Research Article

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Trees Supplies and the Relevance of Ecosystem Services in Brazzaville Urban Environment

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Abstract

The study of the contributions of the trees of court and the relevance of the ecosystem services was carried out in Brazzaville in the district 7 Mfilou. This research, which contributes to the floristic knowledge of the environment, promotes the goods and ecosystem services provided to humanity. The methodology is based on a literary review, a floristic inventory of plots and ethnobotanical surveys involving the populations. The criterion for the selection of surveyed plots is to have at least two trees of diameter at breast height (dbh) ≥ 10 cm. The floristic inventory counted 1655 trees for 45 species and 26 families. Mangifera indica is the dominant species and Fabaceae the most diverse. Backyard trees provide a food, economic, phytotherapeutic and environmental contribution. In addition to this contribution, fourteen ecosystem services grouped into three categories (provisioning, regulatory and socio-cultural) are identified. Data from ethnobotanical indices highlight the adherence of populations to the material and immaterial values of urban forestry. The duality of man and his environment, the fruit trees are plebiscited and the resilience of the city collects the major fraction of the frequencies of citations. Urban arboriculture, despite its paucifloristic character, is a source of biodiversity that sometimes underlies socio-cultural values.

Key Words: Congo, phytodiversity, ecosystem services, urban arboriculture, biological diversity index, ethnobotanical indices.

Introduction

According to the United Nations report on the prospects of world urbanization, the world's urban population is growing exponentially. From 750 million in 1950, it increased to 1.3 billion in 20 years (i.e., in 1970) and to 3.9 billion in 2014 and would reach 6.3 billion by 2050 [1]. Rapid urbanization is taking place in developing countries [2]. African cities, particularly sub-Saharan, are experiencing annual population growth of over 4%. This strong demographic growth, which is proportionally correlated with a horizontal development of the city, results in an almost chronic food deficit [3]. The availability of basic and nutritious food products at a decent cost to residents is increasingly difficult and very poorly assured [4]. Generally urban populations, south of the Sahara, have very modest purchasing power, which makes them vulnerable and exposed to food insecurity, malnutrition, and disease [4, 5]. Indeed, the prohibitive cost of health care and medicines is one of the major obstacles in a city where the majority of households struggle to gather the bare necessities for daily expenses. The unforeseen costs of illness are a major disruption to the precarious budget of these city dwellers [6, 7].

The activities inherent in urbanization affect biodiversity in all its dimensions including associated ecosystem services [8, 9]. Founded in 1880, the city of Brazzaville is no exception, since its original plant cover has almost disappeared in favor of an allochthonous flora that has radically modified the floristic composition in quantity and quality. Congo, a 65% forested country, has 12.4% of the Congo Basin forests, subdivided into three main regions: the Mayombe in Kouilou (1.5 million ha), the Chaillu (3.5 million ha) which extends from Niari to Lékoumou; and the North Congo massif covering the departments of Cuvette-Ouest, Sangha and Likouala with 17 million ha [10, 11]. These ecosystems, which play a major ecological and socio-economic role, overshadow the benefits of small area forests and among which urban, natural and/or artificial woody formations resulting from arboriculture [12].

In relation to the almost chronic pauperization of the said city dwellers, the contributions of Non-Timber Forest Products (NTFP) are an additional support to the formation of income and to the perpetuation of the socio-cultural base. This safe val-

ue of urban forests, which more than one citizen enriches almost daily, provides herbal medicine, food, fuelwood, handicrafts and medicinal products [8, 9, 13]. In order to cover pecuniary needs and to ensure a quasi-permanent or even inexhaustible supply of useful substances, populations knowingly introduce new taxa into the urban space. These anthropic contributions are made to the detriment of the spontaneous flora, which is most often considered useless. Notwithstanding the material assets, urban forests offer an intangible value that goes far beyond the limits of their area. These ecosystem goods and services ensure the well-being and resilience of city dwellers by combating the heat islands resulting from the functioning of the city [14-16].

In urban areas, these woody formations produce goods and generate ecosystem services that improve the well-being of urban residents and increase the resilience of cities to environmental shocks [4, 5]. Indeed, urban forestry provides a range of functions, including climate regulation; carbon sequestration; removal of air pollutants; reduction of flood risk; contribution to food, energy and water security; and, improvement of the physical and mental health of urban residents. In addition to these aspects, the beautification of cities is one of the resulting assets, not to mention social cohesion [5, 8, 9].

In order to collect data on the anthropogenic contribution and relevance of ecosystem services associated with urban forestry in Brazzaville, the 7 Mfilou district was the testing ground. The quest for ecosystem benefits leads city dwellers to tree their living environment according to their ethnic or social origin [9]. The assessment of this contribution is only possible by following the flora of the neighborhoods of the city of Brazzaville [8, 9].

This work of urban forestry aims to improve knowledge on the importance of arboriculture in urban areas according to the duality of man and his environment. The study is based on (i) the inventory of the woody resource of Mfilou, (ii) the evaluation of the benefits provided by trees in this district, (iii) the assessment of the relevance of the ecosystem services provided by this ecosystem to the population.

Material and Methods

Presentation of the study area

Brazzaville is located between 4° 4' - 4° 16' S and 15° 2' - 15° 17' E covers an area of 26.40 km², for a population estimated at 1838348 inhabitants in 2017 [9, 17, 18]. Brazzaville has nine administrative districts (Makélékélé, Bacongo, Poto-poto, Talangai, Ouenzé, Moungali, Mfilou, Madibou, and Djiri) and is bordered to the north by the Igné district; to the southwest by the Goma tsetse district; to the east by the DRC; and to the northwest by the Mayama district [19].

The study took place in District 7 Mfilou, which consists of 13 neighborhoods (Kahounga, Kibouéndé, Mpiéré-Mpiéré, Massina, Moutabala, Indzouli, Mbouala, Kiélé-Ténard, Ngambio, Case Barnée, Cité de 17, Nzoko, Mbimi and Itsali). This administrative entity is bounded by the districts of Talangaï to the North, Makélékélé to the South and the Djoué River, Moungali to the East, and the district of Goma Tsétsé to the West. District 7 Mfilou, which covers 3875 hectares for 13 districts, 88 zones and 250 blocks, is geographically located on the outskirts of the city (Figure 1).

The climate is of the low Congolese type; corresponding to the AW4 type according to Köppen's classification [20-25]. The climatic characteristics are a relatively high temperature (annual average of about 25°C) and a low thermal amplitude of 5 to 6°C [26]. The average annual rainfall varies from 1200 to 1400 mm and undergoes large variations depending on the year. The rains begin at the end of September and last until May, with a decrease in rainfall between January and February. This is the rainy season, which is humid and warm, resulting in stable air. The months of June to September are dry and correspond to the dry season, which is cool [17]. The relative humidity, higher than 70%, presents an absolute minimum in August and September, a relative minimum in February and March. The minimum varies from 50 to 60%, while the maximums are between 88 and 94%. Evaporation has a relative maximum from February to March and an absolute maximum between August and September [27].

