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Contribution of GIS to the Characterization of Urban Green Spaces: Case of Cocody Municipality, Abidjan, Southeastern Côte d'Ivoire

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Abstract **Original Research Article**

In the municipality of Cocody (Abidjan), public green spaces are increasingly threatened by demographic pressure and urban expansion, reducing their availability and accessibility in favor of other priorities. To date, the lack of studies incorporating georeferenced data prevents the assessment of whether the remaining areas are sufficient to ensure residents' well-being. This raises a key question: How can Geographic Information Systems (GIS) contribute to the characterization of Cocody's green spaces? This study aims to answer this question by evaluating whether the available green space per capita aligns with urban planning and well-being standards. Specifically, the study describes the spatial distribution of green spaces in Cocody, assesses the ratio of green space area to population, determines their diversity, and identifies their uses. The methodology involved a field inventory, digitization of green space boundaries using recorded coordinates, and user surveys. The results indicate that Cocody has 42 public green spaces distributed across 16 of its 26 neighborhoods. The floristic diversity includes 169 plant species from 146 genera and 63 families. In terms of available green space per capita, the analysis reveals a very limited surface area, with a ratio of 0.14 m² of public green space per inhabitant. The city center (older neighborhoods) has a ratio of 0.44 m² per inhabitant, while the outskirts (newer neighborhoods) show only 0.06 m² per inhabitant. These figures remain significantly below WHO recommendations. Residents mainly use these green spaces for rest, benefiting from the shade they provide. These findings will help guide the development policy for green spaces in Cocody.

Keywords: Green spaces, GIS, diversity, usage, Cocody, Abidjan.

INTRODUCTION

Green spaces play an essential role in the balanced development of urban areas (Ali-khodja, 2010). Indeed, urban vegetation fulfills crucial functions in terms of health, sociocultural, economic, and ecological aspects (2Van Dillen and Sonja, 2012). However, demographic pressure, urban expansion, and the development of road infrastructure increasingly threaten trees in urban environments (Veron, 2007). This phenomenon is particularly pronounced in developing countries, especially in West Africa, where urban residents' interest in vegetation seems to decline as urban density increases (Rusterholz, 2003).

The municipality of Cocody, in Abidjan, is no exception to this trend (Nassa, 2009). Its growing population and rapid urbanization have placed significant pressure on its green spaces. Several studies have sounded the alarm to alert authorities about the need to preserve and better manage these spaces (Nassa, 2009; Bindé, 2022). Indeed, the availability of and access to green spaces tend to decrease as these areas are redeveloped to meet other urban priorities. Yet, the World Health Organization (WHO) recommends a minimum of 10 m² of green space per inhabitant to ensure a healthy and balanced environment.

In this context, the municipality of Cocody faces growing challenges in managing its green spaces. It is therefore crucial to ask the following questions: Does the municipality have a sufficient amount of green space for its inhabitants? Are residents able to fully benefit from it? To answer these questions, it becomes essential to quantify and evaluate the green space ratio per inhabitant to better guide urban development policies.

Until now, several studies have primarily focused on species diversity and carbon stocks through biomass assessment (Kouadio *et al*., 2016; Bindé, 2022). However, few of them provide georeferenced data, which is nevertheless indispensable for the accurate quantification of green spaces. In this regard, a central question arises: How can Geographic Information Systems (GIS) contribute to the characterization of green spaces in the municipality of Cocody? From this main question, several subsidiary questions emerge:

- What is the green space ratio per inhabitant in the municipality of Cocody?
- Is there enough green space for the well-being of the population?

It is to address these questions that this study is conducted. Its general objective is to characterize the green spaces of the municipality of Cocody. Specifically, it aims to:

- Describe the spatial distribution of green spaces in Cocody
- Evaluate the green space ratio per inhabitant
- Determine the diversity of these green spaces
- Identify their uses

1. MATERIALS AND METHODS

1.1 Study Area

The municipality of Cocody is one of the communes of the Autonomous District of Abidjan (Tra and Adou, 2017). It is located in the northeast of Abidjan, approximately between latitudes 5°3’ and 5°4’ North, and longitudes 3°9’ and 4° West. It covers an area of 132 km². Its boundaries are defined to the north by the communes of Abobo and Anyama, to the south by the Ebrié Lagoon, to the east by the commune of Bingerville, and to the west by the commune of Adjamé (Figure 1).

