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Functions and Societal Values of Urban Trees in Brazzaville, Capitol of Congo

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Abstract: The societal functions and values of trees planted in urban areas is conducted in Brazzaville, in the district No. 8 Madibou. The concept of resilient and ecological cities stipulates, a significant woody cover with carefully selected species and individuals ordered according to well-defined requirements, in the urban space. The study highlights the perception of ecosystem services and disservices by the residents and the daily coverage of their needs. A less sustained theme, the study is based on botanical inventory and ethnobotanical survey data. The floristic inventory conducted in 197 housing plots with at least two trees of dbh ≥ 10 cm, counted 1202 individuals corresponding to 49 species and 27 families, the distinctive ones being Arecaceae and Fabaceae. The fruit trees are privileged and the dominant ones in decreasing number of individuals are *Mangifera indica, Persea americana, Dacryodes edulis* and *Elaeis guineensis*. Ethnobotanical data, according to socio-professional and age classes, reveal 22 ecosystem services covering the three main categories of which regulatory services are highly valued. The average woman's perception of ecosystem services and disservices reaches 2/3 of citations per item. Notwithstanding the benefits rendered to populations, trees would affect social cohesion; without minimizing the disservices caused by their organs on roads, houses, physical communication infrastructures, goods and other properties. Since the added value is unequivocal, increasing forest cover would be the ideal solution for improving and maintaining the well-being of city dwellers, urban resilience and mitigating the effects of climate change, particularly urban heat islands. Urban arboriculture as a provider of ecosystem goods and services induces disservices while remaining a source of perpetuation of the Us and customs of the residents, via the virtues of biodiversity.

Keywords: Congo, Brazzaville, Urban Forestry, Ecosystem Services and Disservices, Floristic Diversity, Urban Resilience, Societal Values

1. Introduction

The world's population is increasingly concentrated in urban areas and has grown from 764 million to four billion in 65 years [1]. This exponential growth is more sustained in African cities and the reasons behind it are rural exodus and accelerated and uncontrolled urbanization [1, 2]. The initial consequences of this urban population growth are environmental degradation, the horizontal extension of the urban perimeter and the impoverishment of neo-citizens [2]. This cocktail, which has only negative aspects, inevitably leads to an increase in the ecological footprint.

Uncontrolled urbanization has led to the fragmentation of ecosystems, causing their degradation, the corollaries of which impact the three levels of biodiversity [3-8]. In Brazzaville, the tangible elements marking this anthropisation are the physical infrastructures (urbanization, schools and universities, sports facilities, roads, etc.), which have affected, sometimes irreversibly, the vegetation cover and biodiversity. The result of the allocation of biodiversity for the populations is reflected in terms of insufficient resources, particularly in terms of

supply [9]. In order to remedy this situation, tree planting in the city can be one of the strategic approaches [10, 11]. Thus, since the place of trees and their benefits in the urban environment are no longer up for discussion, a sustainable city is only possible if its development is coupled with dynamic urban forestry [12, 13].

Ecosystem services in urban areas are a current reality for the harmonious management of the living conditions of city dwellers [14-17]. Trees in cities are a source of benefits that are essential to the balance of the city [18-20]. Indeed, urban trees and shrubs, through their ability to provide material elements (food, phytotherapy, crafts), are involved in supply services [4-7, 17]. In addition to this aspect, trees and shrubs perform several intangible roles and functions (ecological, socio-cultural and economic) in cities [4, 7, 21, 22]. This set of functions is translated in terms of erosion control and mitigation of the effects of climate change by the ability to trap large quantities of atmospheric carbon in their tissues through the process of photosynthesis [23-26]. As urban cities are essentially sources of heat emissions, urban forestry developed in northern countries for aesthetic purposes currently covers a wider range of benefits, including the improvement of living conditions [6, 14, 27]. In developing countries, the issue of the benefits of urban forestry is a new and growing theme [13, 28].

In Congo, and particularly in Brazzaville, urban forestry has led to floristic characterization and monitoring of plant cover [14, 15, 29-31]. Notwithstanding this progress, woody flora-population interactions are less exploited in the Brazzaville area [15]. These interactions need to be analyzed in relation to population criteria. Among other criteria are the living conditions of city dwellers, the priorities and/or preferences on urban trees underlying their existence, or even the socio-cultural base [13].

A pre-survey conducted on August 16, 2019 indicates that most inhabited plots have at least two tree plants, compared to zero in the uninhabited ones. This observation suggests that the trees in the inhabited plots were intentionally planted for a specific purpose. Despite these facts, no study addressing the theme of interactions between populations and planted trees has been conducted in the Madibou 8 district. The control of these interactions would be important, in more than one respect, in the definition of an efficient and sustainable policy on urban forestry. The concept of resilient and ecological cities stipulates a significant woody cover whose species are carefully selected and individuals ordered according to well-defined requirements, in the urban space. The emphasis is on the dual needs of a resilient city, guaranteeing the well-being of the citizens and the daily coverage of goods and services inherent to the virtues of plants. The objective is to promote an urban arboriculture that concomitantly integrates urban resilience and social well-being without compromising the endogenous knowledge of populations. This study, which addresses the issue of man and his environment, focuses on the ecosystem services and disservices provided by urban trees and the perpetuation of the socio-cultural foundations of local residents.

2. Materials and Methods

2.1. Presentation of the Study Area

Brazzaville, the capital of the Republic of Congo, was created in 1884 and lies between 4°4' South latitude and 15°2' East longitude [32]. The city is composed of 9 districts including Madibou which is one of the last two districts according to Law No. 9-2011 of May 17, 2011 creating the districts No. 8 Madibou and No. 9 Djiri. Madibou, which covers an area of 80.45 km^2, is home to about 100, 000 inhabitants, a density of 1243 inhabitants per km^2. This district, which is bounded to the northeast by the confluence of Djoué with the Laba River, to the southeast by the Congo River and to the west by the Djoumouna River, consists of 11 districts (Mansimou, Mafouta, Massissia, Poto-Poto Djoué, Mayanga, Madibou, Mbouono, Kombé, Kibina and Ntsangamani).

The climate is of the Bas-Congolese type and characterized by moderate rainfall varying between 1200 and 1500 mm, with an average temperature oscillating around 25°C and a low annual temperature range of 4 to 6 °C [32]. Depending on the rhythm of rainfall distribution, the dry season extends from June to September and the rainy season from October to May [32]. November, March and April are the rainiest and warmest months.

Phytogeographically, the Madibou district is located in the Plateau des Cataractes district [33]. The vegetation of this district is made up of two types of formations, which are, among others, forest and grassy formations [34].

2.2. Materials

The study material consisted of the woody plants of diameter at breast height (dbh) ≥ 10 cm found in at least two individuals in the housing plots. The plant material is placed in a herbarium, for non-common taxa, and deposited at the national hebarium (IEC). The identification of taxa was carried out in situ and confirmed at the national herbarium. The classification adopted is APG IV [35] and the nomenclature followed is that of Lebrun and Stork [36]. The data collected, in addition to dbh, concern ethnobotanical uses and services rendered to the population, geographical origin, status (spontaneous or not) and if possible the organ or diaspore used.

