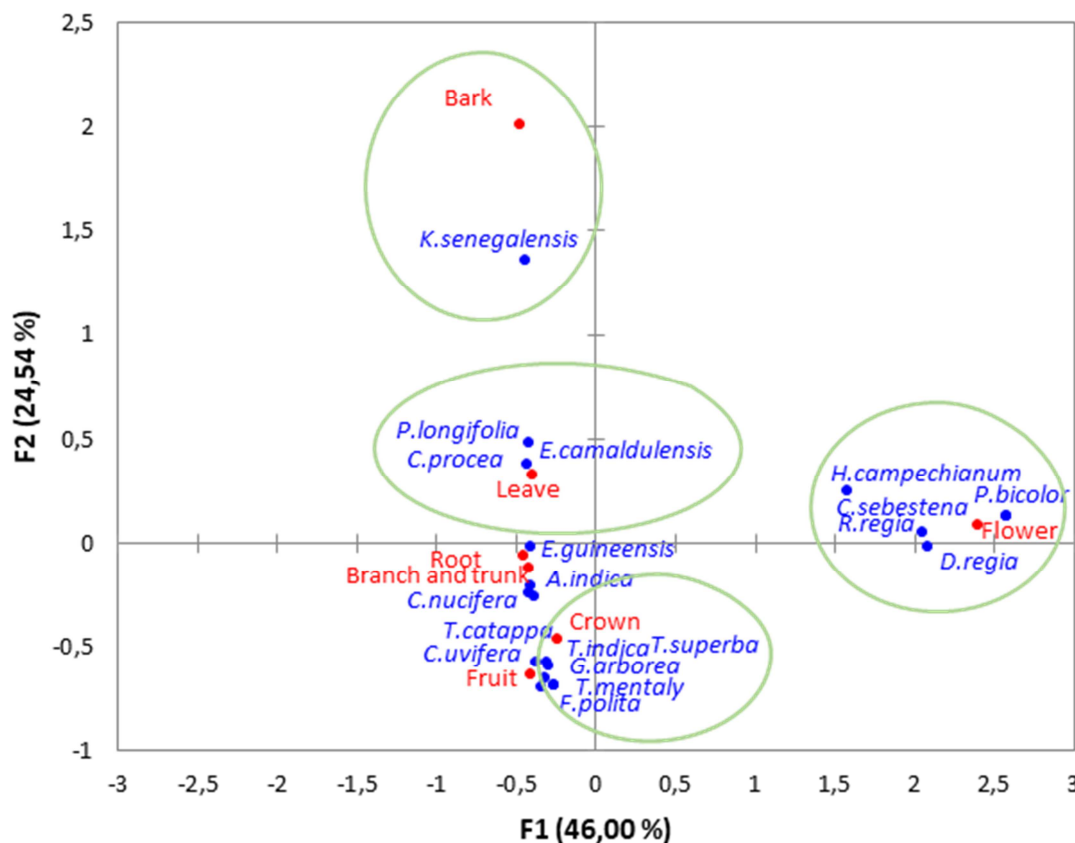


Figure 3. Grouping of species according to the organs or parts of plants that provide ecosystem services.

Table 3. Classification of forms of use into ecosystem services.

Species	Branch and trunk	Flower	Leaves	Fruit	Bark	Crown	Root
Azadirachta indica Juss.	Energy wood		Pharmacopoeia	Pharmacopoeia		Shady	
Calotropis procea Brow.			Pharmacopoeia				Pharmacopoeia
Coccoloba uvifera Linn.	Energy wood		Pharmacopoeia	Feeding		Shady	
Cocos nucifera Linn.	Ecological Habitat		Palisade	Feeding		Shady	Pharmacopoeia
Cordia sebestena Linn.		Aesthetic	Aesthetic			Shady	
Delonix regia Boje. and Rafi		Aesthetic				Shady	
Elaeis guineensis Von.	Energy wood		Palisade	Feeding		Shady	Pharmacopoeia
Eucalyptus camaldulensis Debn.	Energy wood		Pharmacopoeia			Shady	Pharmacopoeia
Ficus polita Vahl.						Shady	
Gmelina arborea Roxb.						Shady	
Haematoxylon campechianum Linn.		Aesthetic	Pharmacopoeia				
Khaya senegalensis Desr. and Juss.	Energy wood		Pharmacopoeia		Pharmacopoeia	Shady	
Parkia bicolor A. Chev.		Aesthetic					
Polyalthia longifolia Sonn.			Aesthetic				
Roystonea regia Kunt.		Aesthetic	Aesthetic				
Tamarindus indica Linn.			Pharmacopoeia	Feeding		Shady	
Terminalia catappa Linn.	Energy wood		Pharmacopoeia	Feeding		Shady	
Terminalia mantaly Perr.	Energy wood					Shady	
Terminalia superba Engl. And Diels.	Energy wood					Shady	