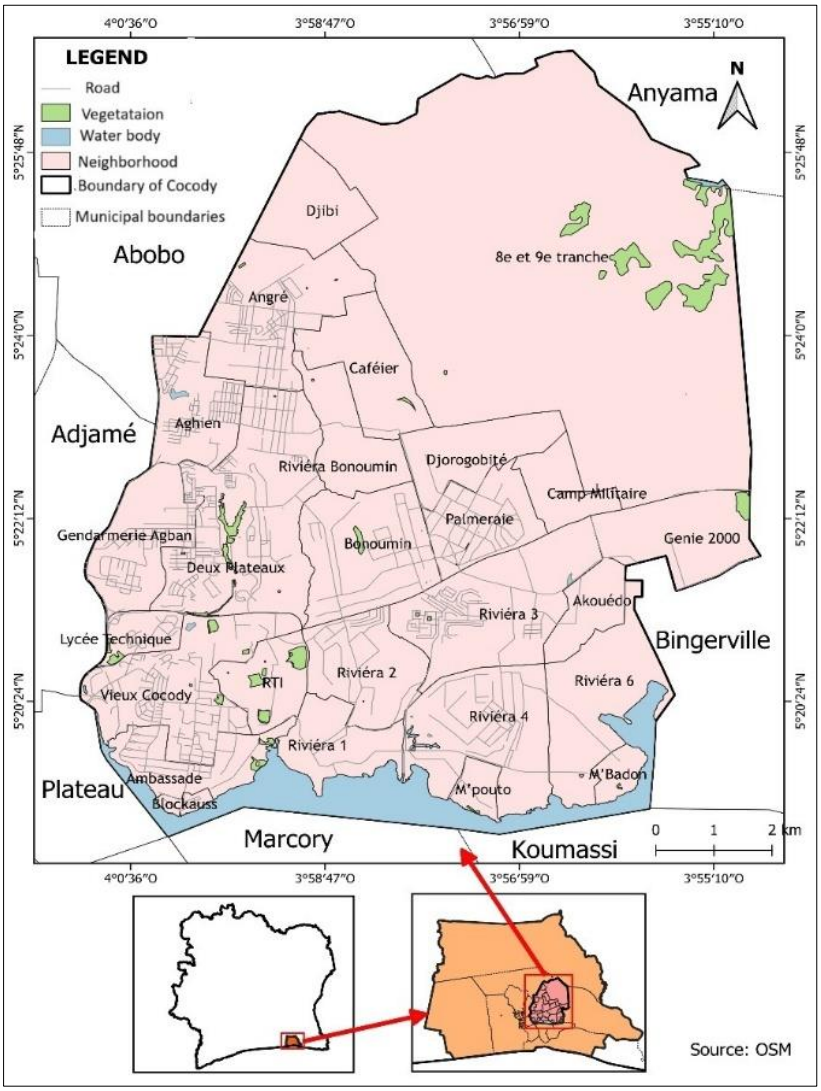

Figure 1 : Cocody municipality presentation

1.2 Data Collection

The study used several methods to collect data on green spaces in the Cocody commune. A list of public gardens was obtained from the Cocody Town Hall, and green spaces (public gardens, vegetated traffic circles, etc.) were identified and modeled as georeferenced

points and lines using Google Earth. A KML file was created to facilitate localization in the field using the Google Maps application, which also enabled the most efficient routes to be planned. Data collection begins by digitizing the outline of each green space, recording the boundary coordinates. This was followed by an itinerant inventory of the plant species present. Finally, a survey was conducted among visitors to understand their interest in urban vegetation. The collection form was designed using KoBoToolbox, and data was collected via the KoBoCollect mobile application, enabling real-time synchronization and saving.

1.3 Data Analysis

1.3.1 Assessment of Floristic Richness and Composition

Floristic richness corresponds to the number of species present on a given site, regardless of their frequency, abundance, size or productivity (Aké-Assi, 1984). To assess this, we established a floristic database including taxonomic information (genus, species, family) for all species encountered. Species nomenclature follows that of Lebrun and Stork (1997), while family nomenclature is based on APG IV (2016).