2.3. Methods of Study

2.3.1. Sampling Process

The space in the semi-rural district of Madibou has been subdivided into three sectors, based on proximity to downtown (Figure 1). Sector A, close to the city center, bordering the district 1 Makélékélé, is made up of four neighborhoods (Mansimou, Mafouta, Poto-Poto Djoué, Moussosso); sector B, intermediate between sectors A and C, is made up of four neighborhoods (Mayanga, Madibou, Massissia, Mbouono); and finally, sector C, peripheral and bordering the sub-prefecture of Goma Tsé-Tsé, is made up of

three neighborhoods (Kombé, Kibina, Ntsangamani).

During the study, each neighborhood was treated as an area of the site whose inventory units are the housing plots with at least two woody trees of dbh ≥ 10 cm. The inventory units were chosen randomly in order to provide equitable coverage of the entire site (Table 1). Of the 11 neighborhoods in Madibou, nine formed the basis of the study, for a sampling rate of approximately 82%.

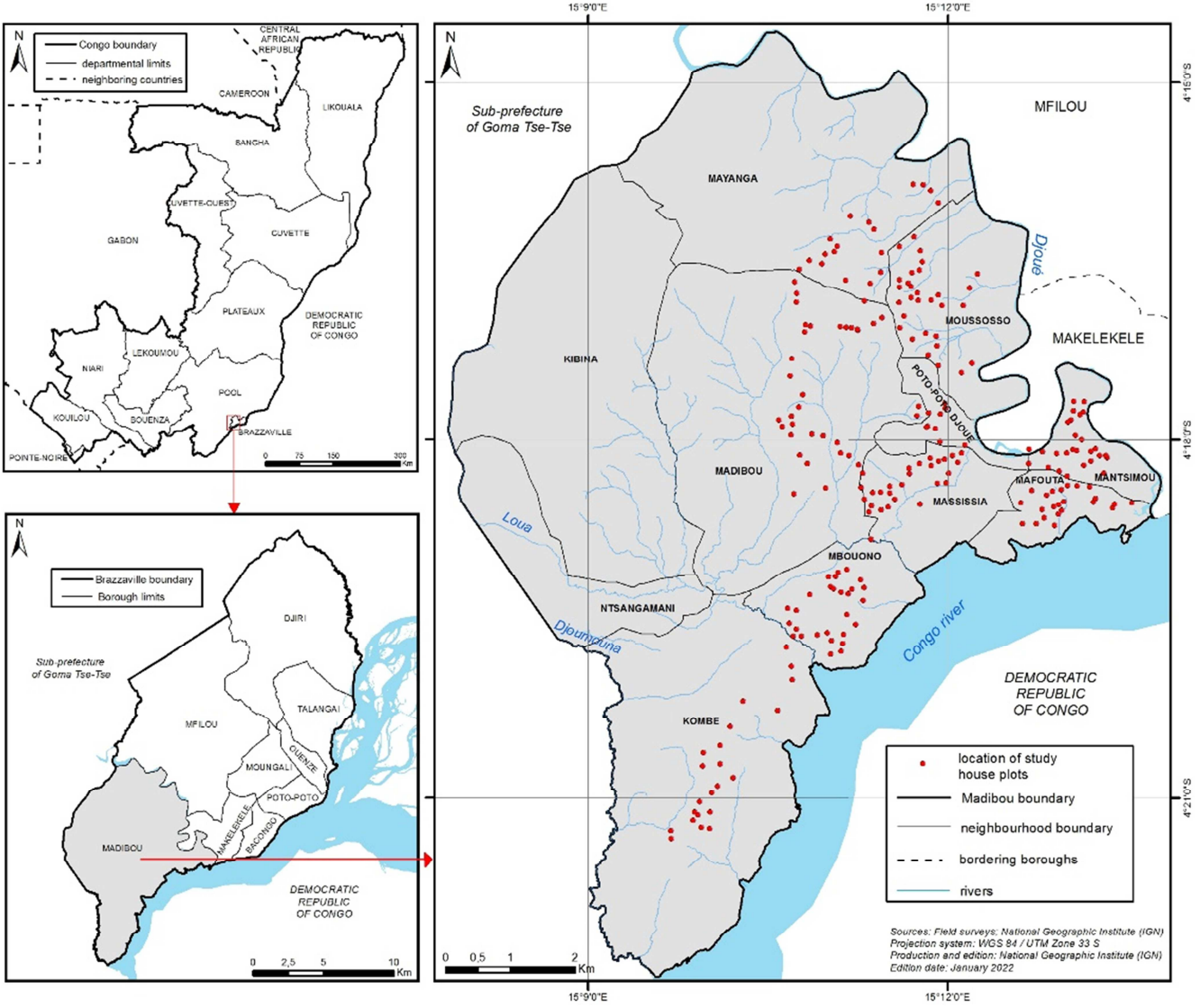


Figure 1. *Overview of Study Area and Location of Surveyed Households by Neighborhood.*

Table 1. *General data on the Madibou plot floristic inventory.*

Sectors	Neighborhoods	Households surveyed		Genders (%)		Total parcels
		Number	Rate (%)	Men	Women	
A	Mansimou	31	15.74	32.26	67.74	97
	Mafouta	19	9.64	42.11	57.89	
	Poto-Poto Djoué	23	11.68	43.48	56.52	
	Moussosso	24	12.18	41.67	58.33	
B	Mayanga	27	13.71	59.26	40.74	80
	Madibou	27	13.71	48.15	51.85	
	Mbouono	26	13.20	38.46	61.54	
C	Kombé	20	10.15	60.00	40.00	20
Total		197	100	45.18	54.82	197

2.3.2. Ethnobotanical Survey

The survey of 197 households identified the societal benefits and drawbacks of trees planted in the Madibou 8 district. The survey, which took place from September 25 to October 10, 2019, is based on direct questioning in local, national or French languages. The questionnaire consisted of 56 open and closed questions, grouped under five headings

including: identification of the respondent, history of the trees, identification of the benefits of the trees planted, identification of the dangers of the trees planted, identification of negative effects related to the absence of tree planting and the floristic inventory sheet. In order to develop a map showing the relative position of the different households surveyed according to their distance from the town center, geographical coordinates were recorded. The survey was conducted using the convenience sampling method.

2.3.3. Floristic Inventory

The floristic inventory had focused on the identification of taxa, the systematic enumeration of trees of dbh ≥ 10 cm present in each inventory unit and finally, the collection of herbarium specimens (Table 1).

2.3.4. Data Processing

The data were manually processed before being computerized with the Sphinx plus 2 software, which generated the results directly according to the variables entered. Finally, the results were transformed into a spreadsheet program in order to present them in the form of tables, diagrams and histograms. Regarding the benefits of phytodiversity, six categories were selected (environmental, comfort, social, therapeutic, economic) [25].

(i). Ethnobotanical Indicators

Two indicators were considered for this study and they are: citation frequency and use value.

1) The frequency of citation was calculated for each benefit category by the following formula

$$FC = (\text{Number of citations per benefit}) / (\text{Total number of respondents}) \times 100 \quad (1)$$

2) The use value of ecosystem services is based on the formula [14, 37, 38].

$$UV = \frac{\sum_i^n Ui}{n} \text{ either } UVt = \sum_1^p UV \quad (2)$$

UV: use value; *Ui*: number of citations for each benefit category; and n: total number of informants.

(ii). Informant Consensus Factor

The Informant Consensus Factor (ICF) defined by Heinrich et al. [39] is commonly used in the field of ethnomedicine to identify culturally important species, agree on their uses, and hypothetically consider their further study [7, 39-41]. The value of the ICF varies between 0 and 1 and indicates a high consensus when it tends to 1. In this study, the ICF was calculated for each of the three categories of ecosystem services.

$$ICF = (Nur - Nt)/(Nur - 1) \quad (3)$$

Nur = number of citations in each ecosystem service category and Nt = number of ecosystem services that comprise it.