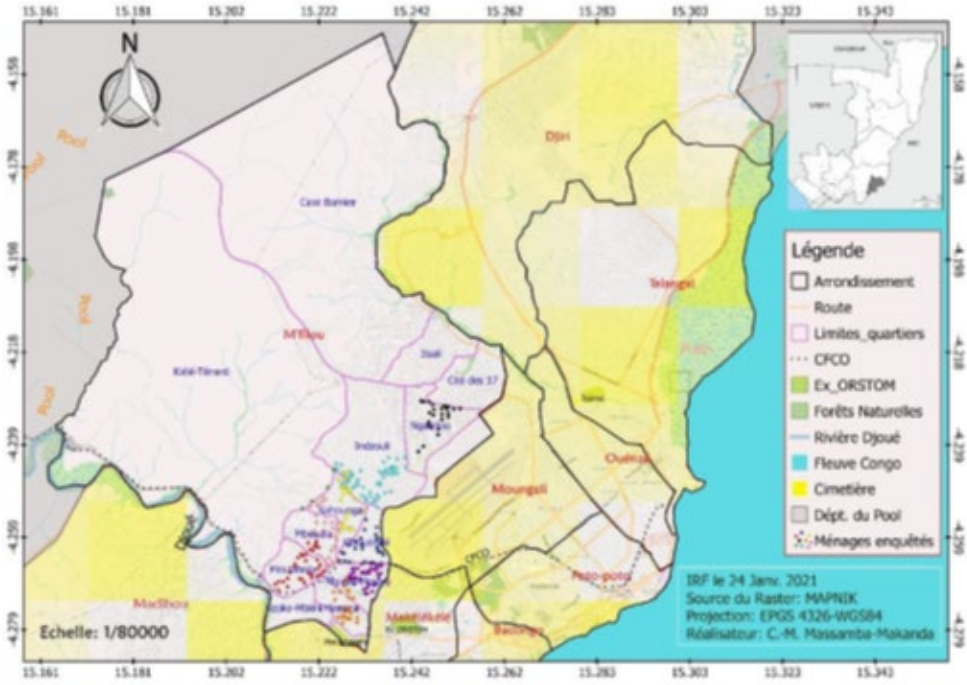

Figure 1: Study site and geolocation of surveyed households

Material

The study material consists of trees and shrubs with diameter at breast height (dbh) ≥ 10 cm evolving in the housing plots. The operations conducted on the taxa were dbh measurement, identification and sample collection. The identification was done in situ, for the common species of the Congolese floras, and the others at the National Herbarium (IEC). The nomenclature adopted is that of Lebrun and Stork and the classification is based on APG IV [28, 29].

Methods

The study method was based on (i) literature review for a state of the art of the issue; (ii) floristic inventory to acquire dendrometric, taxonomic and taxon count data; and (iii) ethnobotanical surveys to assess anthropogenic input and relevance of ecosystem services [4, 5, 8, 9, 30-35]. This component is based on an open-ended questionnaire and may be supplemented by personalized and/or focus group interviews.

Selection of households

The floristic inventory and ethnobotanical surveys were conducted in nine neighborhoods of District 7 (Kahounga, Kibouéndé, Mpiéré-Mpiéré, Massina, Moutabala, Inzouli, Mbouala, Kiélé-Ténard and Ngambio). Households surveyed should meet the criteria of (i) the presence of at least two trees of dbh ≥ 10 cm in the plot, (ii) the age of the respondent selected was 15 years minimum.

Data processing

The collected data were subjected to several bioecological indices and ethnobotanical indicators.

Biodiversity indices

(i) Jaccard's similarity coefficients

Jaccard's similarity coefficients gives the same rating to the presence and absence of species [36].

Jaccard : J (%) = C /$A+B-C$ (equation 1)

With: A: number of specimens from the first survey; B: number of specimens from the second survey; C: total specimens common to both surveys.

(ii) Shannon index

This index allows bettering appreciating the biological diversity. The Shannon index highlights abundant species [31, 36-38].

$H' = -\sum_{i=1}^{s}(pi)\ln(pi)$ (equation 2)

ni: number of individuals for a species; n: total number of individuals, all species combined.

(iii) Maximum diversity index

The maximum floristic diversity provides information on the degree of diversity that a plant community can reach in the case of a homogeneous distribution of the constituent individuals of the flora. The maximum diversity index that plots can have is calculated by the formula [31].

$H'_{max} = Ln(S)$ (equation 3)

With S = total species of the survey

(iv) Equitability index (regularity or Pielou index)

The Pielou index marks the level of diversity achieved by an ecosystem in relation to the maximum possible [39]. This index, which oscillates from zero to one, expresses intra-community variations [36, 40]. Its value tends towards zero when almost all the numbers correspond to a single species in the stand and towards one when a similar number of individuals represents each species [41, 42].

$Eq = H'/ H'_{max}$ (equation 4)

(v) Alpha Fisher Index

The Alpha Fisher index focuses on species richness (S) and total

number of individuals (N) [30, 37, 43]. The advantage of this index is that it is not sensitive to sampling effort and only requires knowledge of the total number of species and individuals in a community.

S= α.ln (1+N/α) (equation 5)

Ethnobotanical indicators

For this study, several indicators were considered. These were frequency of citation, use value, level of fidelity, and informant consensus factor.

(i) Frequency of citation

Citation frequency is the regularity in the translation of a species relative to the total number of individuals surveyed [44-46]. The citation frequency of the ecosystem services will be calculated for each ecosystem service category by the following formula:

FC = (Ni / N) x 100 (equation 6)

Ni: number of people who cited a service; N: total number of respondents.

(ii) Relative frequency

The relative frequency was calculated to highlight the importance of traditional knowledge. The index that shows the local importance of each species is the ratio of the frequency of citation (FC) by the total number of respondents (N) [47].

RFC = FC / N (equation 7)

(iii) Use value

The use value of ecosystem services [48-50] is given by the formula

$VU = \sum_{i=0}^{n} Ui\ /N$ VUt = $\sum VU$ (equation 8)

VU: use value; Ui: number of citations for each ecosystem service category and N: total number of informants.

(iv) Level of Fidelity

This indicator provides information on the level of fidelity (LF) of local populations to the perception of ecosystem services offered by arboriculture [51].

LF = (NP / N) × 100 (equation 9)

Where Np = number of people who cited a type of ecosystem service or use; and N = total number of people who benefit from any ecosystem service.

(v) Informant Consensus Factor

The Informant Consensus Factor (ICF) defined by Heinrich et al. [52] is typically used to identify culturally important species, agree on their uses, and potentially consider further study. The value of the ICF ranges from zero to one and indicates a high consensus when it tends toward one. In this study, the ICF will be calculated for each of the three categories of ecosystem services.

