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Floristic diversity and health status of street trees on some public roads of the plateau municipality in the city of Abidjan, Côte d'Ivoire

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Abstract

Trees of alignment, private and public gardens are becoming essential to maintaining and improving the quality of life for urban populations. It is with this in mind that the present research was initiated in the Plateau municipality. An mobile survey and linear inventories were carried out on avenues and boulevards in order to obtain up-to-date information on tree populations. The objective was to assess floristic diversity and determine the health status of trees of alignment in the municipality of Plateau. These inventories allowed us to count 1776 individuals in total. These individuals are distributed among 75 species, 67 genera and 23 families. The Shannon-Wiener diversity index is average, at 2.649 and 2.726 for boulevards and avenues respectively. The horizontal structure shows that, at both sites, high numbers of individuals are concentrated in the class above 100 cm in diameter. The health status of woody plants reveals that at both sites, more than half of the woody plants at each site are healthy. However, parasitism rates are observed in both environments. These are 21.2 % and 30.06 % of parasitized individuals on boulevards and avenues, respectively. As a result, good urban forestry practices prove effective through the careful selection of diverse tree species and by considering trees as essential infrastructure for sustainable planning and management.

Keywords: Urban Woody Flora; Floristic Diversity; Health Status; Plateau Municipality; Côte d'Ivoire

1. Introduction

Trees are essential to humanity. They provide goods and services to humans, in addition to their ecological, pharmacological, economic, food and social roles [1]. Given their multiple importance, they have always been at the heart of society's concerns. Trees regulate the climate, sequester carbon and purify air quality [2, 3]. Indeed, all cities today are home to natural or introduced vegetation. These populations are largely represented by street trees and public or private gardens [4]. However, in cities, street trees are often subject to demographic pressure and road construction. Parasitic plants also threaten the sustainability and proliferation of certain woody plants [5, 6]. The direct consequences of biodiversity loss include the loss of natural habitats and forest cover [7]. Similarly, changes in floristic composition and structure are also observed [8].

Today, it is estimated that more than half of the world's population lives in cities [9]. Given this growing urban population, trees of alignment, private and public gardens are becoming essential to maintaining and improving the quality of life for city dwellers. This is the case in the Plateau municipality of Abidjan, Côte d'Ivoire. In general, in Côte d'Ivoire, cities located in forested areas have always had a large population [10].

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Trees, which contribute to making urban areas more pleasant to live in and more sustainable, are an essential part of the ecosystem [11, 12]. Since the colonial period, they have been subordinated to the urban environment in Africa. This can be explained by the logic of colonial policy aimed at creating public parks and gardens, as is the case in the Autonomous District of Abidjan, Plateau commune, which benefited from the policy of developing public parks and gardens integrated into what are known as affordable housing and road networks [13].

The municipality of Plateau, the administrative capital of Côte d'Ivoire, offers its population a high-quality urban landscape. However, this beautiful landscape is heavily dominated by parasitic plants, which cause the death of certain trees. For this reason, particular attention must be paid to this issue given its importance. Furthermore, the conservation and sustainability of this tree population must be a concern for everyone. This is why an assessment was carried out through a floristic inventory with the aim of providing the Plateau town hall with an up-to-date database in order to better manage this heritage [14]. Good management of the trees will be essential through this database for the municipality of the Plateau [15]. This study was initiated within this framework, with the overall objective of providing up-to-date knowledge on the tree population for better management. More specifically, it involved (1) assessing floristic diversity and (2) determining the health status of the tree population in the Plateau municipality.

2. Materials and methods

2.1. Study site

The Plateau municipality is located in the Autonomous District of Abidjan, which comprises 10 municipality (the city of Abidjan) and four sub-prefectures, including Songon, Anyama, Bingerville and Brofodoumé (Figure 1). Located in the center of the city of Abidjan, in the heart of the Ebrié lagoon that surrounds it, the Plateau municipality is bordered by the communes of Treichville (to the south), Adjamé (to the north) and Cocody (to the west). It is the smallest municipality in Abidjan, with an area of approximately 6 km^2. Plateau municipality is the administrative and political center of the country, as it is home to the Presidency of the Republic, the Prime Minister's office, ministries, embassies, etc. It is also the business center, with the headquarters of banks, large companies and insurance companies. The Plateau municipality remains a strategic area for trade, finance and national governance. It is also strongly marked by the presence of modern buildings, hotels, towers and administrative infrastructure. The climate of the city of Abidjan is of the Guinean type [16]. The average annual temperature is around 26°C, with a maximum of 28.5°C between January and March and a minimum of 24.5°C in August. The city of Abidjan is built on sandstone and sand, sometimes clayey, metamorphic schistose rocks and rocks from the volcanic-sedimentary complex [17].