Analysis of floristic composition involved determining the biological type and phytogeographical distribution of each species identified. Biological type was determined based on the work of Aké-Assi (2001; 2002). The terminology used is that of Raunkiær (1934), adapted to tropical regions.

As far as phytogeographical distribution is concerned, 4 groups have been identified: Guinéo-Congolese species (GC), species from the Guinéo-Congolese and Sudano-Zambézian transition zone (GC-SZ), species from the Sudano-Zambézian region (SZ), and introduced (i) or exotic species (Aké-Assi, 2001; 2002).

1.3.2 Spatial Analysis

Using Google Eath, we modelled the public gardens as polygons, and the areas were automatically generated by the software.

With regard to spatial distribution, a distribution map was produced on which aligned planting and the embellishment of road surfaces are represented by lines and public gardens by dots. This method provides a detailed view of the spatial distribution of green spaces.

1.3.3 Recovery Rate

The coverage rate shows the proportion of Cocody's neighborhoods covered by public gardens. The coverage rate for public gardens was calculated using the formula:

$$RR = \frac{\text{APG}}{\text{TA}} X\ 100$$

RR = recovery rate of green spaces in a neighborhood;
APG = area of public gardens in the neighborhood;
TA = Total area of neighborhood.

1.3.4 Ratio of Green Space per Inhabitant

The green space per capita ratio is a measure of the amount of green space available for leisure and recreation for each of the territory's residents. This ratio is expressed in square meters (m²) per inhabitant.

The World Health Organization (WHO) recommends 10 m² of green space per inhabitant in the city center (old neighborhoods) and 25 m² of green space per inhabitant on the outskirts (new neighborhoods).

The ratios of green space per inhabitant in the commune of Cocody were calculated using the formula:

$$Rgs = \frac{Ags}{PS}$$

- **Rgs** = ratio of green space per inhabitant;
- **Ags** = Area of green spaces;
- **PS** = Population size.

Downtown (Old Neighborhoods):

- **Rgs** < 10 m²: the ratio of green space per inhabitant has not been reached;
- **Rgs** ≥ 10 m²: the ratio of green space per inhabitant is reached.

Periphery (New Districts):

- Si Rev < 25 m²: the ratio of green space per inhabitant has not been reached;
- Si Rev ≥ 25 m²: the ratio of green space per inhabitant is reached.

1.3.5 Analysis of Public Garden Use

The data collected was analyzed using descriptive statistical methods. Results were presented in graphical form for ease of interpretation. The main variables analyzed included :

- Demographic characteristics: gender, age and other socio-demographic factors of visitors.
- Motivations for visiting: Identification of the main reasons why users visit public gardens, such as rest, play and aesthetics.

2. RESULTS

2.1 Spatial Distribution of Green Spaces

Cocody has a total of 42 public green spaces managed by the municipality. These spaces are divided into three categories: public gardens (including parks and squares), linear green spaces (including roadside green spaces and avenue trees) and vegetated traffic circles. These green spaces are distributed across 16 neighborhoods (Figure 2).