4. Discussion

4.1. Reliability of the Collected Information on Ecosystem Services Associated to Avenue Trees

The importance of flora diversity for the well-being of local populations has been widely studied through their experiences, perceptions and endogenous knowledge [26]. But in urban areas, the daily practices and knowledge of city dwellers are influenced by the mobility and dynamics of the population. This is why certain conditions were necessary for the investigation to ensure the reliability of the answers provided by informants. These include, among other things, the roving and reasoned choice approach that made it possible to target respondents who were actually users of the resources from the alignment trees. These requirements made it possible to construct a representative sample that circumscribes the individuals to the study area, in order to limit bias in the responses provided [27]. In addition, respondents spend a good part of the day and of their working time near trees. This dual spatio-temporal proximity makes the interactions between informants and alignment trees evident [13]. All this was reinforced by the level of maturity determined by their age, activities and level of education which guarantee seriousness in the interviews [28]. However, given that the survey mainly sought the memory of individuals from different socio-professional categories [29], it was not easy to collect similar information on the use of urban trees in daily practices populations of Sèmè-Podji. This uncertainty was removed by the Pearson correlation test carried out on the respondents, which revealed a concordance between the opinions of three socio-professional categories out of the four considered in this study. This guarantees a certain reliability of the information collected and reassures that the use of avenue trees in daily practices is not an isolated fact in the study area.

4.2. Importance of Avenue Trees in the Provision of Ecosystem Services to the Populations

In the typology of ecosystem services mentioned, supply services take upstairs with four forms of use. This is justified by the frequent intervention of forms of use of this category in daily habits and the socio-cultural context [30]. However, we note that the regulation services have the highest use value, indicated exclusively for the shade offered by trees with large crowns to populations. Shading being an intangible good [25], it is appreciated by all road users, especially artisans and traders who carry out their activities near trees. In addition, it offers residents the possibility of benefiting from a softened local temperature during periods of high heat [31], which allows them to save energy during the day [32, 15].

The tree species involved in the provision of ecosystem services are varied and in demand depending on the organs or parts of the plant that are useful to populations. This is a

selective form that is often linked to the socio-cultural habits of populations [33]. This practice can involve the same species several times for different uses. For example, *Terminalia catappa* and *Coccoloba uvifera* are both in demand for their fruit as circumstantial food, and their crown, which provides shade. Likewise, *Calotropis procea* and *Polyaltia longifolia* are used exclusively for their leaves, but for different uses. Thus, we see that the alignment trees are useful and really integrate the daily practices of the populations living near the developed roads of Sèmè-Podji, as is the case of most secondary towns in the West African sub-region [34]. It would therefore be important to consider the interactions between communities with the phytodiversity of the streets in the city's greening programs [35], through the creation of harvesting plantations in urban or peri-urban areas.

However, the use of organs or parts of plants from alignment trees is not recommended, as this gives rise to excessive harvesting, thus creating mutilations that compromise the aesthetics of the city's green landscape and the viability of the trees [36]. We must therefore advocate for controlled access to ecosystem services from these trees. This provision is provided for by the forestry code of Benin, which regulates the use of trees in the public domain as well as in the private domain, from [37]. Unfortunately, this provision is rarely applied. We therefore need actions such as awareness raising to get populations out of ignorance, then the establishment of a mechanism to control access to urban plant resources [38] to make urban development in this city sustainable. It is also possible to strengthen the local regulations of the municipalities in terms of urban forest management.

5. Conclusion

This study showed the importance of ecosystem services provided by avenue trees in the daily life of people. The supply, regulation, support and socio-cultural services resulting from thunderstorms and parts of urban trees are benefited or reported by several socio-professional categories that make up the demographic structure of the municipality of Sèmè-Podji. The species that offer more forms of use are *Eleais guineensis* and *Cocos nucifera*, while the most widely used organs or parts of plants are the leaves and crowns of trees. Although avenue trees are useful to neighboring populations in several domains, harvesting methods constitute a form of pressure that can compromise their viability. Thus, the trees which are supposed to ensure the socio-ecological functions of the city are exposed to mutilation and other damage to the green landscape of the streets, all of which compromises the attractiveness of the landscape and the sustainable management of the city. It is important that the territorial forecast takes into account the specificities of use of plantations and green spaces in the development, in order to guarantee sustainable development in this city. For that, it will be important that the future researches on this topic take account:

- 1) The impact of the use of avenue trees by residents on urban development;
- 2) The economic and socio-cultural importance of the use of avenue trees by the populations in the municipality of Sèmè-Podji;
- 3) The mechanisms of access and control of the use of urban trees by populations.

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