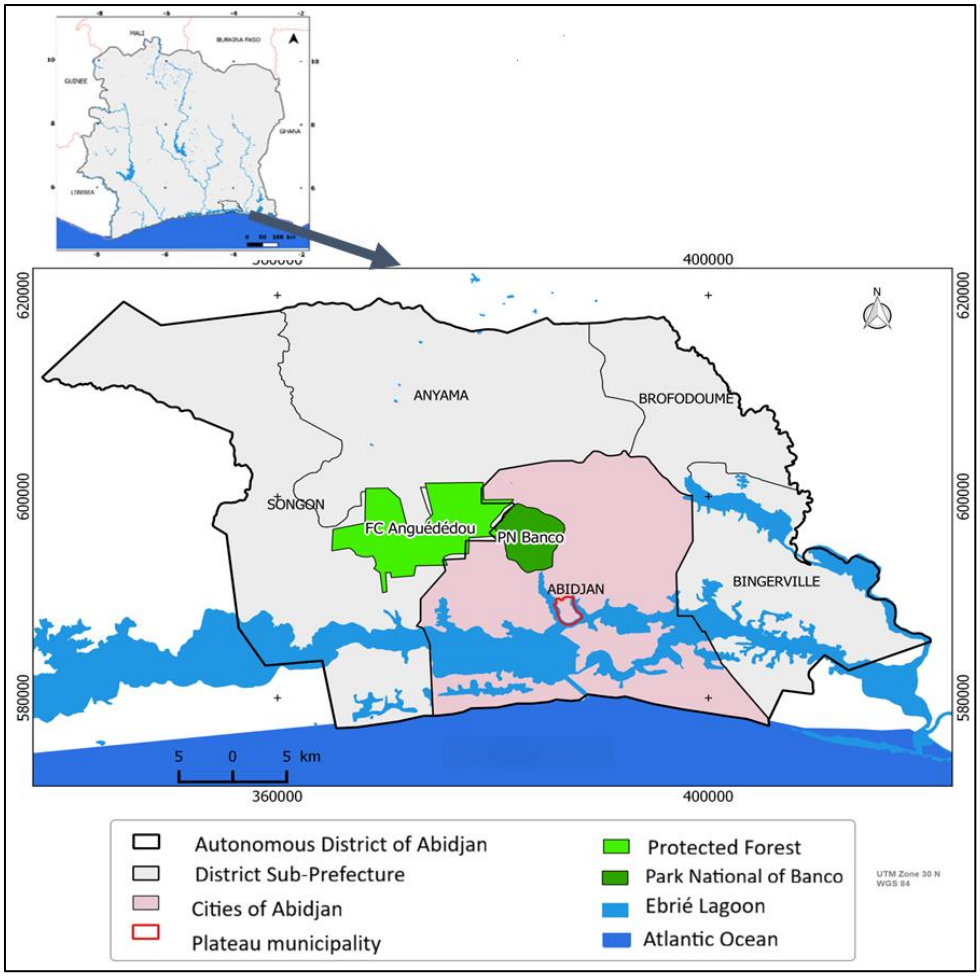

Figure 1 Location of the Plateau municipality (Abidjan Autonomous District, Côte d'Ivoire)

2.2. Data collection

Vegetation is the most important factor in promoting biodiversity in an urban environment. The work consisted of locating land use on avenues and boulevards (Figure 2). To assess the current state of vegetation in this study, a mobile survey was used. This involves walking through the vegetation in all directions and noting all the species encountered [18, 19]. According to these authors, it is effective and suitable for the rapid assessment of plant formations or ecosystems, as well as for the assessment of floristic diversity, and has the advantage of being less restrictive, less costly in terms of personnel and free of selection criteria.

During the inventory, the circumferences of individuals with a diameter at breast height greater than or equal to 10 cm (i.e. a circumference of 31.4 cm) were recorded. The heights of individuals over 2 meters were recorded using interlocking markers. For identification purposes, the species inventoried were identified in the field. The nomenclature used to designate species is that of [20]. Families were updated with [21]. The update of scientific names has been carried out on the site : https://www.ipni.org/. Due to a security issue, the presidential area has not been inventoried.