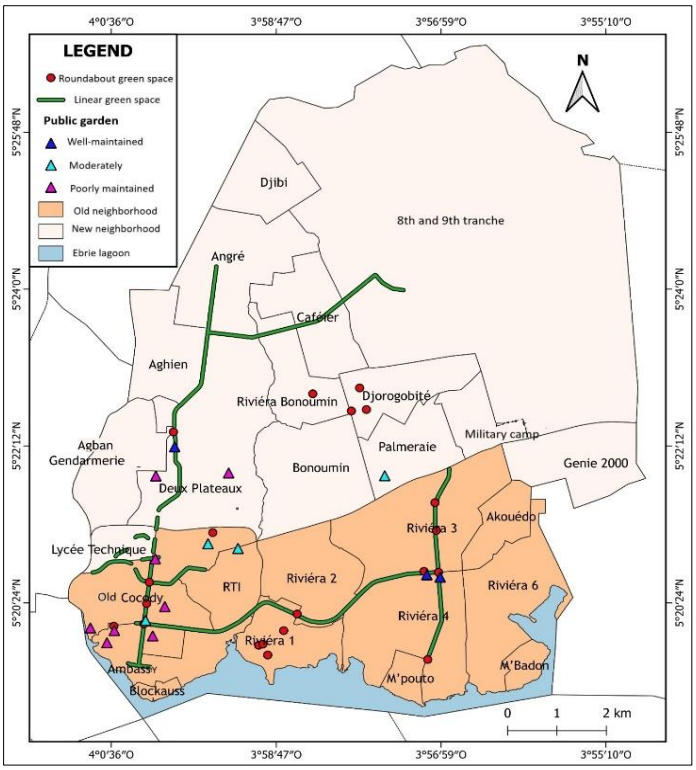

Figure 2: Map showing the distribution of green spaces in the municipality of Cocody

2.2 Recovery Rate in Public Gardens in Cocody Districts

Generally speaking, Cocody's neighborhoods have few public gardens. They cover just 3.96% of the commune's total area. The Riviera 4 district stands out with the highest rate of public garden coverage, covering 31.84% of its territory. In contrast, Riviéra 6, Akouédo, Blockauss, Bonoumin, Camp Militaire, Djibi, Gendarmerie Agban, Genie 2000, M'Badon and M'pouto have the lowest coverage of public gardens in the commune, with zero coverage rates (Figure 3).

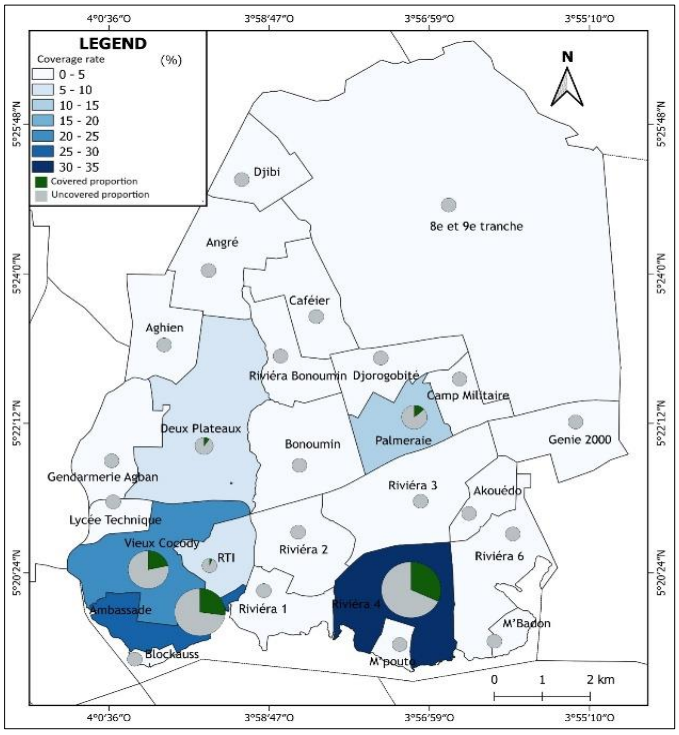

Figure 3 : Recovery rate in Cocody public gardens

2.3 Ratio Green Space per Inhabitant of Cocody Municipality

The commune of Cocody has a very limited surface area of public gardens per inhabitant, with a ratio of 0.14 m² per inhabitant. More specifically, the downtown area has a ratio of 0.44 m² per inhabitant, while the outskirts have a ratio of 0.06 m² per inhabitant. These ratios are still well below WHO recommendations.

2.4 Richness and Composition of Flora

Floristic richness is estimated at 169 plant species, divided into 146 genera and 63 families. The most important families (Figure 4) are Poaceae (17 species or 10.06%), Apocynaceae (9 species or 5.33%), Caesalpiniaceae (9 species or 5.33%) and Euphorbiaceae (9 species or 5.33%).