ICF = (Nur – Nt / Nur − 1) (equation 10)

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

Results

Data on the group of informants

The survey is based on 274 households, 38.70% of which are managed by men and 61.30% by women. The distribution by neighborhood is as follows: Inzouli (21.20%), Mpiéré Mpiéré (14.13%), Moutabala (12.36%), Massina (12.36%), Mbouala (10.60%), Kibouéndé (8.83%), Kahounga (8.83%), Ngambio (8.83%) and Kiélé Ténard (2.82%). This disparity is due to the density of trees and more specifically the number of plots with at least two trees of dbh ≥ 10 cm. Finally, seen by age class, the subjects over 45 years old are the most numerous, while the numbers are clearly more homogeneous in all the others (Table 1). As for marital status, the composition of the group of informants is broken down into married (55%), single (39.80%), widowed (4.40%) and divorced (1.10%). Finally, the level of education reveals that 59.10% of the informants have reached secondary school, 19.70% university, 15% primary school and 6.20% have not attended school (unschooled).

Table 1: Distribution of households surveyed by age group

Age groups	Number of citations (%)	Frequency of citation (%)
15-25 years old	62	22,60
25-35 years old	65	23,70
35-45 years old	58	21,20
45 years and older.	89	32,50
Total	274	100

Floristic data

The systematic inventory counts 45 species belonging to 26 families. The number of species per family varies from one to eight and the most diversified are the Fabaceae (eight species) which are followed by the Arecaceae (four species), the Anacardiaceae and the Malvaceae with three species each (Table 2). Of this floristic cohort, *Mangifera indica* with 551 individuals is the dominant species, followed by *Persea americana* (330 individuals), *Carica papaya* (327 individuals). However, nine species *(Bridelia ferruginea, Cactus sp., Caryota urens, Chaetocarpus echinocarpus, Litchi chinensis, Psidium guajava, Artocarpus altilis, Theobroma cacao, Paramacrolobium coeruleum)* are present through a single individual. The inventoried flora is mainly from intercontinental exchanges, particularly American and Asian. The components covered concern ecosystem goods and services. Many of them remain under the control of man, and generally constitute a reserve of resources essential to daily life.

Spatialization of site taxa

Of the nine neighborhoods surveyed, Inzouli has the most trees (22.53%) compared to the other neighborhoods (Table 2). This neighborhood alone contains almost 23% of the floristic inventory. Overall, the best-endowed neighborhoods are not only the oldest, but also those that have emerged from the ashes of former villages recently integrated into the urban fabric. Notwithstanding the fact that the population is predominantly from the lower social class, seeking fruit and leafy vegetable plants, the spatial distribution of species is not exsanguinated from a social determinism of the occupants of the plots.

Table 2: Total number of individuals per species, per family and per neighborhood

Taxa	Distribution of individuals by neighborhood									Total
	Inzouli	Kahoun-ga	Ki-bouéndé	Kiélé Ténard	Massina	Mbouala	Moutabala	Mpiéré Mpiéré	Ngambio	
Caricaceae	64	30	27	6	27	40	66	50	17	327
Carica papa-ya L.	64	30	27	6	27	40	66	50	17	327
Achariaceae	1	1	-	-	2	1	-	1	-	6
Caloncoba welwitschii (Oliv.) Gilg	1	1	-	-	2	1	-	1	-	6
Anacardia-ceae	172	52	52	8	39	88	72	55	47	585
Mangifera indica L.	165	51	48	7	36	85	64	50	45	551
Spondias dulcis Sol. ex Parkin-son	1	1	1	1	3	1	2	2	2	14
Spondias mombin L.	6	-	3	-	-	2	6	3	-	20
Annonaceae	-	-	1	-	-	-	-	-	3	4
Annona muricata L.	-	-	1	-	-	-	-	-	3	4
Arecaceae	2	-	6	-	-	-	-	4	1	13
Borassus aethiopum Mart.	-	-	2	-	-	-	-	-	-	2
Caryota urens L.	-	-	1	-	-	-	-	-	-	1
Cocos nucif-era L.	2	-	3	-	-	-	-	4	1	10
Elaeis guineensis Jacq.	14	8	7	-	5	7	12	15	13	81
Asparaga-ceae	-	-	-	-	-	-	-	3	-	3
Dracaena mannii Baker	-	-	-	-	-	-	-	3	-	3
Bignonia-ceae	2	-	8	-	8	1	-	16	1	36
Newboul-dia laevis (P.Beauv.) Seem. ex Bureau	2	-	8	-	8	1	-	16	1	36
Burseraceae	29	10	6	1	16	25	31	13	5	136
Dacryo-des edulis (G.Don) H.J.Lam.	29	10	6	1	16	25	31	13	5	136

Cactaceae	-	-	-	-	-	-	-	1	-	1
Cactus sp.	-	-	-	-	-	-	-	1	-	1
Cannabaceae	1	-	-	-	-	-	1	-	-	2
Trema orientalis L.	1	-	-	-	-	-	1	-	-	2
Clusiaceae	-	-	-	-	3	-	-	-	-	3
Garcinia mangostana L.	-	-	-	-	3	-	-	-	-	3
Combretaceae	-	1	1	-	-	1	-	4	-	7
Terminalia catappa L.	-	-	1	-	-	1	-	3	-	5
Terminalia mantaly H. Perrier	-	1	-	-	-	-	-	1	-	2
Ebenaceae	-	-	-	-	1	1	5	-	-	7
Diospyros heterotricha (Welw. ex Hiern) F. White	-	-	-	-	1	1	5	-	-	7
Euphorbiaceae	5	1	6	1	1	-	2	-	-	16
Euphorbia tirucali L.	5	-	5	1	-	-	-	-	-	5
Hura crepitans L.	-	1	1	-	1	-	1	-	-	4
Fabaceae	7	-	6	-	11	2	6	10	3	45
Acacia mangium Wild.	-	-	2	-	-	-	-	-	-	2
Albizia Lebbeck (L) Benth.	2	-	1	-	-	-	-	1	-	4
Dichrostachys cinerea (DC.) Wight & Arn.	1	-	-	-	2	-	2	1	-	6
Millettia laurentii De Wild.	2	-	1	-	3	-	-	3	3	12
Paramacrolobium coeruleum (Taub.) J.Léonard	1	-	-	-	-	-	-	-	-	1
Peltophorum pterocarpum (DC.) Backer ex K. Heyne	1	-	-	-	-	1	-	1	-	3