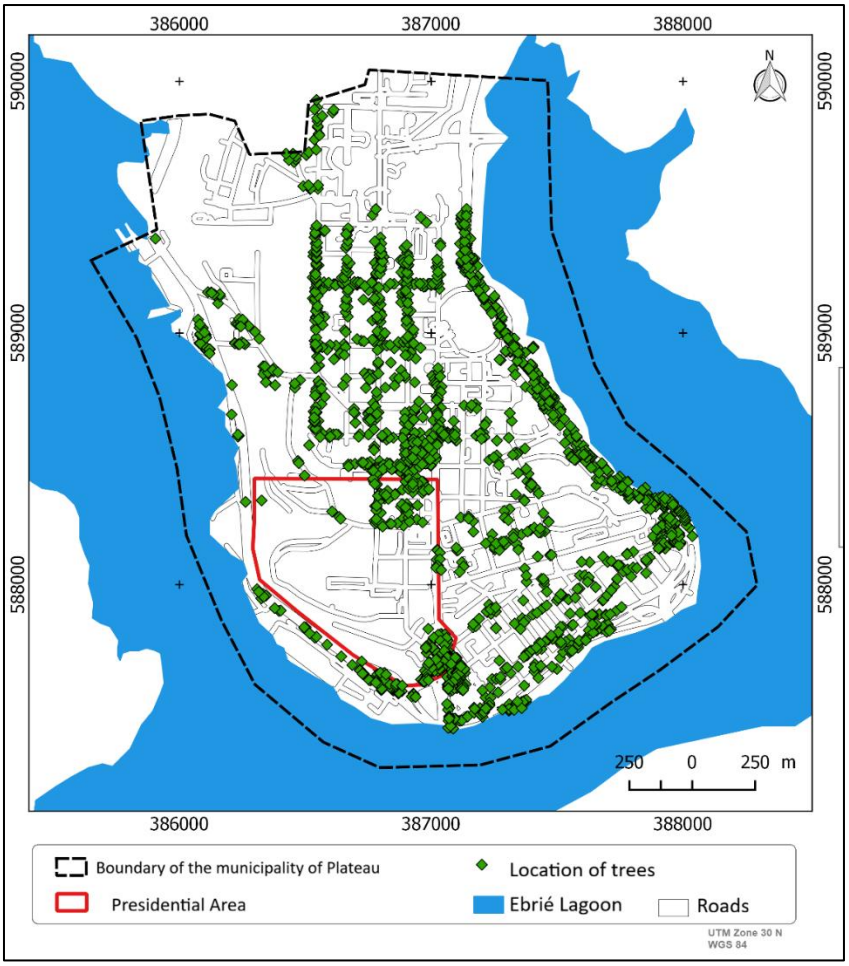

Figure 2 Spatial distribution of all alignment trees

3. Data analysis

3.1. Floristic parameters

3.1.1. Floristic richness and composition

Floristic richness is defined as the total number of species present in a given area, regardless of sample size [22]. Floristic composition was based on floristic lists with information on the genus and family of each species.

3.1.2. Floristic diversity

With regard to floristic diversity, the Shannon-Wiener index (H') and Pielou's evenness index (E) were calculated. The Shannon-Wiener index was used to assess the heterogeneity and diversity of a biotope [23]. This index (H') ranges from 0 to 4 [24]. When the value of this index is zero (0), it indicates that the individuals belong to one species; similarly, when the value of this index is less than 2.5, it indicates that diversity is low; when the value is between 2.5 and 4, it means that diversity is average; when diversity is high, its value is 4. The Shannon-Wiener diversity index is calculated using the following formula [19] :

$$H' = - \sum_{i=1}^{n} (pi) \times \log_2 (pi) \qquad (1)$$

Note: Where pi is the frequency of species i ; pi = ni / N; ni : number of individuals of species i ; N : total number of individuals of all species combined in the environment.

The Pielou equitability or Evenness index (E) reflects the distribution of individuals among species [25] Equitability values range from 0 to 1. For a dominant species, its value tends towards 0, and for a good distribution of individuals among species, its value tends towards 1. This index is calculated using the following mathematical formula:

$$E = H' / \ln S \quad (2)$$

Note: Where H' is the Shannon- Wiener diversity index; S is the total number of species.

For the present study, the diversity indices (Shannon-Wiener and Pielou's equitability) were calculated using the PAST 2.16 software [19].

3.1.3. Health status of the wood settlement

The health status of the tree population in the municipality of Plateau was assessed by visual observation [5]. Four assessment class were defined. These are: healthy individuals, diseased or parasitized individuals, dried-up or dead standing individuals, and individuals that have been stripped of their bark or attacked by insects. To determine the proportion of infestation, the parasitized trees were counted during sampling. The infestation rate was calculated using the following mathematical formula [5]:

$$pi\ (\%) = (pp / pt) \times 100 \quad (3)$$

Note: Where: pi = proportion of infestation; pp = infested plants and pt = total number of plants inventoried.

3.2. Structural parameters

To determine the horizontal structure and characterize the demographic structure of woody vegetation in the Plateau municipality, diameter class were defined with a 10 cm range [19] Indeed, the way in which individual trees are distributed across the different diameter class can provide information on the history, degree of disturbance and regeneration of the woody stand concerned [26].

3.3. Statistical analysis

For this study, Student's t-test was used to compare the two study areas, namely avenues and boulevards. The averages of the floristic parameters (species richness and diversity index) were compared in both areas. As with the one-factor analysis of variance, normality (Shapiro-Wilk test) and homogeneity of distributions (Barlett test) were verified for these tests (conditions for applying the student's t-test). The significance test chosen was performed at $p = 0.05$. Mann-Whitney non-parametric tests were applied in the absence of normality and homogeneity of distributions. Whenever the calculated probability was significant, Tukey's test was performed to compare the means in pairs and assess the differences. PAST 2.16 software was used to perform these statistical tests [27].