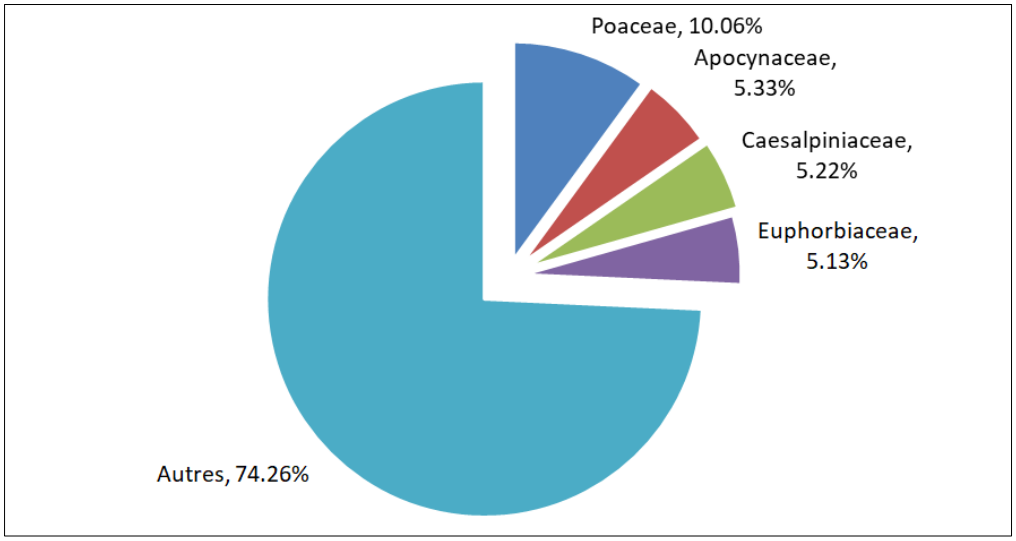

Figure 4 : species distribution per family

The biological spectrum of species inventoried in the green spaces studied highlights nine (9) biological types. Microphanerophytes dominate with 56 species (33.1%), followed by Nanophanerophytes with 50 species (29.6%), then Chamephytes with 19 species (11.2%) and Therophytes with 15 species (8.9%). Stolons are represented by just one species (0.6%) (Figure 5).

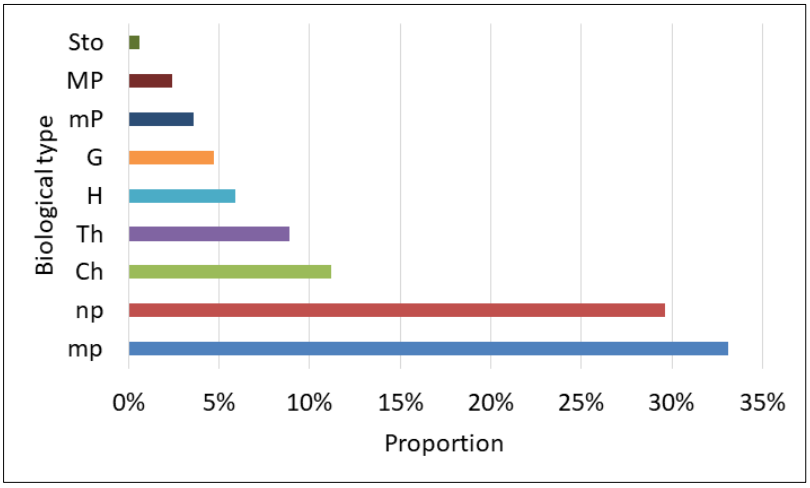

Figure 5 : Biological types of inventoried species

Legend:

Th: Therophyte; np: Nanophanerophyte (taxon whose height is between 0.25 and 2 m); mp: Microphanerophyte (taxon between 2 and 8 m high); mP: Mesophanerophyte (taxon between 8 and 32 m tall), Ch: Chamephyte; G: Geophyte; H: Hemicryptophyte; Sto: Stolon

In terms of phytogeographical distribution, introduced species (i) are in the majority, with 83 species (49.11%). In contrast, species from the Sudan-Zambezi region are the least represented, with 6 species or 3.55% (Figure 6). The other regions have representation values intermediate to these two extreme values.