(iii). Fidelity Level

This indicator was used to calculate the fidelity level (FL) of informants on the ecosystem services offered by the Djoumouna Forest. It was calculated using the formula defined by Friedman et al. [42].

$$FL = \frac{Number\ of\ citations\ of\ an\ ES}{Number\ of\ citations\ for\ all\ ES\ categories} \times 100 \quad (4)$$

2.3.5. Biodiversity Indices

(i). Jaccard and Sørensen Similarity Coefficient

Jaccard's (J) and Sørensen's (S) similarity coefficients are the most commonly used in ecological studies to compare records.

$$J\ (\%) = C / (A + B - C) \quad (5)$$

$$S\ (\%) = 2C/ (A + B) \quad (6)$$

In these equations, A and B represent the number of taxa in each of the surveys and C represents the number of taxa common to surveys A and B.

(ii). Shannon's Index

This index expresses the level of biological diversity of a community.

$$H' = - \sum_{i=1}^{i} pi \log(pi) \quad (7)$$

With pi = *ni/n* where *ni* is the number of individuals of taxon *i* and *n* the total number of individuals in the survey.

(iii). Highest Diversity Index

This index expresses the maximum degree of diversity that a community can reach

$$H'_{max} = \log (S) \quad (8)$$

The total species in the survey is expressed as S.

(iv). Pielou's Index or Equitability

The Pielou index provides information on the type of taxon distribution (aggregative or random).

$$Eq = H' / H'_{max} \quad (9)$$

3. Results

3.1. Informants and Location of Surveyed Households

Out of a sample of 221 targeted households, 89.14% had time to complete the survey. For various reasons, 10.86% did not give any interest at all. The survey by sector shows that the number of informants decreases as one moves away from the city center (49.24% in sector A; 41.17% in sector B; 9.64% in sector C). Neighborhood rankings do not favor those in any one sector. Women's participation in the survey, by sector, was 60.83%, 51.25% and 40% respectively (Table 1). A household distribution map for the study area was produced using the geographical coordinates of each household surveyed (Figure 1).

3.2. Informant Group Data

3.2.1. Gender and Age Group Subdivision

The survey reveals that women dominate the informant group at 54.8%, compared to 45.2% of men. With the exception of the age group of 45 years and over, which does not fall within the range of 20% to 24% of informants, the grouping gives fairly balanced classes. With the exception of the 45+ age group, where the women's participation is below 50%, it is between 57.50% and 62.77% for the rest. Except for the 45+ age group where the female contribution is below 50%, it ranges from 57.50% to 62.77% (Figure 2). The Kruskal-Wallis test applied between groups (P. value = 0.1573 > 0.05) showed no significant difference. The inter-group comparison does not predict significant differences at the 5% probability level.

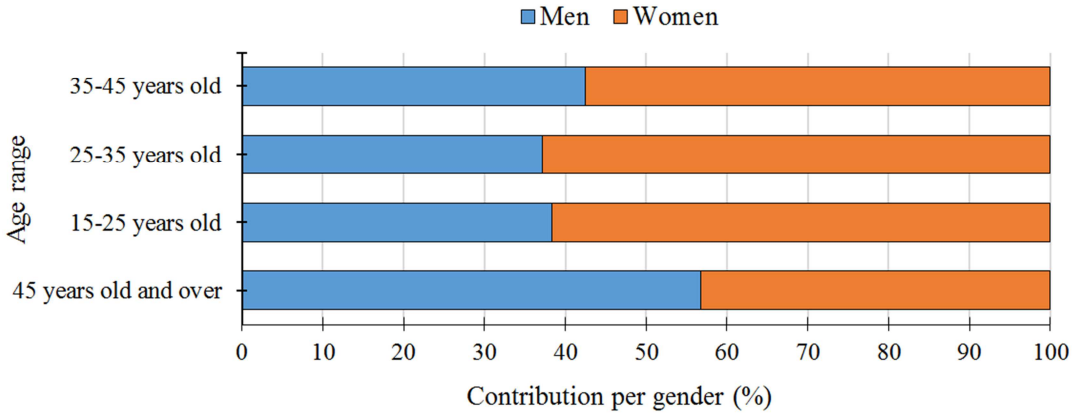


Figure 2. *Grouping of Informants into Age Classes.*

3.2.2. Grouping by Education Level

Grouping by educational level reveals deep divisions among informants. While informants with a secondary level of education represent more than 2/3 of the target population, those with no schooling lag behind with 1.01%. The number of informants by level of education ranges from 1.01% to 67.51%. The cumulative proportion of women with at least secondary education is 85.18%. This high representation reflects a female awareness of environmental issues. The cumulative proportion of women with at least a secondary education is 85.18%. This high representation would reflect a female awareness of environmental issues (Figure 3). The Kruskal-Wallis test revealed significant differences between groups (P. value = 0.02129 < 0.05.

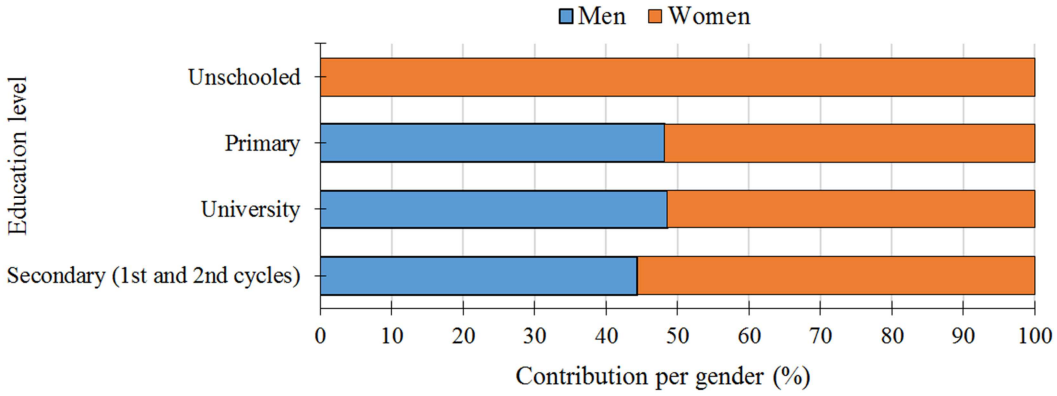


Figure 3. *Distribution of informants by education level.*

3.2.3. Influence of Marital Status

Marital status shows that more than half of the informants (53.30%) are married. The number of single people is almost double (31.47%) the number of divorced people (15.23%). Taking into account the age groups, the average number of married women varies from 14 to 19, without the 15-25 year olds, the majority of whom are not able to form a couple. As for divorce, the 45 and over age group is more affected with 14 people. Apart from the 15-25 age group, where no cases are recorded, the number of divorced people varies from three to four for the 25-35 and 35-45 age groups. Finally, the majority of single women (22) are in the 15-25 age group and six in the 25-35 age group. It should be noted that the other two age groups are not. The Kruskal-Wallis test did not reveal any significant differences between these groups (P. value = 0.8078 > 0.05). The inter-group comparison did not suggest any significant difference at the 5% probability level. This result is confirmed by Bonferroni's raw P. values, sequential significance.