4. Results

4.1. Floristic composition

These inventories allowed us to count 1776 individuals in total. These individuals are distributed among 75 species, 67 genera and 23 families. The compilation of floristic data from the inventories revealed a total of 38 species recorded at the avenue sites. These species are divided into 33 genera belonging to 18 families. The most dominant families with more than 10 individuals are, in ascending order, Arecaceae (94 individuals), Fabaceae (69 individuals), Combretaceae (39 individuals), Lythraceae (15 individuals), Myrtaceae and Bignoniaceae with 14 individuals each, and Moraceae (11 individuals). The species with more than 10 individuals collected are *Ravenea rivularis* Jum. & H.Perrier (64 individuals), *Albizia lebbeck* (L.) Benth. (51 individuals), *Terminalia catappa* L. (38 individuals), *Peltophorum pterocarpum* (DC.) K.Heyne and *Lagerstroemia speciosa* (L.) Pers. with 15 individuals each, and *Spathodea campanulata* P.Beauv. (11 individuals), as shown in Figure 3.

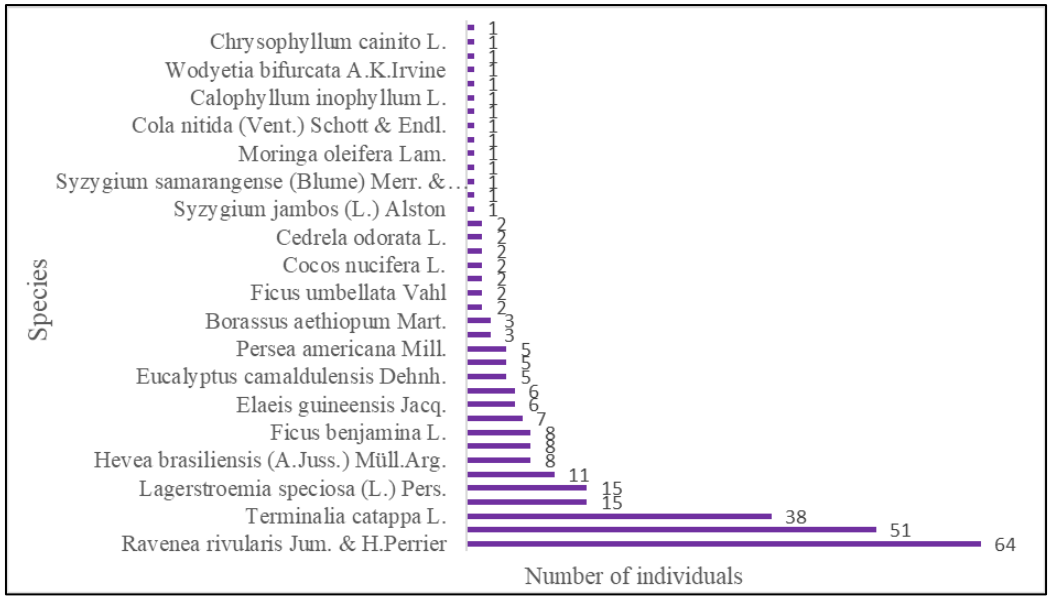

Figure 3 Histograms of individuals by species obtained at the avenue sites

As for the collections from the boulevard sites, 42 species belonging to 39 genera and 14 families were collected. The most common families, with at least 10 individuals recorded, are Arecaceae (258 individuals), Fabaceae (122 individuals), Euphorbiaceae (36 individuals), Anacardiaceae (33 individuals), Combretaceae (19 individuals), Bignoniaceae (15 individuals) and Moraceae (11 individuals). Similarly, the species with more than 10 individuals are *Ravenea rivularis* Jum. & H.Perrier (158 individuals), *Albizia lebbeck* (L.) Benth. (72 individuals), *Wodyetia bifurcata* A.K.Irvine (43 individuals), *Mangifera indica* L. (33 individuals), *Hevea brasiliensis* (A.Juss.) Müll.Arg. (27 individuals), *Cocos nucifera* L. (24 individuals), *Delonix regia* (Bojer ex Hook.) Raf. (23 individuals), *Washingtonia robusta* H.Wendl. (22 individuals), *Terminalia catappa* L. (19 individuals), *Peltophorum pterocarpum* (DC.) K.Heyne (16 individuals) and *Spathodea campanulata* P.Beauv. (11 individuals), as shown in Figure 4.