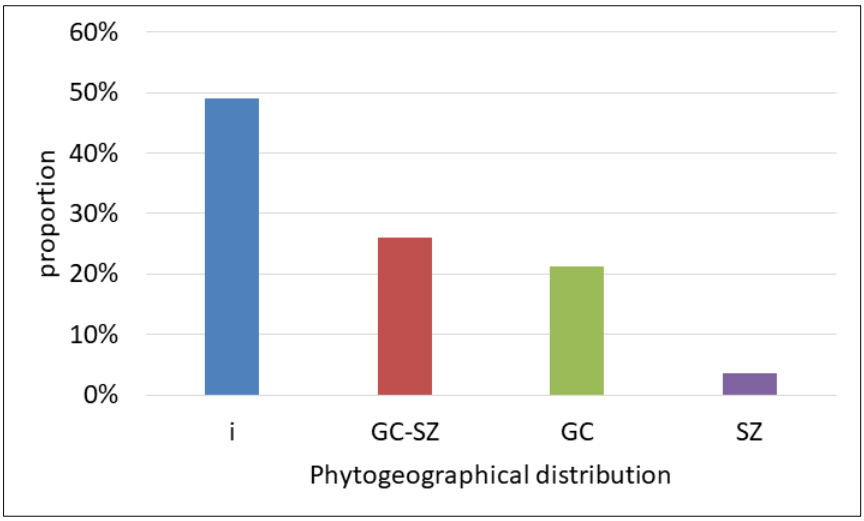

Figure 6 : Phytogeographical distribution of species

Legend:

GC: Taxon from the Guineo-Congolese region; SZ: taxon from the sudano-zambezienne region; GC-SZ: taxon from the transition zone between the Guineo-Congolese and Sudano-Zambézian regions; i: introduced exotic taxon.

2.5 Socio-Demographic Characteristics of Green Space Visitors

2.5.1 Gender of Visitors

The survey enabled us to count 104 visitors. Of those interviewed, 36.54% were women and 63.46% men. The proportion of men is higher than that of women.

2.5.2 Age of Visitors

The age of visitors to public gardens ranges from 10 to 51 years or more. Overall, the majority of visitors are aged between 10 and 20 (42.31%), followed by those in the 21 to 30 age bracket (28.85%). The smallest proportion of visitors (3.85%) are aged 51 and over.

2.5.3 Education Level

Visitors to public gardens are generally well-educated. Non-educated visitors account for just 5.77% of all visitors. In contrast, the highest proportion of visitors (94.03%) are educated. They are mostly characterized by secondary (48.08%) and higher (41.35%) education. Visitors with primary education represent 4.81% of all visitors.

2.6 Use of Green Space

2.6.1 Time Spent in Green Spaces

The length of time spent visiting public gardens ranged from less than an hour at the minimum to over 5 hours at the maximum. The proportion of people who spend time in a public garden varies from 5.77% to 68.27%. The most numerous visitors are those who spend between 1 and 2 hours on the site. Conversely, the lowest proportion of visitors is found among those who spend more than 5 hours on the site.

2.6.2 Frequency of Visits to Green Spaces

Overall, the proportions of weekly visits vary from 0.96% to 38.46%. Weekly users are the most numerous. The proportion of this group is 38.46%. The lowest proportion of visitors, 0.96%, is found among those who visit the public gardens 6 times a week. Other visitor frequencies have proportions intermediate to these two values.

2.6.3 Reasons for Visiting Green Space

The main reasons for people's visits were expressed in the following themes: inspiration, aesthetics, restoration, rendezvous, play, ceremony, rest/shade. Rest/shade is the main reason for visiting public gardens. It was cited by 48.08% of visitors questioned. It is followed by play. An estimated 25% of respondents visit for play. The lowest proportion of visitors was recorded among those whose reason for visiting was aesthetics. Only 1.92% of respondents mentioned this reason for their presence.

3. DISCUSSION

This research revealed the presence of 42 public green spaces in the Cocody commune. Compared with other studies, the flora of these spaces, estimated at 169 species, proves to be rich. Indeed, this flora is higher than that reported by Bindé (2022) in a previous study in the same commune, which mentioned 90 species. This difference could be explained by the scope of our study, which took into account all the commune's public green spaces, unlike Bindé's study, which focused on seven selected green spaces. Our results also exceed those of Kouadio *et al*., (2016), who counted 29 species divided into 20 genera and 17 families in alignment plantations in the communes of Cocody and Plateau. This difference can be explained by the fact that their study was restricted to alignment trees.