Pithecellobium dulce (Roxb.) Benth.	-	-	1	-	6	1	4	3	-	15
Senna siamea (DC.) Irwin and Barneby	-	-	1	-	-	-	-	1	-	2
Lauraceae	70	29	28	2	20	53	66	36	26	330
Persea americana Mill.	70	29	28	2	20	53	66	36	26	330
Malvaceae	1	-	-	-	-	1	2	12	-	16
Glyphaea brevis (Spreng,) Monachino	-	-	-	-	-	1	1	4	-	6
Pachira glabra Pasq.	1	-	-	-	-	-	1	8	-	10
Theobroma cacao L.	-	1	-	-	-	-	-	-	-	1
Moraceae	1	1	-	-	3	-	1	2	1	9
Artocarpus altilis (Parkinson) Fosberg	-	-	-	-	-	-	-	1	-	1
Trilepisium madagascariense L.	1	1	-	-	3	-	1	1	1	8
Moringaceae	3	-	-	-	1	-	-	1	1	6
Moringa oleifera Lam.	3	-	-	-	1	-	-	1	1	6
Myrtaceae	1	1	1	-	1	1	1	1	1	8
Corymbia sp.	1	1	-	-	1	-	-	-	1	4
Eugenia uniflora L.	-	-	-	-	-	2	-	-	-	2
Psidium guajava L.	-	-	1	-	-	-	-	-	-	1
Syzygium malaccense (L.) Merr. & L.M.Perry	-	-	-	-	-	1	1	1	-	3
Peraceae	-	-	-	1	-	-	-	-	-	1
Chaetocarpus echinocarpus (Baill.) Ducke	-	-	-	1	-	-	-	-	-	1

Phyllanthaceae	-	-	-	-	-	-	-	-	1	1
Bridelia ferruginea Benth.	-	-	-	-	-	-	-	-	1	1
Rutaceae	-	-	-	-	-	-	5	-	-	5
Citrus sinensis (L.) Osbeck	-	-	-	-	-	-	5	-	-	5
Salicaceae	-	-	-	-	-	-	1	1	1	3
Oncoba spinosa Forssk.	-	-	-	-	-	-	1	1	1	3
Sapindaceae	-	-	-	-	-	-	1	-	-	1
Litchi chinensis Sonn.	-	-	-	-	-	-	1	-	-	1
Total	373	135	149	19	138	223	272	225	121	1655

Biological Diversity Index Data

Jaccard's similarity coefficient shows differences in floristic composition between neighborhoods. Except for a maximum similarity reached of 50% to 53% and recorded four times, all other values are in the range of 26% to 43%. This observation is confirmed by the biodiversity index values (Table 3). However, Pielou's index data allow us to detect a subtle gregariousness within this flora. The neighborhoods with high floristic diversity are Kibouéndé, Massina, Mpiéré-Mpiéré and Moutabala. However, the Alpha-Fisher index shows that Mpiéré-Mpiéré is the most diverse of all the districts, with an index of 8.06. This floristic similarity is based on the criteria used by the populations to choose fruit trees over all other species. Indeed, the multidimensional use of fruit trees is a major asset in meeting their daily needs.

Table 3. Presentation of biodiversity index values

Biodiversity indices	Districts								
	Inzouli	Kahounga	Kibouéndé	Kiélé Ténard	Massina	Mbouala	Moutabala	Mpiéré Mpiéré	Ngambio
Shannon (H')	1,71	1,64	2,14	1,58	2,22	1,67	1,96	2,37	1,87
H'maxi	3,04	2,48	3,04	1,94	2,83	2,77	2,99	3,29	2,70
Equitability	0,56	0,66	0,70	0,81	0,78	0,60	0,66	0,72	0,69
Alpha-Fischer	4,81	3,18	6,25	4,00	5,09	3,63	5,31	8,05	4,51

Household participation in planting and use of tree products

The contribution of households to tree cultivation shows that 67.50% of them have not planted a single tree. Of the minority that have done so, 62.22% declare that they have done so from seeds and 33.33% from seedlings. In the case of the seeds, 93.75% of quotations reveal that they are found in Brazzaville, and 3.75% come from outside. The other organs (stem and root) were only very slightly involved, with an individual citation frequency of 2.22%.

The vast majority of households (99.62%) recognize that trees provide products used in food and medicine. The main food products are fruits (98.43%), leaves (1.17%) and seeds (0.39%). With regard to herbal medicine, 51.45% of households use products from trees (Table 4). This average frequency of use can be explained by: (i) the transmission and empiricism of knowledge within traditional societies, and (ii) the level of education acquired by the population, which obscures endogenous knowledge. The majority of households (68.01%) recognize trees as providers of products that form a source of income (Table 4).

Table 4: Types of tree products used in the pharmacopoeia

Organs collected	Pharmacopoeia basis		Income source basis	
	Number of citations	Frequency of citations (%)	Number of citations	Frequency of citations (%)
Barks	84	43.07	6	3.35
Flowers	2	1.02	-	-
Roots	22	11.28	1	0.58
Fruits	6	3.07	165	92.17
Seeds	1	0.51	1	0.58
Leaves	79	40.51	6	3.35
Others	1	0.51	-	-
Total	195	100	179	100

Floristic inputs and populations

There are four reasons for floristic contributions, all of which are primarily driven by the social condition of the people. This predominantly exotic floristic cohort finds favor with the people as a provider of ecosystem goods and services. With an almost similar frequency of citation, floristic contributions are essentially associated with the source of income (29%), food (28%) and environmental benefits (28%). The phytopharmaceutical portion, although important, covers only 15% of the inputs. Although all the respondents recognize the importance of food, the exploitation of these goods and services is mixed. These parameters, mainly herbal medicine, the source of income and the established environment, are subject to the influence of education and social category. In spite of the frequency of quotation values, more than one informant is not an adept of herbal medicine or, even less, finds in plants his source of income or even food. The trivialization of these aspects by an increasingly young and educated population could explain these facts, without omitting the cyclical fact of the fruiting of trees and the recourse to modern medicine.

Dietary intake by gender and education level

Women, with a rate of 61%, recognize the contribution of trees in the diet more than men do (39%). Respondents with a secondary level of education (59.61%) recognize the contribution of trees to the diet, while those with a university or primary level of education (18.84%) and less than 2% (Figure 2). This finding is supported by two reasons, namely (i) the youthfulness of the informant population, and (ii) the very high number of informants with sufficient education on the value of biodiversity.

Analyzing the frequency of citation in relation to informants' level of education, the Kruskal-Wallis statistical test [chi-squared = 1.1923, df = 2, p-value = 0.5509; with Shapiro-Wilk test (W = 0.52781, p-value = 2.854e-05)] shows no significant difference between services (of food, medicine, and income sources). However, the Kruskal-Wallis test [chi-squared = 9.6667, df = 3, p-value = 0.02162, with the Shapiro-Wilk test (W = 0.52781, p-value = 2.854e-05)] based on the analysis of frequency according to use, highlights very significant differences between levels of instruction, on the perception of services (food, drugs and sources of income). These differences in perception are very marked between subjects with no schooling and those with secondary education.