3.2.4. Socio-Professional Categorization

The socio-professional grouping of informants reveals seven categories of qualification. Workers and learners are the most numerous with 22.34% and 22.34% respectively (Figure 4). Note that the number of subjects per socio-professional category varies from nine to 44. Female participation, analyzed according to age groups, reveals that they are present in all socio-professional categories. The level of education attained by the majority of them gives them an efficient background, which explains their strong environmental involvement (Figure 5). In the Kruskal-Wallis test (P. value = 0.09047 > 0.05), no significant difference is recorded.

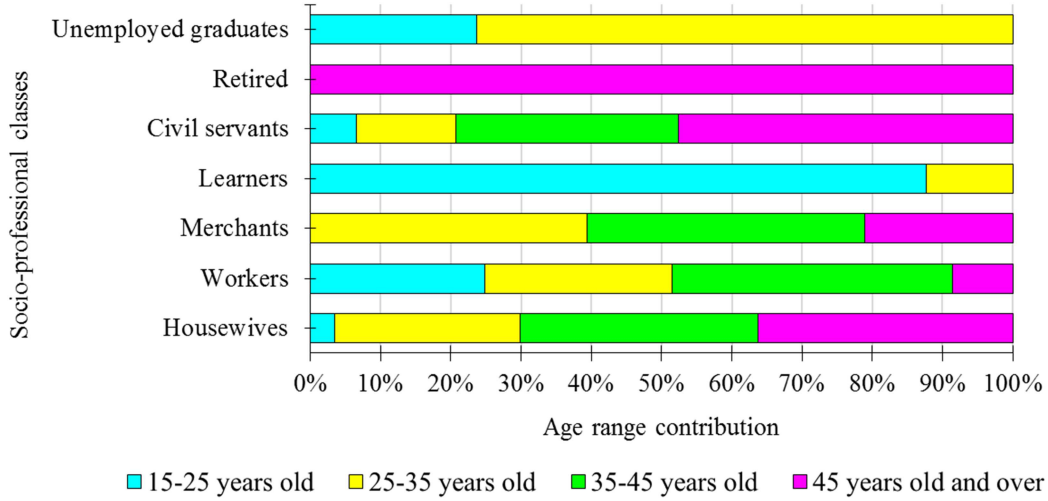


Figure 4. *Grouping of informants into socio-professional categories and age range.*

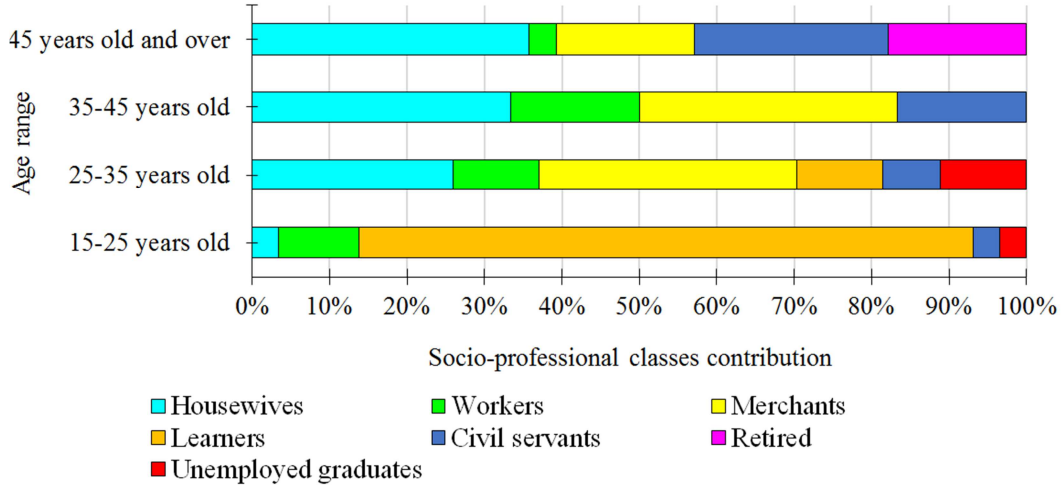


Figure 5. *Grouping of women informants into socio-professional categories such age range.*

3.3. Urban Tree Planting and the Environment

3.3.1. Tree Planting

Analysis of the survey data reveals that 61.40% of the informants have already planted at least two trees. However, the other 38.60% acknowledge that they have never contributed to the maintenance and increase of forest cover in their borough. For this useful work, 59.50% of the respondents who reported planting trees did so by seedlings, compared to 48% who used seedlings. This relative dominance would be explained by the fact that the choice of seed is generally the result of the organoleptic feeling after consumption of the fruit, for fruit growers. However, in the case of ornamentals, the snobbery or the aesthetic value of the subject is of particular interest. The women of Madibou carry out this task, usually assigned to men, with apotheosis. The proportion of women involved varies from 12.96% to 44.44% depending on the age group (Figure 6). In the Kruskal-Wallis test (P. Value = 0.2122 > 0.05) between the groups, no significant difference was found.

Although the Madibou population recognizes the importance of trees and cultivates them, almost all planters (97.52%) do not consult specialists in management and silviculture or arboriculture before planting, and only 2.48% say they have done so. Planting a tree in one's plot of land is a commonplace gesture for the average landowner. Many of them are unaware that the tree must be part of a well thought-out development plan for the plot and the neighborhood.

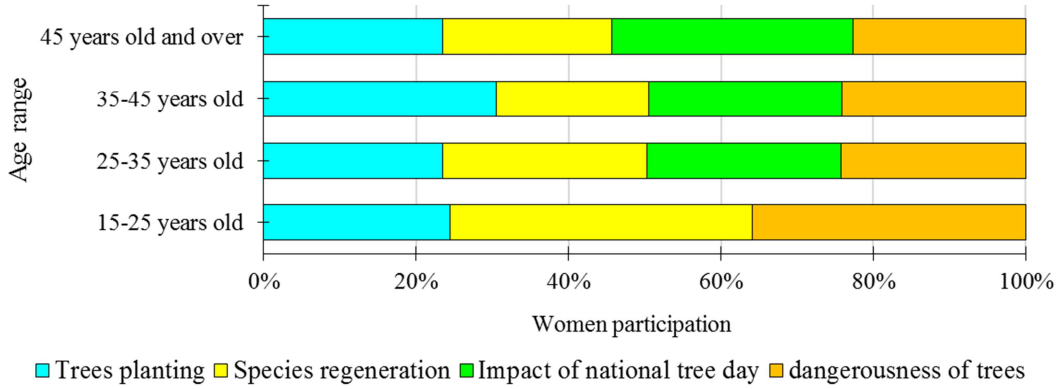


Figure 6. *Female intervention in tree planting according to age groups.*

3.3.2. Species Regeneration

Nearly three-quarters (71.90%) of informants report not noticing natural regeneration of the species planted in their plots. However, 27.27% mention natural regeneration, but 96.97% of owners destroy seedlings for reasons of space and cleanliness, while 3.03% point to natural degeneration. Indeed, the piece of land available is not extensible, so an increase in the number of trees would increase the associated risks. This reason is enough to understand the attitude of the owners towards the invasion of seedlings. Under these well-established conditions, natural regeneration is impossible unless the issue is approached from the point of view of replacing individuals. Within the small group of informants involved in maintaining the taxa, women are not on the fringe. Depending on the age group, their contribution ranges from 21.05% to 42.10%. According to Cochran's Q test (P. value = 0.00810 < 0.05), the differences are highly significant.