The predominance of the Apocynaceae, Euphorbiaceae and Caesalpiniaceae families in our inventory can be explained by their better adaptation to urban climatic and edaphic conditions (Merimi and Boukroute, 1996; Bekkouch *et al*., 2011; Dardour *et al*., 2013). These families not only group together the largest number of exotic ornamental species, but are also the most represented in dense tropical forests, particularly in Côte d'Ivoire (Kouamé, 1998; Adou, 2005). As far as native exotic species are concerned, the richest family is the Acanthaceae, according to Aké-Assi L. (2001).

The predominance of phanerophytes, particularly microphanerophytes and nanophanerophytes, corroborates the observations of Kouassi (2014) in the green space "Le Palmier" at the Université Félix HOUPHOUËT-BOIGNY in Cocody. The low representation of therophytes, geophytes, hemicryptophytes, chaméphytes and epiphytes is also consistent with the results of Nomel *et al*., (2020), Koné (2019), and Kouassi (2014). According to Trochain *et al.*, (1981), variations in the proportions of biological types are linked to the ecology of the regions where the vegetation types were inventoried. Also, in the urban context, vegetation is strongly influenced by man. The choice of species is therefore linked to their use and the role they are expected to play. Phanerophytes are generally favored for their ability to grow tall and provide shade, an important criterion for visitors seeking rest areas.

The preponderance of exotic species in the gardens studied can be explained by the fact that planners limit urban vegetation to mere decoration, although this trend is changing these days (Clergeau, 2007). In fact, the diversity of colors in their foliage and flowers makes these species highly prized by landscapers. Thus, the search for aesthetic appeal has a strong influence on the choice of species.

This study shows that the number of green spaces in Cocody is insufficient, and varies considerably from one district to another. The commune's coverage rate for public green spaces is just 3.96%. The ratio of surface area per inhabitant is 0.14 m², with 0.44 m² per inhabitant for the town center and 0.06 m² per inhabitant for the outskirts. These values remain well below the standards set by the World Health Organization, which are 10 m² per inhabitant for the city center and 25 m² per inhabitant for the suburbs. This situation could be explained by the fact that municipalities lack the financial resources to develop and manage more green spaces. This observation has already been made by Kassay (2010). Moreover, in developed countries where public green spaces are taken into account as an urban amenity, some cities stand out by meeting or even exceeding these standards, thereby guaranteeing the well-being of city dwellers. For example, with 211 m² of green space per inhabitant, Besançon is recognized as one of France's leading green cities. Tours and Strasbourg offer over 100 m² of green space per inhabitant, well above the national average of 48 m².

The vast majority of visitors to green spaces say they come to enjoy a moment of rest and tranquillity. These spaces seem to offer a peaceful, quiet and unhurried environment. Indeed, by acting as a screen against noise, urban vegetation enables people to isolate themselves from this scourge and thus evacuate urban stress. This observation corroborates the work of Ulrich (1986), Parsons *et al*., (1998), Kuo (2001), Guite *et al*., (2006) and McPherson *et al*., (2007).

4. CONCLUSION

The study revealed the presence of 42 public green spaces in 16 of the 26 districts of the Cocody commune. In these spaces, 169 plant species were identified, belonging to 146 genera and 63 families. The RTI district has the highest rate of green space coverage, while several other districts have none at all. In terms of the area of green space available per inhabitant, the analysis shows that Cocody has a very limited surface area of public gardens, with a ratio of 0.14 m² of public green space per inhabitant. More specifically, the downtown area (old districts) has a ratio of 0.44 m² per inhabitant, compared with just 0.06 m² per inhabitant in the outlying areas (new districts). These figures remain well below the standards recommended by the WHO. Inhabitants mainly use these green spaces to rest, taking advantage of the shade they offer. This information will enable us to guide the development of green spaces in Cocody more effectively.

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