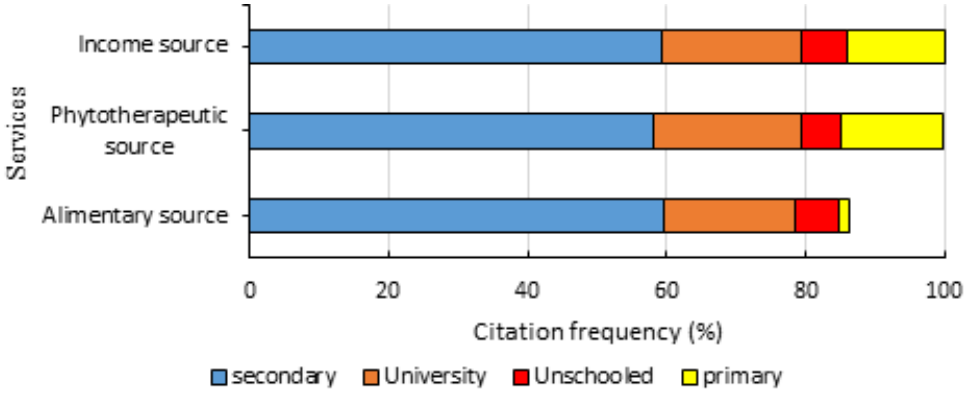

Figure 2: Frequency of citing sources of floral input by education level

Herbal medicine by gender and education level

Herbal medicine is cited by 61% of women, compared to 39% of men. The majority of informants (94.33%) who mentioned herbal medicine are educated and 58.15% of them are in secondary school. Thus, the recognized virtues of plants allow curing and/or relieving more than one disease associated to the different spheres of illness. Among these diseases, those with a high frequency of quotation are hemorrhoids (27.47%), dental caries (14.60%), malaria (10.11%), diarrhea (7.30%), blood pressure (5.05%), cough (3.93%), and typhoid fever (3.37%). The oth-

er ailments treated have a respective frequency of citation of 0.56%. The relationship between the frequency of quotation and the level of education reveals that these two parameters evolve proportionally and do not reflect the level of use of the plants. In view of the low rates of disease citation frequencies, only a fringe of the population, which could be described as marginal, uses traditional herbal medicine. The frequency of quotation of the subjects not educated and those of the primary level would express the degree of use of the benefits and/or virtues of plants. Less informed about the values conveyed by the school, the lives of this minority of informants are intimately associated with the exploitation of biodiversity. These data highlight the gap between knowledge of information and exploitation of knowledge.

Financial contribution according to gender and education level

The survey reveals that 61% of women and 39% of men affirm the monetary value of arboriculture. However, informants with secondary education support the majority (59.25%), while those without education represent barely 6.53%. The dominant proportion of women, in the financial contribution, could be explained by societal facts. Often housewives with no significant income, the sale of non-timber forest products from backyard fruit trees would be a plus for household survival. The high frequency of quotation of the informants of secondary level would be only function of the school knowledge, and not of a real exploitation of the organs resulting from the trees of yard.

Environmental contributions by gender and education level

In terms of the environment, the populations are in favor of air pollution control (55%) and shade (45%). Women at 48.13% for shade and 59.12% for air pollution control cite these two aspects. Like for men, the participation rates are 31.74% for shade and 36.49% for air pollution control. High school respondents largely affirmed that trees participate in maintaining air quality at 56.20%. While the benefits associated with shading cannot be discussed, the subtlety of the environmental virtues (de-pollution and even maintenance of air quality) calls for knowledge. This observation is based on environmental education provided in schools and other sources such as the media. In fact, at the secondary level, the enrolment rate of girls is generally higher than that of boys, before being reversed at the university level.

Contributions of trees according to marital status

According to marital status, married people are the ones who recognize more food intake with a frequency of 55.55%. However, divorced people are the least active with a frequency not exceeding 2%. This dietary intake is mainly associated with the consumption of fruits (Figure 3). Observing the data on phytotherapy, leaves and barks are the most used parts. These organs are more sought after by single people, whose frequency of quotation is 32.43% for leaves and 24.05% for bark. On the other hand, divorced people make the least use of bark with a frequency of quotation lower than 1%. Married people (55.18%) and single people (30.62%) are the groups of informants whose main source of income is tree farming. Finally, the majority of respondents emphasize the influence of trees on the microclimate of the locality, by renewing fresh air and lowering the ambient temperature (Figure 3). Despite the known impoverishment of citizens, marital status would influence the use of tree products.

Based on the frequency of citation reported on the organs and marital status of the respondents, Kruskal-Wallis tests (i) [chi-squared = 11. 445, df = 7, p-value = 0.1204; with Shapiro-Wilk test (W = 0.74246, p-value = 4.006e-06)], and (ii) [chi-squared = 14.121, df = 3, p-value = 0.002746; with Shapiro-Wilk test (W = 0. 73753, p-value = 1.012e-05) reveal that organ collection is significantly different according to the marital status of the respondents. However, Dunn's test finds highly significant differences between (i) divorced and single, and (ii) divorced and married.

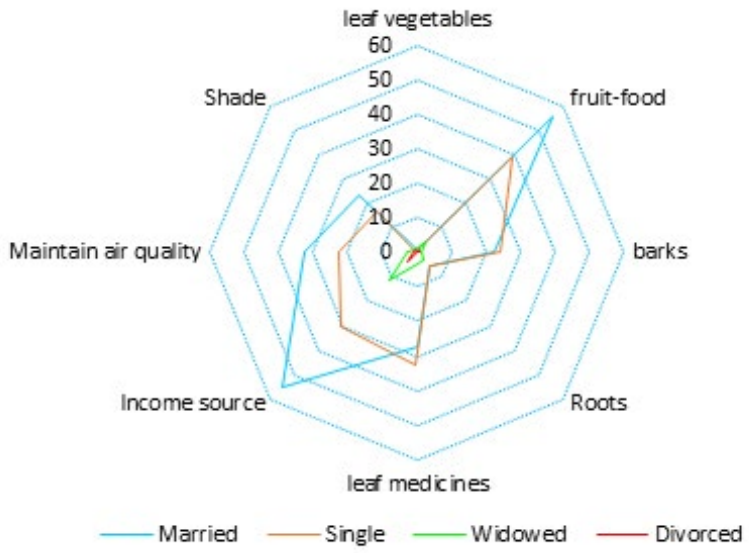

Figure 3: Frequency of citing floristic contributions by marital status

Contributions of trees by age group

The nutritional contribution of trees is especially recognized by respondents over 45 years old. With a frequency of 32.14%, this age group is ahead of the 35 to 45 year olds who show a rate of 21.82% (Figure 4). As for the phytotherapeutic use where the leaves and barks, with a frequency of citation of 18%, are the organs most valued by the over 45 years. This observation also applies to the monetary value of the fruits, the main source of

income for certain social strata, and the environmental aspect, which is synonymous with the resilience of the city (Figures 4). The analysis of goods and services associated with the age groups clearly shows that the exploitation of backyard trees, although unanimously supported by the informants, does not have the same value in the eyes of all. In general, since the transmission of knowledge is progressive from generation to generation, the older people are the ones who benefit the most from the knowledge acquired from the trees.

According to the surveyed age groups, the Anova test [(F-value = 1.0544, Pr (> F) = 0.3868); with the Shapiro-Wilk test (W = 0.94813, p-value = 0.1777)] informs that no significant difference is noted on the perception of ecosystem services.