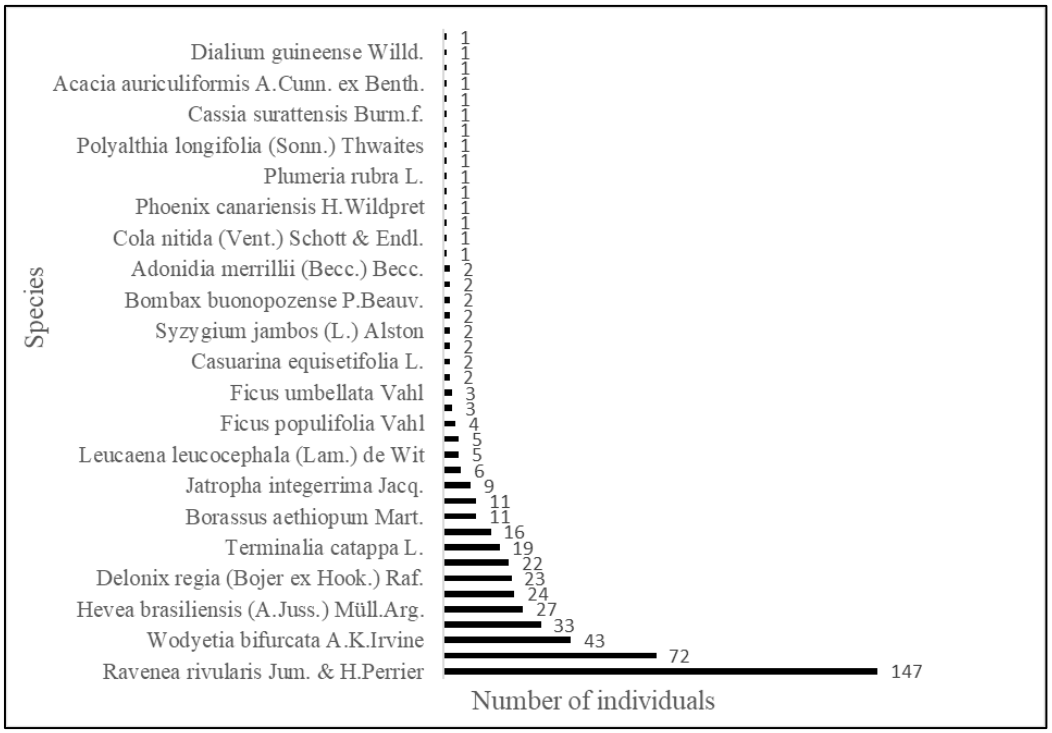

Figure 4 Histograms of the numbers of species collected at the boulevard sites

Figure 5 illustrates the comparison of numbers within each family in the two study areas. Statistical analysis using the non-parametric Mann-Whitney test reveals a highly significant difference ($p < 0.0001$) between species richness at the avenue and boulevard sites (Table 1).

