ISSN: 3029-0724

Research Article

Journal of Environmental Science and Agricultural Research

Collection and Analysis of Data on Plant Diversity and Tree Carbon Stocks in Urban Areas in Cameroon: The Cases of Biyem-Assi South-West and Elig-Efffa West

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Received: October 14, 2025; **Accepted:** October 23, 2025; **Published:** October 29, 2025

ABSTRACT
In Cameroonian cities, urban trees play a vital role in the well-being of residents but face increasing pressure from urbanization. Effective reforestation should prioritize species with high carbon sequestration potential and strong social acceptance. This study, conducted in Biyem-Assi South-West and Elig-Effa West within the Yaoundé 6 municipality, assesses tree species diversity and carbon stock in urban areas. Floristic inventories were carried out using systematic surveys and quadrats, identifying 234 woody individuals across 20 species and 14 families, with Mangifera indica being the most dominant. Diversity indices (Shannon (2.65), Pielou (0.86), and Simpson (0.89)) indicate moderate diversity, with a relatively balanced distribution but dominance by a few species. Carbon stock, estimated through allometric equations, reached 16.08 tC over 68.9 ha in Elig-Effa (0.2334 tC/ha) and 20.10 tC over 69 ha in Biyem-Assi (0.2792 tC/ha). Most species are fruit trees, though the forest species Alstonia boonei is also well tolerated. The low levels of sequestered carbon are attributed to the limited tree density. This study offers strategic guidance for urban reforestation in Cameroon by identifying species best suited to local ecological and social conditions.

Keywords: Data collection, Carbon Stock, Phytodiversity, Tree Structure, Urban

Introduction

Rapid urbanization is now a major challenge for territorial sustainability, especially in developing countries. This process, driven by accelerated infrastructure expansion and sustained urban population growth, leads to profound spatial, social, and environmental transformations [1]. In 2022, over half of the world's 8 billion inhabitants lived in cities approximately 4.4 billion and this figure is projected to reach 1.4 billion in Africa by 2050 [2-4].

Although cities occupy only 5% of the Earth's surface, they consume 66% of global energy and generate 75% of greenhouse gas emissions [5,6]. They are thus both contributors to ecological crises and key actors in climate regulation and biodiversity preservation. Urban green spaces (parks, gardens, tree alignments) provide essential ecosystem services such as carbon sequestration, thermal regulation, air purification, stormwater management, heat island mitigation, and biodiversity support [7-9]. However, this dynamic remains marginal in Cameroon, where urban planning still gives limited attention to vegetation despite growing ecological concerns and human pressure on natural environments.

Citation: Tchomcheni AJ, Kenfack Voukeng SN, Tumenta PF, Amougou Manga LF, Ghogue JP. Collection and Analysis of Data on Plant Diversity and Tree Carbon Stocks in Urban Areas in Cameroon: The Cases of Biyem-Assi South-West and Elig-Efffa West. J Envi Sci Agri Res. 2025. 3(5): 1-6.
DOI: doi.org/10.61440/JESAR.2025.v3.99

Since the 1990s, structural adjustment programs in Cameroon have led to a gradual withdrawal of the state from urban planning, resulting in chaotic urbanization and fragmented urban fabric [10]. This trend, fueled by rapid demographic growth, puts significant pressure on vegetation cover, causing deforestation, biodiversity loss, and reduced ecosystem services [11].

Yaoundé exemplifies this evolution. Its population grew from 58,000 in 1958 to over 3.5 million in 2023, with an average annual growth rate of 4.97% [12,13]. Over two decades, its urban area expanded fivefold to nearly 468 km², while green space coverage dropped from 28.6% to just 5.4% [14,15]. Today, about 67% of residents live in precarious neighborhoods, often lacking vegetation, such as Biyem-Assi—once planned, now marked by spontaneous and unregulated urbanization [16].

In response to habitat fragmentation, multiple forms of pollution, soil artificialization, and invasive species, strengthening urban resilience has become an urgent necessity [17-20]. This involves integrating green infrastructure (retention basins, ecological corridors, green roofs) and implementing targeted reforestation policies based on accurate data on tree species and their carbon sequestration potential.

While the social benefits of urban vegetation are well documented, its physical effects—especially in climate regulation and air purification—remain understudied in the African context. Most research on these ecological functions has been conducted in North America, Europe, and Asia, leaving a scientific gap regarding the role of urban trees in African cities [21-24].

This study builds on preliminary work by Tchomcheni et al., titled Assessment of Plant Diversity and Carbon Stock in an Informal Neighborhood of Yaoundé, Cameroon: The Case of Elig-Effa West [20]. Its general aim is to contribute to the evaluation of carbon sequestered by preserved or planted trees in densely populated urban areas, to guide sustainable reforestation policies and strengthen ecological resilience in cities.

To achieve this, the study expands its scope to two neighborhoods in Yaoundé 6 (Biyem-Assi South-West and Elig-Effa West). These areas, representative of African urban peripheries, are characterized by uncontrolled urbanization and significant vegetation loss. Specifically, the objectives are to :

- Inventory the woody species present in these neighborhoods;
- Assess floristic diversity indices ;
- Estimate the carbon stocks sequestered by the identified trees.