3.3.3. Influence of National Tree Day

More than three-quarters (90.86%) of the informants stated that they had never participated in this activity, some of whom were unaware of the enactment of a national tree day. Finally, 9.14% contributed to this activity while recognizing this legal and regulatory provision. Among those who respected this provision, 38.89% declared planting trees in the village, 50% in Brazzaville and 11.11% in schools. Except for the very small proportion in schoolyards, this measure has no influence on increasing the neighborhood's wood coverage (Figure 6). In relation to the National Tree Day, the female intervention in the commune of Madibou is between 20 and 60%. However, the informers are in the age groups of 25 to over 45 years. Academic preoccupation would explain the non-involvement of individuals in the 15-25 age group. Cochran's Q test (P. value = 0.00542 < 0.05) shows highly significant differences.

3.4. Informants' Overall Perception of Urban Trees

3.4.1. Planted Trees and Urban Infrastructure

Out of 197 households surveyed, more than 80% said that the trees planted do not pose a danger to the inhabitants; however, 14% thought the opposite. This point of view, which seems to be contrary to reality, is explained by the fact that yard trees are most often quite distant from houses. Thus, disservices due to yard trees is less observed in these semi-rural neighborhoods.

Over 90% of informants reveal that the planted trees do not pose a danger to the public, while 7% have the opposite opinion. Finally, the others have no opinion on the issue. Among the facts noted, the destruction of roads (physical communication route and rainwater drainage channels, electrical and water supply networks) is cited by 14%. The main organs implicated in the said disservices are the roots. The breaking of branches on people, houses and/or cars was cited by 84% of the respondents. The survey, in both cases on the allocation of assets, both public and private, emphasizes that women are aware of this and mention it in a proportion of 19.05% to 42.86%, depending on the age group. Cochran's Q Test (P. Value = 0.00182 < 0.05) reveals highly significant differences.

3.4.2. Urban Trees Disservices

The disservices invoked by the respondents are of different kinds. The destruction of fence walls and/or houses is the first cause cited by 56%, of which 23% are caused by cracks due to root extension. Accidents due to broken branches and/or fruit correspond to 44% of the quotes. This last category affects (i) the physical integrity of the population and (ii) property such as windscreens. Women's views on the classification of harm show that they are not on the sidelines. The observation according to age groups shows a progressive female awareness that evolves almost proportionally with age. Overall and according to age groups, the range of citation rates is between 24.14% and 53.57%. However, the differences were found to be highly significant by Cochran's Q test (P. value = 0.00018 < 0.05).

Isolated trees and/or uninhabited plots of land are recognized by 20% as a source of insecurity for the surrounding populations. Despite the lack of opinion (18%), 60% of respondents (informers) found them to be without any influence on people and their property.

3.4.3. Urban Trees Social Disservices

According to 85% of the informants, plants do not cause conflicts in the neighborhood. However, a minority (15%) claim to have been victims of neighborhood antagonism at

least once. The source of disputes was cited by 56% of the respondents as the insalubrity of the leaves; 2% cited the management of the fruit, especially branches that extend beyond the boundaries of the concession; and finally, 17% cited the destruction of walls due to the extension of roots or even, exceptionally, branches.

3.4.4. Impact of the Zero Trees Scenario

The group of informants is fully aware of the role of the tree in the functioning mechanisms of urban balances. Indeed, their concerns are based on climate change, the different components of biodiversity and the socio-cultural base (Figure 7). The zero plant scenario seen in relation to age groups highlights the ecological awareness of women. Whatever the age group, more than 2/3 of women are aware of the roles and functions of trees in the city. Thus, 89.66% of women recognize the benefits of plants in the 15 - 25 years age group, 92.59% for the 25 - 35 years age group, 72% for the 35 - 45 years age group, and 85.71% for the 45 years and over age group. This result would be associated with two reasons, namely the level of education of the population and its relative youth.

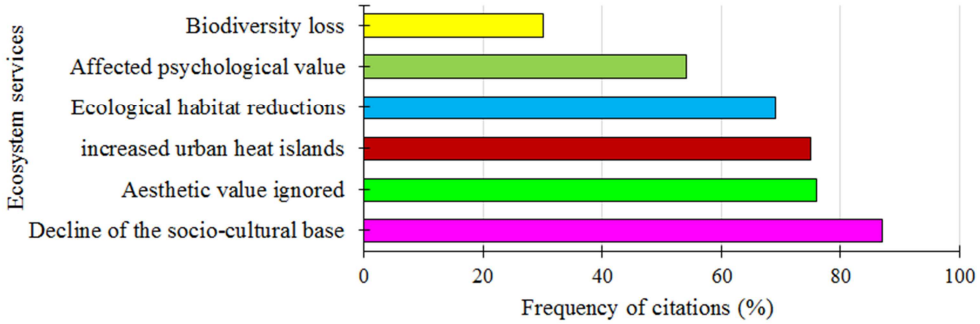


Figure 7. *Impacts Revealed by Informants in the Zero Tree Scenario.*

Table 2. *Distribution of taxa by sector and their areas of use.*

Taxa	Sector A				Sector B			Sector C	Number of trees	Number citation	Function or interest
	Man	Maf	Pot	Mou	May	Mad	Mbo	Kombé			
Indet 6	2	-	-	-	-	-	-	-	2	1	Therapeutic
Indet 17	-	-	-	-	-	-	1		1	1	Therapeutic
Indet 18	-	-	-	-	-	-	1	1	2	2	Therapeutic
Achariaceae											
Oncoba welwltschii Oliv.*	-	3	-	1	-	-	1	1	6	4	Therapeutic
Anacardiaceae											
Mangifera indica L.	64	21	45	48	54	68	73	44	417	151	Food, shade, therapeutic
Spondias dulcis Sol. ex Parkinson	4	3	2		6	1	3	1	20	12	Food
Annonaceae											
Annona muricata L.	1	1	-	-	1	-	1	1	5	5	Food, therapeutic
Polyalthia longifolia (Sonn.) Thwaites	4	-	-	-	-	1	-		5	2	Ornamental
Arecaceae											
Cocos nucifera L.	2	1		3		1	1		8	6	Food, ornamental
Elaeis guineensis Jacq.*	15	8	8	7	10	7	8		63	38	Food, shading, therapeutic, handicraft
Phoenix cf. reclinata Jacq.	-	3	-	-	-	-	3	7	13	3	Ornamental
Raphia sp. *	-	-	-	-	-	-	1		1	1	Ornamental
Asparagaceae											
Dracaena mannii Baker*	-	-	-	-	4	-	-		4	2	Ornamental, live hedge
Burseraceae											
Dacryodes edulis (G. Don) H. J. Lam*	21	23	42	15	14	46	16	32	209	87	Food, shade, therapeutic
Cactaceae											
Opuntia ficus indica (L.) Mill.	2	4	-	-	-	4			10	3	Lightning arrester
Cannabaceae											
Trema orientalis L.*					1				1	1	Therapeutic
Capparaceae											
Buchholzia coriacea Engler*	-	1	-	-	-	-	-	-	1	1	Therapeutic
Clusiaceae											
Garcinia mangostana L.	1	-	-	-	-	1	-	-	2	2	Food
Combretaceae											
Terminalia mantaly H. Perrier	1								1	1	Ornamental
Ebenaceae											