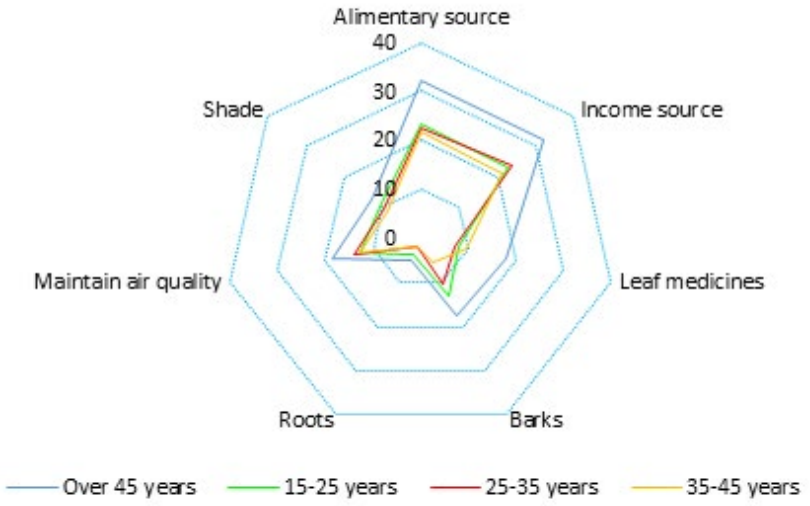

Figure 4: Frequency of citing floristic inputs by age group

Ecosystem services and ethnobotanical indices

The population identified three categories of ecosystem services comprising fourteen ecosystem services. These include the main services proven in urban areas and an almost mechanical understanding of their importance. In relation to the informant group, 46% benefit from regulation services, 30% from provisioning services and 24% from socio-cultural services (Table 5).

The total use value of the three categories of services varies from simple to double. This value is respectively 2.71 for the supply service; 4.08 for the regulation service; and 2.11 for the socio-cultural service (Table 5). The three pillars of the provisioning service identified are food, pharmacopoeia and wood energy (Figure 5). As for the regulation service, the best citation frequencies are recorded for shading and maintaining air quality. Finally, the informants cited inspiration, recreation and leisure, and aesthetics as the basis of the socio-cultural service (Figure 5). The fidelity index values of the ecosystem services highlight, in order of importance, food, pharmacopoeia and finally shade. Except for these three ecosystem services, all others have a range of values covering an interval of 0.95 to 8.89. Finally, the informant consensus factor is overall very high and similar for all ecosystem service categories (Table 5).

Table 5: Fidelity level of the different ecosystem services

Service categories	Ecosystem services	Ui	VU	NF	FCI
Provisioning services	Food	267	0.98	11.09	0.99
	Pharmacopoeia	251	0.92	10.43	
	Wood energy	214	0.79	8.89	
Regulatory services	Maintenance of air quality	213	0.78	8.85	0.99
	Fight against erosion	164	0.60	6.81	
	Role of windbreaks	169	0.62	7.02	
	Air pollution control	133	0.49	5.52	
	Interception of rainwater	141	0.52	5.86	
	Shading	243	0.9	10.09	
	Noise moderation	40	0.14	1.66	
Socio-cultural services	Recreation and leisure	183	0.67	7.60	0.98
	Source of inspiration	208	0.77	8.64	

	Sanctuary of initiation (exorcism)	23	0.08	0.95	
	Aesthetics	157	0.58	6.52	
Total		2406	8.9	100	-

Legend: Ui = number of citations for each ecosystem service (ES), VU = use value of each ES, NF = Fidelity Level.

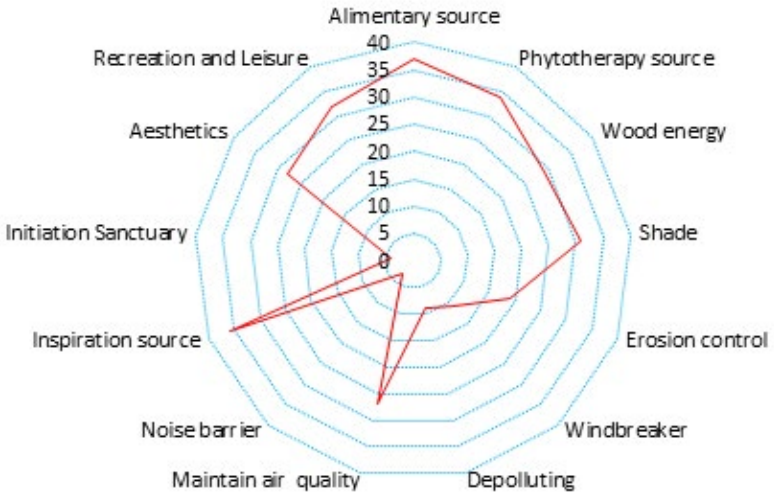

Figure 5: Frequency of citing ecosystem services of yard trees

Provisioning services

The population of respondents in arrondissement 7 Mfilou recognizes the three main provisioning services provided by trees in the urban environment. According to the frequency of quotation, the difference between the entities is almost slight. As a reminder, let us cite, in order of importance, food, phytotherapy and wood-energy. The imprint of the worldly society could explain these low rates of citation of the different ecosystem services.

Regulating services

The regulatory services identified are generally those that have an empirical specificity, without forgetting the particular emphasis of the school. For example, shading and maintaining air quality are two to three times more frequently cited than all others.

Socio-cultural services

At the socio-cultural level, people recognized four ecosystem services provided by backyard trees. The most frequently cited services are inspiration, recreation, leisure, and aesthetics. These three services are also one of the reasons for the modification of the original urban flora.

Perception of ecosystem services by the population

Gender analysis

Provisioning services: women, in terms of frequency of quotation of provisioning services, are ahead of men. While none of the ecosystem services reaches a frequency of 40% for men, women's interest in these services reaches values of 50% or more for food, medicine and wood energy (Figure 6).

Regulation services: of the seven regulation services cited, women in terms of frequency of citation favor six. Shading is the service most cited by more than 50% of informants and all the others have citation frequencies ranging from 25 to 38%. Except for noise moderation, which has the lowest frequency of citations (8.51%), all other ecosystem services have frequencies between 23 and 37% for men.

Socio-cultural services: two socio-cultural services are widely cited regardless of gender, without reaching 50% frequency of citations. However, women represent the group of informants who clearly stand out in terms of frequency of citations for the source of inspiration and, recreation and leisure (Figure 6).

According to gender, Welch's test [(t = 1.7548, p-value = 0.09407); with Bartlett's test (K-squared = 3.6785, p-value = 0.05512) and Shapiro-Wilk's test (W = 0.93641, p-value = 0.0896)] finds that the perception of ecosystem services is not significantly different.