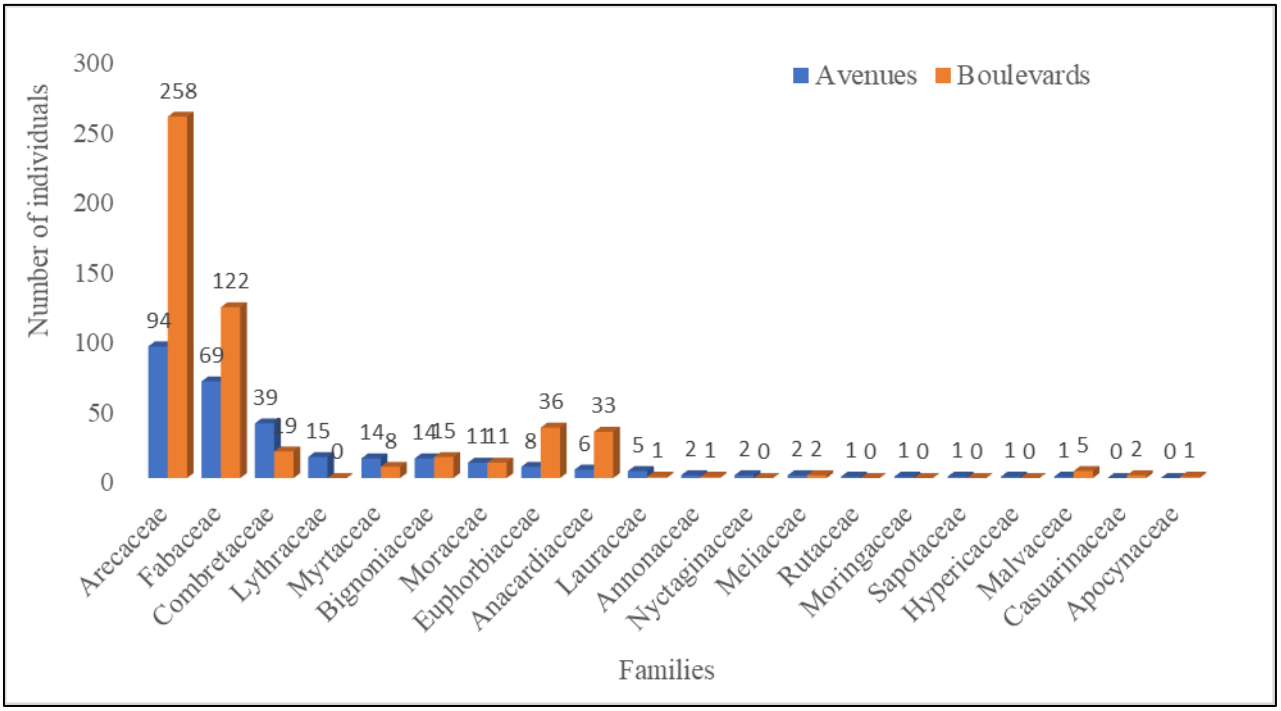

Figure 5 Histograms comparing the number of individuals within families

Table 1 Comparison of specific richness between different study site

	Study site		**Statistical parameters**	
	Avenues	**Boulevards**	***z***	**U**
Specific richness	38	42	-	-
Average specific richness	7.58 ± 2.23[a]	12.23 ± 3.94[b]	< 0.0001	754

Average values plus or minus the standard error that do not have the same letters are significantly different at the 5 % threshold (Tukey test).

4.2. Floristic diversity

From the entire inventory in the two study areas, avenues and boulevards, the Shannon-Wiener diversity index obtained are average. The Shannon-Wiener diversity index is 2.726 for avenues, compared to 2.649 for all boulevard sites. With regard to the Pielou evenness index, overall, both environments are relatively even. The Pielou evenness index value obtained for avenues is 0.749. However, the value obtained for all boulevard sites is 0.708. The summary table comparing the diversity indices is given in Table 2. The Student's t-test shows that there is no significant difference ($p > 0.05$) between the floristic diversity at the avenue and boulevard sites.

Table 2 Comparison of floristic diversity parameters between avenue sites and boulevard sites

Floristic parameters	Study site		Statistical parameters	
	Avenues	Boulevards	*t*	p
Number of species	38	42	-	-
Number of individuals	286	514	-	-
H'	2.726	2.649	-	-
E	0.749	0.708	-	-
H' average	1.337 ± 0.164[a]	1.364 ± 0.2[a]	-0.106	0.916
E average	0.783 ± 0.041[a]	0.694 ± 0.062[a]	1.228	0.234

Note : **H':** Shannon-Wiener diversity index **; E :** Pielou's evenness index. Mean values plus or minus the standard error with the same letters are not significantly different at the 5 % threshold (Tukey test).

4.3. Demographic structure

Figure 6 illustrates the histogram comparing the numbers of individuals collected in the different class of diameters. In general, in all class of diameters, the numbers of individuals obtained at boulevard sites remain higher than those at avenue sites. The histogram comparing the numbers within the different class of diameters can be divided into three groups.

From the 10 to 50 cm class of diameters onwards, the numbers of individuals obtained increase at each site representing the first group, with 171 individuals identified at boulevard sites compared to 60 at avenue sites. In the second group, numbers decrease from the 60 to 70 cm class to the 90 to 100 cm class. On boulevards, 161 individuals were counted, compared to 56 individuals identified on avenues. These numbers then increase again in the class of diameters above 100 cm, illustrating the third group. On boulevards, 182 individuals were recorded, compared to 170 collected on avenues.

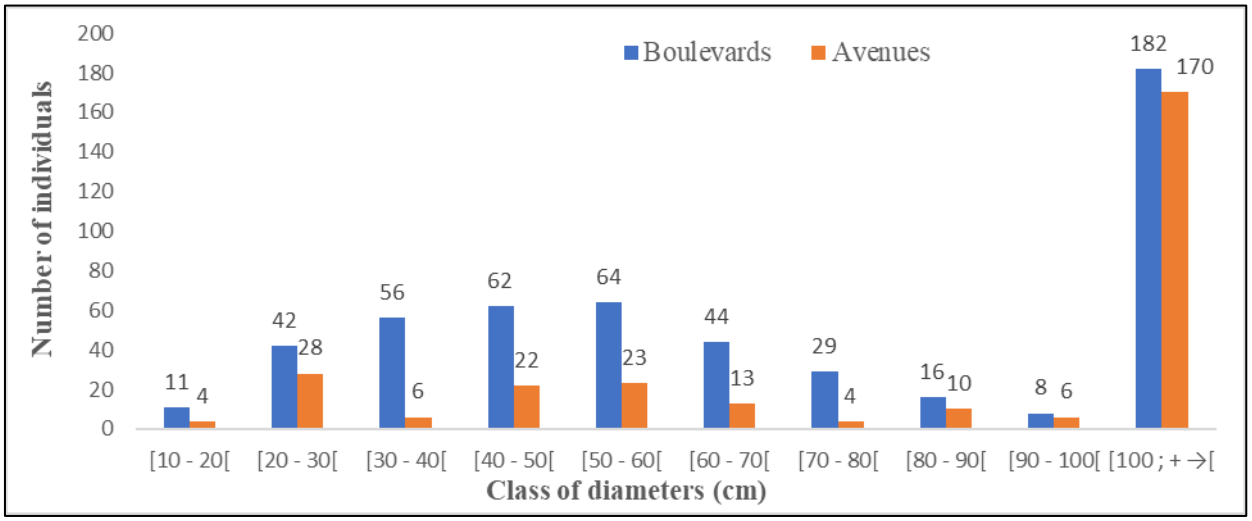

Figure 6 Histograms comparing the number of individuals within class of diameters showing the horizontal structure