Taxa	Sector A				Sector B			Sector C	Number of trees	Number citation	Function or interest
	Man	Maf	Pot	Mou	May	Mad	Mbo	Kombé			
Diospyros heterotricha (Welw. ex Hiern) F. White*	1	2	-	-	2	-			5	3	Ornamental
Euphorbiaceae											
Alchornea cordifolia (Schumach. & Thonn.) Müll. Arg.*	1	-	1	-	-	-	-	-	2	2	Therapeutic
Euphorbia tirucalli L.	4								4	2	Lightning arrester
Hura crepitans L.						1			1	1	Ornamental
Fabaceae											
Acacia mangium Wild.	1	2	-	-	1	-	1		5	4	Ornamental
Dichrostachys cinerea (DC.) Wight et Arn*	-	-	-	-	1	-	-	-	1	1	Therapeutic, Live hedge
Mimosa pudica L.*	1	-	-	-	-	-	-	-	1	1	Ornamental
Pithecellobium dulce (Roxb.) Benth.	5	1	-	3	-	1	1	-	11	7	Ornamental
Lauraceae											
*Beilshmiedia sp.**			1						1	1	
Persea americana Mill.	61	27	37	28	52	57	41	30	333	138	Food, shade, therapeutic
Malavaceae											
Cola acuminata (P. Beauv.) Schott & Endl.*	1	1	1			1			4	4	Therapeutic
Glyphaea brevis (Spreng,) Monachino*			1						1	1	Therapeutic
Theobroma cacao L.*	-	-	2	-	-	-	-	-	2	1	Food
Meliaceae											
Capara procera DC.*			1						1	1	Therapeutic
Khaya senegalensis (Desr.) A. Juss.*	-	-	1	-	-	-	-	-	1	1	Therapeutic
Moraceae											
Artocarpus altilis (Parkinson) Fosberg	1	-	-	-	-	-	-	-	1	1	Food, shade
Ficus sp.			1						1	1	Ornamental
Milicia excelsa (Welw.) C. C. Berg.*			1		1				2	2	Shading, Therapy
Trilepisium madagascariense DC.*	-	-	2	-	1	-	-	-	3	2	Food, therapeutic
Moringaceae											
Moringa oleifera Lam.	2	1	2						5	3	Therapeutic
Myrtaceae											
Syzygium malaccense (L.) Merr. & L. M. Perry		2				2	1		5	3	Food
Psidium guajava L.	1	-	-	-	-	-	-	-	1	1	Food, therapeutic
Syzygium brazzavillensis Aubr. & Pellegr.*					1				1	1	Therapeutic
Nyctaginaceae											
Bougainvillea spectabilis Willd.	1	-	-	-	-	-	-	-	1	1	Ornamental, Live hedge
Oxalidaceae											
Averrhoa carambola L.	-	-	-	-	-	-	2	-	2	1	Food
Phyllanthaceae											
Bridelia ferruginea Benth.*	1								1	1	Therapeutic
Pinaceae											
Pinus sp.	1	2	-	-	-	2	1		6	4	Ornamental
Rubiaceae											
Sarcocephalus latifolius (Sm.) E. A. Bruce*	1			1		1	3		6	5	Therapeutic
Rutaceae											
Citrus limon (L.) Osbeck		1				1			2	2	Food, therapeutic
Sapindaceae											
Litchi chineensis Sonn.	6	6			3	6			21	4	Food, shade
Total	206	113	148	106	152	201	159	117	1202	-	-

(*) taxons locaux non natives de la région de Brazzaville

3.5. Floristic Composition Data

The floristic inventory lists 1202 woody belonging to about fifty species distributed in 27 families, unspecified excluded (Table 2). The number of species per family varies from one to four and the most diversified are the Fabaceae and Arecaceae (four species each), the Euphorbiaceae, Myrtaceae and Moraceae with three species. The majority of woody species are found in sectors A and B with 46.67% and 42.60% individuals respectively. Species such as *Mangifera indica* (417 trees), *Persea americana* (333 trees), *Dacryodes edulis* (209 trees) and *Elaeis guineensis* (63 trees) dominate this floristic composition. The comparative analysis of the floristic composition underlines that very few species are common to the three sectors (Figure 8). This low specificity is more pronounced once the taxa common to all three sectors or even to the sectors are removed. Thus, sectors A and C are left without common taxa and C without marker taxa. This observation would be in adequacy with the rhythm

of installation or even occupation of the sectors. In fact, the most affluent neighborhoods are also the oldest created. The place of the dominant taxa being no longer to be demonstrated in the daily life of the populations, the refinement of the floristic data shows that 36% of the taxa inventoried are introduced from the local flora not native to the region of Brazzaville. The ethnobotanical value reveals that the majority (52.17%) of the species inventoried have therapeutic virtues. In addition, in equal proportions of taxa (30.43%) are found food providers and ornamental plants including quickset hedges, materializing the boundaries of the plots.

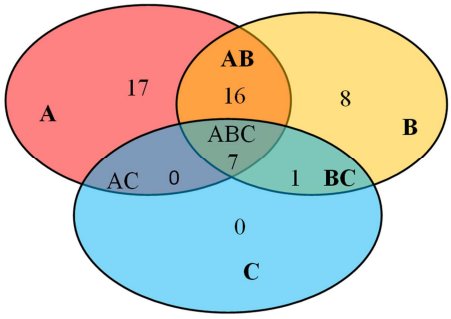


Figure 8. *Spatial distribution of marker and common species in the study areas.*

In addition to the aesthetic value of the exotic species (Asian and American) to the Guinean-Congolese region, these species are for the populations, a safe source of food, phytomedicine, income and wood energy. Notwithstanding the importance of the services provided, local species not native to Brazzaville have an undeniable value in perpetuating the socio-cultural base, a major reason for their introduction. Following a gradient of distance from the city center, we note a progressive recruitment of taxa supporting local knowledge. Among which *Trema orientalis, Oncoba welwitschii, Alchornea cordifolia, Sarcocephalus latifolius, Bridelia ferruginea, Dichrostachys cinerea, Buchholzia coriacea, Trilepisium madagascariense.* These plants generally come from the local flora or from the corollaries of the rural exodus, are the witness of the investments made in the values and virtues sought by the populations.

3.6. Biodiversity Index Data

3.6.1. Similarity Coefficient

Whatever the index (Jaccard or Sørensen), the three sectors do not present any floristic similarity. According to the Jaccard index, the similarity coefficients vary from 0 to 29.09%, while with Sørensen this same coefficient is in the range of 0 to 45.07%. Nevertheless, the floristic composition of sector A is clearly different from that of sector C. This difference is marked by a similarity rate of almost zero (0.17%) according to the Jaccard similarity coefficient and 61% according to Sørensen. The coefficients of similarity between sectors A and B are 29.09% (Jaccard) and 45.07% (Sørensen), while between sectors B and C the values are 2.23% (Jaccard) and 5.13% (Sørensen).

3.6.2. Biological Diversity Index

The biological diversity indices are very low overall (Table 3). In terms of species richness, the three sectors are paucispecific (low diversity). As for the flora, the Pielou index reveals a strong gregariousness in each sector. This distribution mode is supported by taxa such as *Mangifera indica, Persea americana* and by far by *Dacryodes edulis*. Indeed, these taxa sufficiently meet the needs of the populations while providing ecosystem services efficiently. Urban arboriculture is dependent on the local population and is supported and oriented according to their needs. These different reasons for the foundation of urban arboriculture are the source of its low diversification.