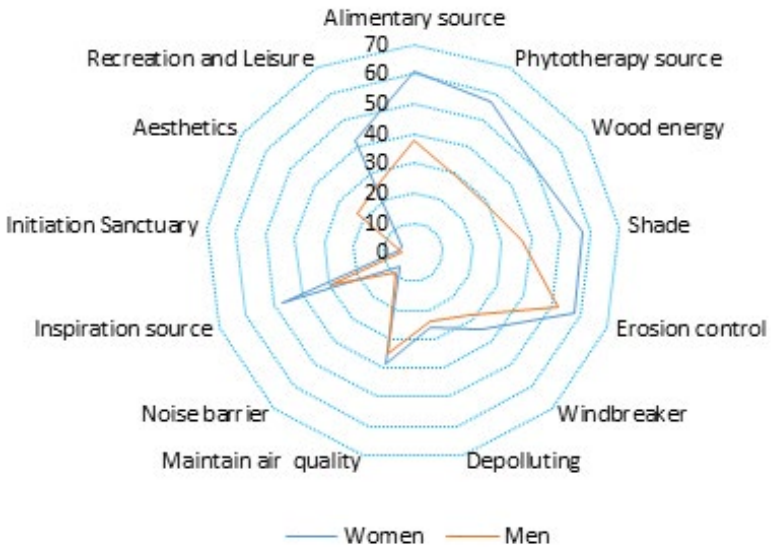

Figure 6: Frequency of citing perceived ecosystem services

Analysis according to level of education

Supply services: All levels of education combined, respondents at the secondary level stand out by plebiscising supply services, particularly food (57.77%), pharmacopoeia (55.55%) and wood energy (48.51%). On the other hand, those at the primary level are very active for wood energy (48.51%). Apart from the uneducated fringe of the informants, the respondents at the university level appear to be those who derive the least benefit from the trees in the yard (Figure 7).

Regulation services: the group of informants at the secondary level has the highest frequency of quotations for all the services cited. The focus is on shading (54.81%), maintaining air quality (43.40%) and acting as a windbreaker (38.14%). The same observation holds true for university level respondents, but to a lesser degree. Noise moderation is the least cited service by respondents at all levels (Figure 7).

Socio-cultural services: once again, high school respondents are the most articulate about ecosystem services. The highest citation frequencies were for inspiration at 46.66%, recreation and leisure at 39.25%, and aesthetics at 26.29%. However, the primary level respondents stand out on recreation and leisure (39.25%).

According to the level of education of the surveyed, the Kruskal-Wallis test [chi-squared = 28.251, df = 3, p-value = 3.216e-06; with the Shapiro-Wilk test (W = 0.79035, p-value = 1.648e-07)] denotes the existence of very significant differences on the perception of ecosystem services.

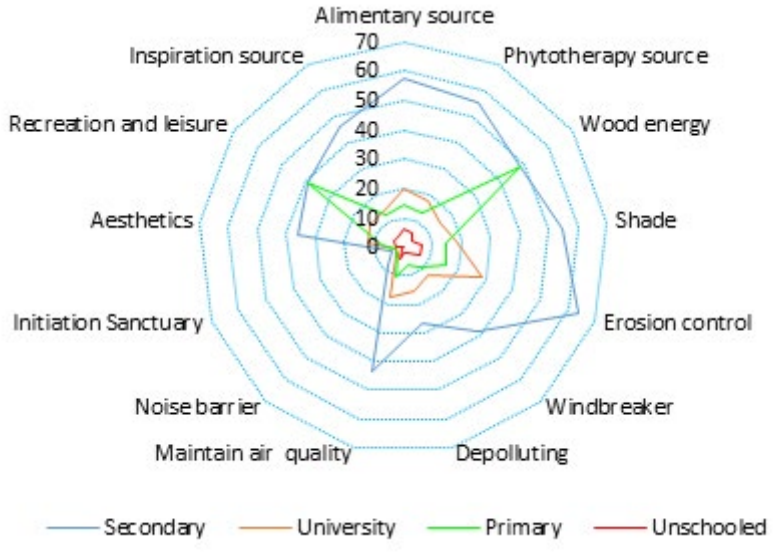

Figure 7: Perception of ecosystem services by education level

Analysis by marital status

Married people are the most likely to cite food (20.08%), pharmacopoeia (19.22%) and wood energy as a supply service. On the other hand, divorced people, who are less represented, have a frequency of quotation that is almost zero for the three categories of services (Figure 8). On the other hand, single people are the most numerous in recognizing all the regulation services, with a particular emphasis on shade. In arrondissement 7 Mfilou, married people are the most active in citing socio-cultural services, especially recreation and leisure (21.47%) and inspiration (18.75%). Noise abatement is the regulatory service least cited by respondents (Figure 8).

According to the marital status of the respondents, the Kruskal-Wallis test [chi-squared = 41.423, df = 3, p-value = 5.318e-09; with Shapiro-Wilk test (W = 0.78653, p-value = 1.342e-07)] underlines the existence of very significant differences on the perception of ecosystem services. These differences are marked between the divorced and the single; the widowed and the single; the married and the divorced and finally the married and the widowed.

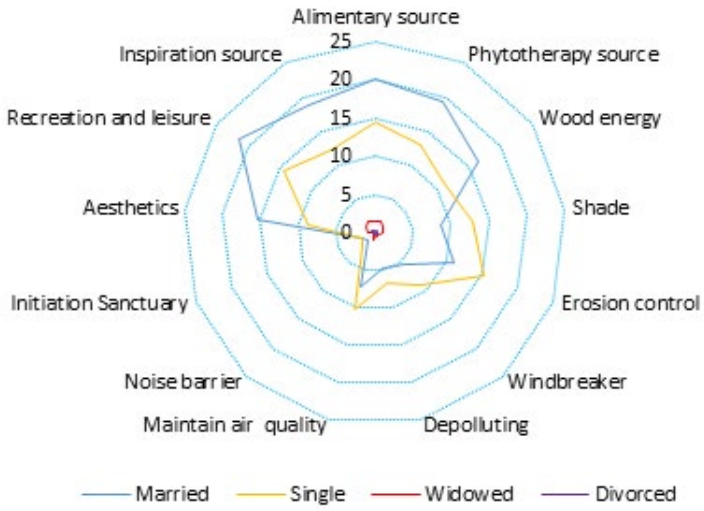

Figure 8: Perception of ecosystem services by marital status

Analysis according to age groups

Respondents over 45 years of age are the most likely to recognize the services provided by trees (food (11.74%), medicine (11.20%) and wood energy (9.15%)). Of the supply services, food (11.74%) remains the product most cited by respondents over 45 years old. In contrast, wood energy is the service least cited by respondents aged 15 to 25 (Figure 9). Erosion control, recreation, and leisure are the services most valued by respondents of all age groups. While the group over 45 years of age is the one that derives the most benefit from the exploitation of backyard trees, a gradual exploitation that is proportionally correlated with age is observed. This observation is based on the culture of knowledge transmission, which is progressive from generation to generation (Figure 9).

Statistical analysis according of the informants age, the Kruskal-Wallis test [chi-squared = 9.0623, df = 3, p-value = 0.02847; Shapiro-Wilk (W = 0.95575, p-value = 0.03869)] reveals highly significant differences between respondents, on the perception of ecosystem services. This difference in perception is more pronounced between (i) 15-25 year olds and those over 45, and (ii) 35-45 year olds and those over 45.