4.4. Health status of trees

In the Plateau municipality, in terms of tree population, particularly on boulevards, 403 individuals, or 78.4 % of the total, are healthy, compared to 69.58 % of healthy individuals, or 199 individuals, collected on avenues (Figure 8).

As for parasitized trees, 109 trees, or 21.2 % of the total number of trees inventoried on boulevards, were parasitized, compared to 86 trees collected on avenues. On avenue sites, the species *Albizia lebbeck* (L.) Benth. (Fabaceae) recorded the highest number of parasitized trees (49 individuals), unlike the boulevard sites, where 64 parasitized trees of the same species were recorded. In addition to this species, *Mangifera indica* L. (Anacardiaceae) was identified with 17

parasitized trees at the boulevard sites. These individuals represent 17.13 % of the total number of individuals collected on avenues, compared to 15.75 % of the individuals inventoried on boulevards.

A small number of dead individuals were recorded. Two (2) individuals (*Ravenea rivularis* Jum. & H.Perrier and *Mangifera indica* L.) were identified out of a total of 514 on the boulevards, compared to one individual (*Albizia lebbeck* (L.) Benth.) identified out of a total of 286 on the avenues (Figure 7).

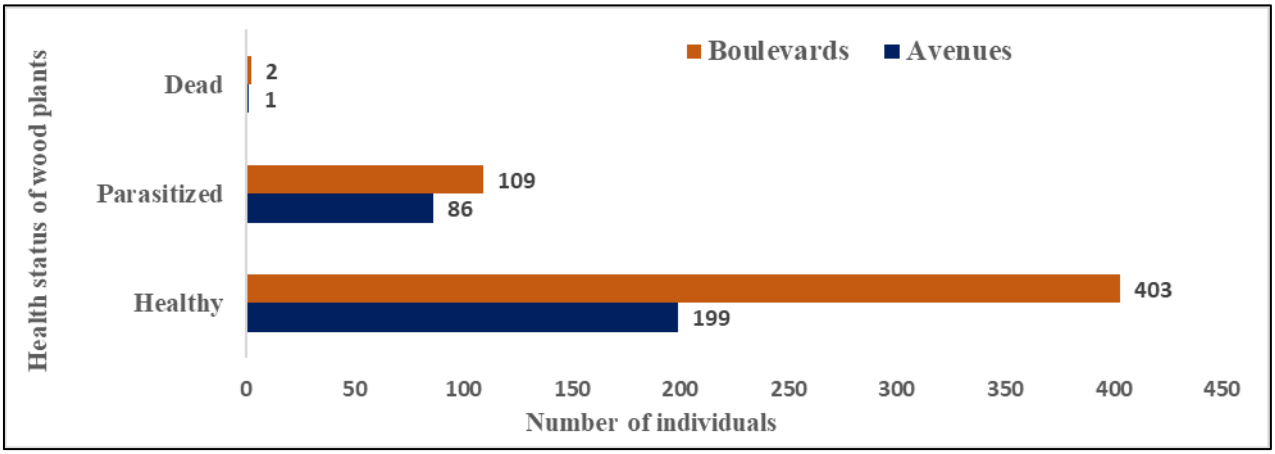

Figure 7 Histogram of the health status of individuals identified at the commune level on the Plateau

5. Discussion

5.1. Richness and floristic composition

Urban vegetation remains the subject of much scientific research, requiring in-depth investigation for sustainable management. These inventories allowed us to count 1776 individuals in total. These individuals are distributed among 75 species, 67 genera and 23 families. This floral richness obtained is superior to that of [28]. This situation could be explained by the high density of trees in the study area despite its small size (6 km^2) compared to 1910 km^2 for the studies of [28]. This specific richness of 75 woody plant species remains higher than that inventoried by [29] which is 28 species. This increase in the number of woody species could be explained by the introduction of new species of the Arecaceae family, such as *Wodyetia bifurcata* A.K.Irvine, *Washingtonia robusta* H.Wendl., *Livistona chinensis* R.Br., and *Phoenix canariensis* H.Wildpret, by the technical services of the Plateau municipality and the Autonomous District of Abidjan. The high rate of species introduced into the various biotopes confirms the fact that urban vegetation has long been limited to mere decoration before evolving over time [30]. The Aracaceae family, whose species have been introduced, remains the most numerous overall. This situation could be explained by the fact that plants in this family are better adapted to the climatic and edaphic conditions of the city [31]. Despite the mobile survey used exclusively for this study, as opposed to the surface survey method combined with the mobile survey method, the specific richness obtained for this study at the level of avenues and boulevards remains higher than that inventoried by [29]. In fact, 11 and 28 species were recorded by [29] on avenues and boulevards, compared to 38 and 42 species at the same study sites. This numerical difference could be due to the recent introduction of species in the Plateau municipality. The same observation was made regarding the number of individuals on avenues and boulevards. For this study, 286 and 514 woody individuals were inventoried on avenues and boulevards, compared to 189 and 516 individuals identified by [29]. at the same sites. The constant number of woody individuals collected on boulevards could be explained by the good conservation of these woody individuals, unlike the sites on avenues where some woody plants were cut down and replaced by other fast-growing ones.