Table 3. *Indicators of biological diversity data.*

Urban areas	H’	H'_{max}	Equitability
A	0.019 ± 0.004	1.60	0.01
B	0.025 ± 0.005	1.50	0.02
C	0.076 ± 0.020	0.90	0.08

3.6.3. Ethnobotanical Value and Associated Contributions

Of the fifty species recorded, a typification based on anthropological data reveals: (i) 28% specific medicinal; (ii) 14% exclusively food; (iii) 26% typical ornamental; (iv) 30% of the taxa with multiple uses (Table 2). In addition to the alien flora (44%) which represents the major part of the taxa, of which (22%) are domesticated for the food trait of the fruits, and which subsequently intervene independently in the other uses. Finally, the local flora is divided into forest taxa (24%), 4% of which are domesticated, and savannah taxa (18%). It should be noted that this local flora is not native to the study area. The introduction of these taxa, for the most part, is related to the socio-cultural value known to the stakeholders.

In terms of endogenous knowledge, the study notes that there are no proven differences between the residents of the three sectors. This observation integrates the data collected according to the social groups of the informants, the age groups and the gender. It should be noted that most of the time; this is popular knowledge, the virtues of plants, useful to all people.

3.7. Planted trees and Associated Services

The survey reveals 22 ecosystem services covering the three main categories whose regulation includes support (Table 4). Depending on the number of citations, the services cover the material and immaterial needs of populations, which are part of their daily lives. A refinement of the result reveals that the informants have a level of knowledge and consideration of the benefits of plants that goes beyond the urban framework of the study. This very global vision of the services provided by trees augurs a bright future for the place held in society. The female contribution, in terms of number of citations of ecosystem services, is very satisfactory. This participation involves at least 2/3 of them and by age groups, for key ecosystem services such as food, herbal medicine, source of income, shade, air pollution control and windbreak. This result marks a clear divide in the appreciation of ecosystem services by women. Of these services, the odds are placed on the tangible

ones while not ignoring the intangible ones.

Table 4. *Use value of each benefit category of planted trees.*

Categories	Ecosystem Services	Ui	UV	FL	ICF
Regulation	Maintaining biodiversity	187	0.95	9.08	0.95
	Soil remediation	3	0.02	0.15	0.40
	Improving soil fertility	27	0.14	1.31	0.62
	Air pollutant	274	1.39	13.30	0.96
	Oxygen production	178	0.90	8.64	0.94
	CO_2 sequestration	63	0.32	3.06	0.84
	Shade	195	0.99	9.47	0.95
	Windbreak	153	0.78	7.43	0.93
	Rain erosion control	90	0.46	4.37	0.89
	Noise barrier	50	0.25	2.43	0.80
	Lightning conductor	7	0.04	0.34	0.67
Cultural	Source of inspiration and recreation	106	0.54	5.15	0.95
	Spatial planning	8	0.04	0.39	0.29
	Palaver tree (social value)	7	0.04	0.34	0.17
	Psychological effects	86	0.44	4.17	0.94
	Health effects	41	0.21	1.99	0.88
	Fruit sharing	30	0.15	1.46	0.83
	Phytotherapy	73	0.37	3.54	0.93
Provisioning	Food	188	0.95	9.13	0.97
	Firewood	102	0.52	4.95	0.95
	Economic value	111	0.56	5.39	0.95
	Reduction of air conditioning costs	81	0.41	3.93	0.94

Legend: number of citations for each societal benefit (Ui), use value of each societal benefit (UV).

4. Discussion

4.1. Analysis of Floristic Diversity

The floristic composition is centered on four domesticated species, 50% of which are Asian and American non-native fruit trees [14, 15, 43-45]. As for the remaining half, two species (*Dacryodes edulis* and *Elaeis guineensis*) with multiple uses, native and domesticated of the local flora form its backbone. The preference for these taxa in the plots is said to be based on several reasons, including community services [46]. It should be noted that several of the non-native species are said to be of African or even indigenous origin, according to the collective consciousness. This would be related to the "new" associated uses [31, 47]. This flora is evidence of transcontinental exchanges, especially between the new and the old world. In addition to these exchanges transgressing natural barriers, this flora allows the marks of exchanges between smaller entities such as phytogeographic districts, within the Guinean-Congolese regional center of endemism [33, 48, 49].

A reflection on the duality of flora and population shows that the focus of interest is on the maintenance of the socio-cultural base and the daily satisfaction of primary needs [14, 50-52]. If it is acquired that more than 80% of the populations, throughout the world, have recourse to the medicinal plants, in particular phytotherapy, to mitigate the various evils which undermine them [7, 21, 50, 51].

4.2. Socio-Cultural Value

Notwithstanding the snobbery justifying the massive introduction of ornamental and other exotic plants, the socio-cultural base of the dwellers is safeguarded by the presence of local species. In Africa, particularly in sub-Saharan Africa, urban arboriculture is generally maintained for the purpose of direct or indirect associated monetary gains [7, 14, 46, 53, 54, 55]. This procession is an uneven association of non-native and local plants dominated by fruits such as *Mangifera indica, Carica papaya, Persea americana, Elaeis guineensis* and *Dacryodes edulis* [14]. Despite the food and pecuniary attractions, all of these taxa have medicinal and/or even artisanal value as is the case with *Elaeis guineensis* and *Millettia laurentii* [6, 7, 14, 21, 47, 56, 57]. In relation to the socio-cultural base, especially its perpetuation, indigenous species are introduced or retained during urbanization. The markers of this cohort whose medicinal properties are no longer to be proven are *Sarcocephalus latifolius, Bridelia ferruginea, Syzygium brazzavillensis, Trilepisium madagascariense, Oncoba welwitschii, Alchornea cordifolia, Dichrostachys cinerea, Cola* spp. [21, 47, 56, 58, 59]. Socio-cultural value being the primary reason for the determinism of urban arboriculture, especially in Sub-Saharan Africa. The magnitude of the resulting tangible benefits obscures almost all of the indirect gains; known as ecosystem services, that urban arboriculture generates [4-6, 14, 46]. Thus, urban arboriculture far from covering only the daily needs of the residents, represents a sure source of conservation of phytodiversity [9, 11, 46].

4.3. Urban Trees Management

Urban trees provide several ecosystem and ecological services making the city resilient in terms of life quality and social well-being [16-20, 23-27]. In order to reap the maximum benefits due to urban trees, certain provisions such as the type of trees and rooting, spacing from roadways or infrastructure, and the rate of replacement must be respected [60, 61]. Notwithstanding social inequalities, failure to observe these elements results in disservices that is very costly for urban communities and even the population to repair [62-65].

In view of the disservices caused by trees on residential plots and avenues (appendix 1), arboriculture is, overall, develops without pre-established urbanization norms [7, 65]. Although the organizational charts of our municipalities show that they have a department in charge of quality of life and the environment, the supervision of the actors is lacking. While promoting urban forestry, it becomes for the populations and the public authorities, a source of expenses that could be avoided, if precautions were taken upstream [7, 26, 60, 62, 66]. As shown in previous works, the lack of regular maintenance and renewal policy of these taxa, the major portion of the disservices is associated with senescent trees [7, 15]. This observation is as true for the trees of the residential plots as those located along the arteries of communication [6, 7, 14]. Urban arboriculture, or urban

forestry, is not integrated as a development fund by municipalities and forestry services [11, 26, 46, 67, 68].