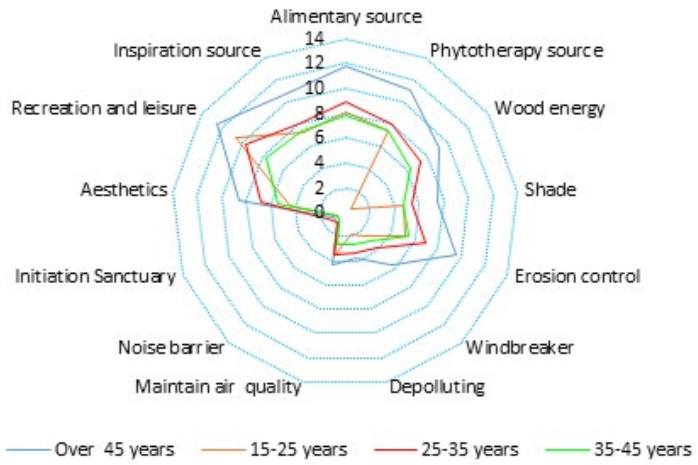

Figure 9: Perception of ecosystem services by age group

Discussion

Floristic analysis

The floristic composition of the urban woodland formation is characterized by a strong heterogeneity. Arboriculture, the basis of urban forestry, is a system marked by a high degree of specific richness associated with a floristic poverty [8, 9, 42, 43, 50, 53-55]. These characteristics are the markers of the corollaries of urbanization, which is carried out to the detriment of the spontaneous flora. The man in the search of the social well-being and the improvement of his environment modifies cheerfully the ecosystems and marks of a serious and irreversible print the three compartments of the biodiversity. The achievement of this research often results in the massive introduction of beneficial and sometimes invasive alien species [31, 56, 57]. In the case of this study, the introduced taxa meet precise criteria based mainly on the daily satisfaction of the needs of the populations [58, 59]. In relation to the impoverishment that the majority of citizen's experience, this daily satisfaction is, most often summarized in the provision of food, medicinal products, and wood-energy and finally constitute a source of income [50, 55, 59, 60]. This dependence of populations on non-timber forest products (NTFPs) alone would explain the low species richness noted in urban forestry south of the Sahara and the pronounced dominance of taxa providing the most prized organs such as the fruits of Carica papaya, Dacryodes edulis, Persea americana, Mangifera indica. The level of floristic diversity found is proportional to the age of the neighborhood and thus the older neighborhoods (Kibouéndé, Massina, Mpiéré-Mpiéré, Moutabala) closer to the city center are more vegetated. This floristic dynamic marks the direction of the horizontal and/or centrifugal sprawl of the City. This observation is authenticated by data from the bioecological indices of the study area.

Contribution of trees to the daily life of the population

The problem of the floristic enrichment of urban cities and the replacement of the original flora obeys to particular direct requirements. These include the demarcation and authentication of the acquired plot of land for future use, shade and the satisfaction of primary needs related to phytotherapy and food, and finally the creation of a source of income, mainly through fruit and leaf vegetables. This first group of factors, which constitute the original interest of the modeling of urban plant cover, ensures in a second part the indirect functions assigned to environmental services, particularly regulation. Regulatory services affecting areas larger than the spatial portion occupied by the tree and/or woody formation, have led city managers to protect urban woody plants regardless of their status.

On a daily basis, to provide for their needs, populations use the plant organs at hand. This accomplishment involves, in unequal proportions, all ecosystem services. The contributions associated with direct necessities (food, phytotherapeutic and wood-energy) are less favored by the group of informants than indirect related to regulatory services and socio-cultural services (income generation) [50, 59, 61]. The source of this observation would be the trivialization of direct aspects by the populations. The level of education and the mediatization of the roles and functions of the trees would be next to the gains generated from the sale of plant organs, are the foundations of this vision. Finally, in the context of climate change, the environmental benefits can only be brought to the forefront of the intentions of the informants, on the trees of yard, following mitigation of urban heat islands [5, 15, 16, 62]. Note that these plant organs (leaves, bark, fruits, fines, and roots) provide a lucrative activity, for an urban population living below the poverty line, centered on herbal medicine [63-66].

Analysis of the relevance of ecosystem services.

The ethnobotanical indices (UV, ICF, LF) are the data that can highlight the relevance of ecosystem services. Despite the global view of the group of informants, the relevance of each of the services is evaluated according to the frequencies of citations coupled with the different ethnobotanical indices. The analysis of the gender effect reveals a clear dominance of the female proportion of the informant group, regardless of the ecosystem service. Notwithstanding the proportions in terms of the number of informants, these data place women in a much higher position than men in terms of environmental sensitivity and management.

The level of perception of ecosystem services by the population is very high, as evidenced by the ethnobotanical indices. This value is strongly correlated to the role of schools in the acquisition of knowledge and to the work of the media in raising awareness of the ecosystem services (material and immaterial) provided by trees in general and particularly in urban areas. This adherence is underpinned by the fact that regulating services, which are typically intangible, are the most highly rated in terms of ethnobotanical indices.

The Informant Consensus Factor (ICF) emphasizes the synoptic view of the diversity of ecosystem services and the assessment of the relative importance of different categories of ecosystem services [50, 59, 67]. The high degree of value of this index for the three categories of ecosystem services marks a strong consensus of informants for each. On its own, this index reveals the close dependence of populations on backyard trees.

Conclusion

The perception of backyard trees in Brazzaville, and specifically in the Mfilou district, has allowed us to have a global knowledge and to establish the preferences of the populations in relation to the social strata. In addition to urbanization, which is the main reason for the replacement of the original flora, the reasons for the floristic contribution crystallize on the satisfaction and coverage of primary needs in daily life. These benefits are summarized in nutritional, phytotherapeutic, energy through wood-energy, and the source of income from the organs of the said plants. The daily life of the populations being intimately associated with these taxa, the trivialization of the direct benefits resulting from their exploitation cheerfully gives way to the immaterial elements that are derived from them. Without having the same scope as the dense rainforests of Central Africa, this urban woody flora seriously influences the life of the populations by supplementing their needs and by ensuring the resilience of the city, by fighting effectively against the climatic changes, in particular the heat islands generated by the functioning of the cities.

The presence of debarked tree specimens, in most of the inhabited or non-inhabited plots, is an irrevocable proof of the services rendered, especially phytotherapeutic. This observation would translate the intentionality of the populations on the trees of court, with the precise aim, to serve as guard eaten and providers of the phytotherapeutic products. The scarcity of data on the interactions between trees planted in urban areas and the population is a handicap for defining an efficient urban forestry policy in Brazzaville. Despite the fact that these trees provide useful goods and services to humans, some citizens ignore the benefits of trees and prefer to sacrifice them, sometimes without reason, to housing and/or other activities. These citizens should be aware of the dangers that humanity would face if urban arboriculture were eradicated.

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