5.2. Floristic diversity

In all the inventories carried out in the municipality of Plateau, the calculation of floristic diversity showed low diversity but high evenness. The Shannon-Wiener diversity index (H') obtained is 2.812 and the evenness index (E) is 0.704. At the avenue sites, H' is 2.726 and E is 0.749, compared to 2.649 and 0.708 representing the Shannon-Wiener diversity and evenness index for all boulevard sites. The average Shannon-Wiener index obtained according to the classification of [24] could explain the low floristic richness recorded in this study. Similar studies have been carried out by [32], which showed that, ecologically, low floristic richness may be linked to low ecological niche diversity. According to the work of [24], the evenness index values obtained at all sites show high equitability. This situation observed in the

plateau commune could be explained by the fact that the inventories were not carried out in a natural environment [29]. Overall results for plant diversity remain acceptable in West African cities [33]. For aesthetic reasons, managers in urban environments choose equitably on a given area and cultivate species of their choice. Indeed, urban vegetation management is often intended for aesthetic and shade purposes [34].

5.3. Demographic structure

The horizontal structure shows a general pattern with individuals present in all class. As the diameter increases, the number of individuals also increases before decreasing and then increasing again. This situation could be explained by the protection of woody plants, which results in larger trees with larger diameters [35]. However, the structures of the woody plant stand differ from one another at the two sites studied. This observed difference could be related to the management methods used for these woody plant stands [36]. The horizontal structure remains dominated by individuals with a diameter greater than 100 cm overall at both sites. This could be explained by the fact that the woody plants collected are in the maturity phase.

5.4. Health status of trees

The results of the health status of the trees inventoried indicate that 78.4 % of the individuals inventoried on boulevards are healthy, compared to 69.58 % for all avenues. This high proportion of healthy individuals in both study areas could be explained by increased monitoring and good management of trees by technical agents of the Plateau municipal council. Furthermore, on boulevards, 21.2 % of trees are parasitized by Loranthaceae and ferns, compared to 30.06 % of trees identified on avenues. The proportion of infestation is high on avenues compared to boulevards. This situation could be explained by the dominance of individuals of the species *Albizia lebbeck* (L.) Benth. (Fabaceae), which is the preferred target of ferns and Loranthaceae [5]. The same situation was observed by [37] in their work, which recorded a proportion of 87 % parasitism, and [38], who estimate that individuals of the species *Vitellaria paradoxa* C.F.Gaertn. (Sapotaceae) in Burkina Faso have rates of between 95 and 100 %. The choice of urban trees should be guided by criteria of sustainability, growth and aesthetic value, while promoting diversity [12]. Unfortunately, these aspects are often neglected in urban development plans, particularly with regard to the promotion of local or indigenous biodiversity [39].

6. Conclusion

This study was conducted as part of the sustainable management of woody stands in the Plateau municipality. The work carried out provided up-to-date knowledge on woody stands with a view to improving management, assessing floristic diversity, studying plant structure and determining the health status of woody stands in the Plateau municipality. These individuals are distributed among 75 species, 67 genera and 23 families. The results revealed a specific richness in each study area. Thus, 38 woody species were recorded in the avenues, compared to 42 for all the boulevard sites. The diversity index showed average (2.649 and 2.726 for boulevards and avenues respectively) values in both environments, while equitability remained high in each environment. The demographic structure shows that individuals were recorded in all diameter class in both environments, with a high concentration of individuals in the class above 100 cm. The health status of the trees shows that at each site surveyed, more than half of the individuals collected are healthy. However, the proportions of Loranthaceae and fern parasitism in both environments should not be overlooked. Parasitism rates of 30.06 % and 21.2 % were noted on avenues and boulevards. This study highlights the urgent need to take long-term measures to reduce the threats to all the different environments. Regular phytosanitary monitoring will need to be implemented using tools such as GIS (Geographic Information System) to target interventions in the most vulnerable areas.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

No conflicts of interest were declared by the authors.

Data availability statement

All the data is included in the content of the article.

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