4.4. Ecosystem Services and Beneficiaries

The daily satisfaction of primary needs (sustenance and therapeutic) pushes urban populations to make appreciable efforts in arboriculture. Depending on the social class of the person, arboriculture may be oriented towards ornamental plants or fruit trees [12, 14, 15, 63]. With the majority of citizens typically living below the poverty line, arboricultural practice favors fruit trees and thus its corollary of associated ecosystem services [4, 5, 15, 22, 69, 70, 71]. While provisioning services are well known to actors, the other two categories (regulatory and cultural) seem less obvious. As urban cities are by nature sources of heat islands, arboriculture becomes a cardinal instrument to combat any temperature rise, via biological mitigation and/or attenuation mechanisms of plants, and other phenomena that can affect the well-being of populations [1, 13, 16, 19, 24, 25, 66, 72, 73].

A fine-grained analysis of the data collected reveals that Madibou populations are aware of the indirect value of woody species on a daily basis. The rate of contribution via the number of citations would be the parameter that best reflects this recognition. The dominance of women, who are considered less careless about environmental issues, in the group of informants is an asset for understanding the roles and functions of the female agent in the fight against global climate change. This study shows that women in all age groups are key actors in urban sanitation for the well-being of all and the fight against urban heat islands, not to mention all the other ecosystem services [19, 27].

4.5. Perception of Ecosystem Services

The analysis of data on the perception of ecosystem services reveals a population, all genders combined, that is very alert to the issue. Often and wrongly considered a subject associated with men, this survey, in which the proportion of women dominates the group of informants and/or respondents in their capacity as head of household, reveals their level of development and knowledge of ecosystem services. This female awareness would be supported by (i) the youth of the citizens and (ii) the high proportion of educated subjects, at least secondary level. In this study, women represent an avant-garde group on environmental issues or better of the man and his environment, assuming their role of actors. In this regard, in all age groups, women clearly express their knowledge about the interest and value of arboriculture in the resilience of an urban city [10, 66, 70, 74, 75].

From an overall point of view, the perception of ecosystem services and disservices by the informants is very satisfactory. However, this enthusiasm must be measured against the fact that the social background of the subjects often influences the scale of prioritization and the value assigned to these needs [61, 63, 76, 77].

4.6. Similarity Between Urban Areas

Before the law n° 9-2011 of May 17, 2011 instituting Madibou as the 8th district of Brazzaville, increasing de facto its surface area, this landscape formed the southern suburbs that developed around the eponymous village. At the same time, a profound change in the flora took place, moving from savannah to woodland dominance, in proportion to the dynamics of population settlement. Formerly centered on fruit trees and medicinal plants, the flora diversified with the practices of the newcomers (occupants) exploiting the typically aesthetic value of the plants. The evolution of the floristic richness is in adequacy with the dynamics of development even of occupation of this district. In spite of the demographic, floristic and exceptionally specific differences marking the three sectors, the homogeneity of the woody cover is almost not affected. This floristic uniqueness supported by the impoverishment of the residents has as its main basis the satisfaction of the daily needs of the provisioning services, and the rest ensuring associated secondary functions.

The ethnobotanical data within and between sectors show similar values that cannot discriminate between social groups of informants, age groups and gender. The knowledge surveyed would be basic and therefore common to all communities. This observation is also valid for the appreciation of ecosystem services and/or disservices. The frequencies of citations noted in the three sectors are almost identical for all social categories and whatever the item. The weakness of tangible differences within the communities led this comparative study to a global research integrating the three sectors into one unit.

Most often, in this type of survey, the group of informants is almost exclusively composed of men, except in Madibou, where the opposite effect was observed. This women's dominance of the informant group is the reason for being interested in their perceptions of the achievements of urban forestry.

5. Conclusion

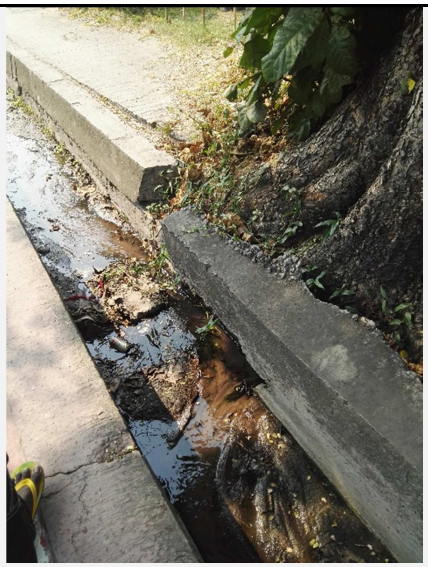
Arboriculture, as in the majority of sub-Saharan cities, is a reliable source of goods and services that have a direct or indirect impact on the population. While ensuring the daily well-being of the surrounding communities, a function that could be described as minor compared to the services rendered to humanity. Indeed, the indirect services resulting from arboriculture generally have a scope that goes far beyond the area covered. The population and the female agent consciously internalize the benefits of woody plants in the fight against climate change in particular. Notwithstanding the introduction of ornamental plants by the middle class, particularly the exotic ones, the foundation of this urban arboriculture is *(i)* the fruit tree, of which certain alien species are considered native by the uninformed, and *(ii)* the local flora (savannah and forest), whose presence marks the originality and perpetuation of

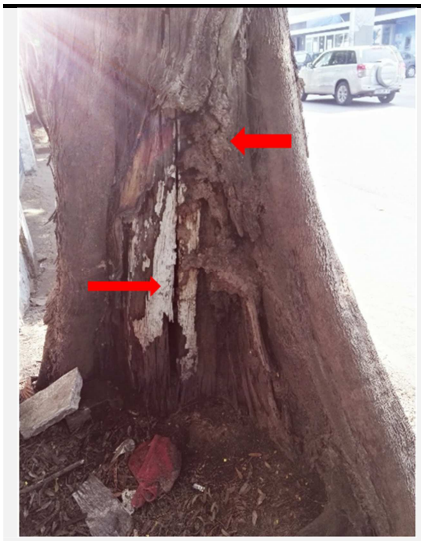
the socio-cultural base, and even of endogenous knowledge. However, it should be recognized that poorly conducted urban arboriculture is a cause of multiple inconveniences, affecting property and people, and even the social cohesion of local residents.

Highlighting the disservices due to arboriculture, in particular avenue trees, on communication and urban sanitation infrastructures, mainly roads (rainwater outlets, water, electricity and telephone networks), people and their goods; coercive measures must be implemented for a rational and sustainable management of the city. In this relational context of man and his environment, a reflection on the standardization of techniques and a reasoned choice of woody species is necessary in order to minimize the impact and costs induced by avenue trees and arboriculture in general. However, urban arboriculture, which is a unit for safeguarding biodiversity, would require the use of local flora to meet the requirements of avenue trees. In view of the roles and functions inherent to urban arboriculture, far from being called into question and without harming the residents, policies must be studied in order to amplify the societal, human well-being and ecological effects. A resilient city must be green in order to fight effectively against climate change (urban heat islands) and offer citizens better living conditions.

Appendix

Table A1. *A view of some of the disservices caused by avenue trees in Brazzaville.*

		
Electric post destroyed by *Terminalia mantaly*	Gutter destroyed by *Terminalia catappa* roots	Sidewalk destroyed by *Terminalia mantaly* roots
		
Peltophorum pterocarpum debarked and senescent in alignment	*Terminalia catappa* debarked and with roots destroying the asphalt roadway	Water supply network and gutter destroyed by *Terminalia catappa*



Peltophorum pterocarpum senescent and victim of a fungus and termite attack

Terminalia catappa having destroyed the gutter and threatening the electric pole and the asphalt roadway

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