Materials and Methods

Study Area

The district of Yaoundé VI, located in the Mfoundi department at the heart of the Centre region, is one of the seven municipal districts that make up the political capital of Cameroon. Established by Presidential Decree No. 93/312 of November 25, 1993, it covers an area of approximately 22.2 km² and includes several neighborhoods, among which Biyem-Assi Southwest and Elig-Effa West are the focus areas of this study [25]. Biyem-Assi Southwest spans 32 hectares and is bounded by the Kribi road to the north, Biyem-Assi Avenue to the south, the Biyeme River to the east, and Mvolyé Avenue to the west (Figure1). Elig-Effa West, also located within Yaoundé VI, covers 68.9 hectares and is bordered by Cité Verte to the north, Obili to the south, Melen to the east, and Mvog-Betsi to the west (Figure 2).

Both neighborhoods share a similar climate equatorial with altitudinal influence characterized by an average temperature of 24°C and annual rainfall ranging between 1,500 and 2,000 mm. Biyem-Assi experiences four seasons: two dry and two rainy, while Elig-Effa has three distinct seasons: a long dry season (December to March), a short dry season (May to August), and a long rainy season (August to November). Hydrologically, Biyem-Assi is crossed by the Biyeme River, which originates in Etoug-Ebé and flows into the Mfoundi River [26]. Elig-Effa is traversed by the Ntougou River, which separates Mvog-Ekoussou from Mokolo and causes seasonal flooding that benefits market gardening. A natural spring, though degraded, is still used as a source of drinking water.

The terrain in Biyem-Assi features alternating steep slopes and valleys, with red ferralitic soils that are poorly permeable, and swelling clays in low-lying areas that retain moisture during the rainy season [27]. As in Elig-Effa, intense urbanization has led to the disappearance of native vegetation, replaced by artificial flora dominated by fruit-bearing species such as mango, avocado, guava, and papaya trees. Elig-Effa is home to approximately 13,000 residents, primarily from the Beti ethnic group, later joined after 1960 by other communities including the Bamileke, Bassa, and Hausa.

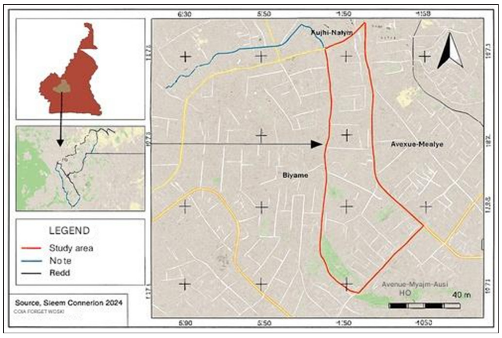

Figure 1: Location map of the Biyem-Assi South-West district

Data Collection

Floristic Inventory

In Biyem-Assi South-West, the inventory of woody vegetation was conducted using a systematic approach based on the existing road network. Each sub-neighborhood was mapped using Google Maps, allowing surveyors to navigate starting from the main axis. Every tree encountered was recorded with its species name, height, and diameter at breast height (DBH, measured at 1.30 m above ground). Specimens that could not be identified in the field (leaves, flowers, fruits) were collected and sent to the National Herbarium of Yaoundé for further identification [20]. All individuals were georeferenced and documented in collection sheets.

In Elig-Effa West, the inventory followed the quadrat method, recognized for its scientific rigor in vegetation studies [28]. Six plots of 10,000 m² were evenly distributed across the site to cover the main biotopes and ensure ecological representativeness. Within each plot, every tree was recorded with its species name, height, and DBH (measured at 1.30 m above ground).

The relative frequency (RF) of species was calculated using the formula: RF = (Number of subplots where the species is present / Total number of subplots) × 100 [29].

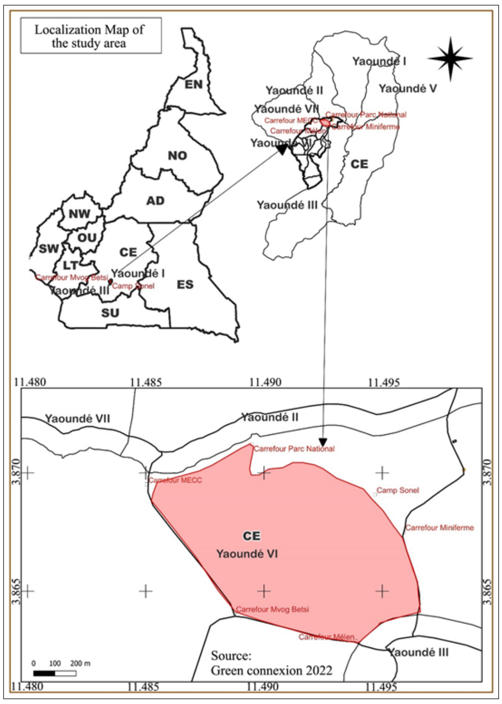

Figure 2: Location map of the Elig-Effa West district

Diversity Indices Evaluation

Species diversity was assessed using the following indices:

- Shannon Index (H'): Calculated as H' = - Σ (Ni/N) $\log_2$ (Ni/N), where Ni is the number of individuals of species i and N is the total number of individuals [30]. This index combines species richness and relative abundance to quantify floristic diversity.
- Pielou's Evenness Index (E): Calculated as E = H' / H'max, where H' is the Shannon index and H'max is the theoretical maximum [31]. It reflects how evenly individuals are distributed among species.
- Simpson's Index (D): Calculated as D = 1 - Σ $(Ni/N)^2$ [32]. A value close to 0 indicates high diversity, while a value near 1 suggests low diversity.

Carbon Stock Estimation

Tree carbon stocks were estimated using allometric equations applied to field data:

- Above-Ground Biomass (AGB): AGB = 0.0673 × $(\rho D^2 H)^{0.976}$, where AGB is in kilograms, ρ is wood density (g/cm³), D is DBH (cm), and H is tree height (m) [33].
- Below-Ground Biomass (BGB): The below-ground biomass is estimated using the formula BGB = AGB × R, where R is the root-to-shoot ratio, set at 0.24 according to IPCC guidelines [34].
- Total Biomass (TB): TB = AGB + BGB, expressed in tonnes.
- Carbon Stock (C): C = TB × 0.47, using a conversion factor of 0.47 [35].

Results

Floristic Inventory

- **Species Composition**

A total of 234 woody individuals with a diameter at breast height (DBH) ≥ 10 cm were recorded, representing 20 species, 19 genera, and 14 families.

The most represented species were Mangifera indica (61 individuals), Persea americana (37), Psidium guajava (29), Dacryodes edulis (21), and Annona muricata (17) (Figure 3).

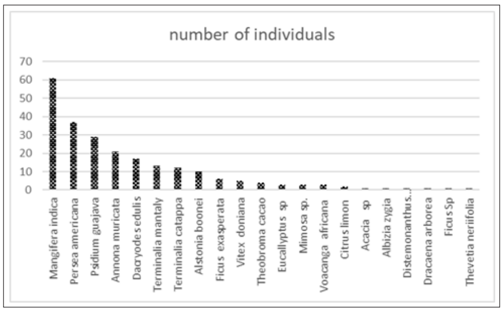

Figure 3: Distribution of individuals by plant species

The most represented families in terms of species richness included Apocynaceae (14%), followed by Combretaceae, Fabaceae, Lamiaceae, Mylvaceae, Mimosaceae, Moraceae, and Myrtaceae, each contributing 9% (Figure 4).

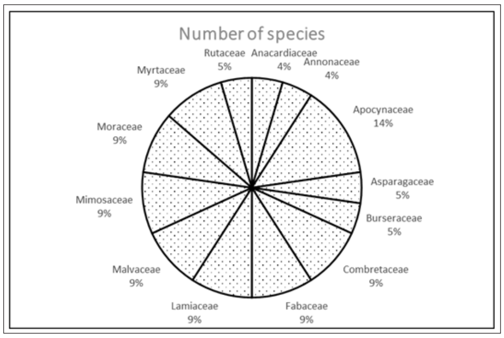

Figure 4: Representation of families according to the number of species

Diversity Indices

Species diversity was assessed using three ecological indices.

The Shannon index was 2.65, indicating moderate diversity with dominance by a few species.

Pielou's evenness index was 0.86, suggesting a relatively balanced distribution of individuals among species.

Simpson's index was 0.89, reflecting high overall diversity. These values are summarized below:

Table 1: Floristic Diversity Parameters

Index	Estimated Value	95% Confidence Interval
Shannon (H′)	2.65 ± 0.15	[2.50 – 2.80]
Simpson (D)	0.89 ± 0.03	[0.86 – 0.92]
Pielou's Evenness (E)	0.86 ± 0.05	[0.80 – 0.90]

Carbon Stock Estimation

Overall, the total carbon stock sequestered by trees in the surveyed areas of Yaoundé VI Subdivision amounts to 38.991 tonnes of carbon (tC), with an average of 0.386 tC/ha. In Elig-Effa West, the estimated stock is 18.095 tC across 68.9 hectares, while in Biyem-Assi South-West, it reaches 20.896 tC over 32 hectares.

Carbon stock per species varies significantly, ranging from 0.012 tC to 21.588 tC. The species with the highest carbon sequestration potential are Mangifera indica (21.588 tC), followed by Persea americana (4.378 tC) and Terminalia mantaly (1.961 tC) (Table 2).

Table 2: Summary of Carbon Stocks by Species

Species	Carbon stocks (tC)
Mangifera indica	21,588
Persea americana	4,378
Terminalia mantaly	1,961
Vitex doniana	1,683
Annona muricata	1,615
Dacryodes edulis	1,512
Voacanga africana	1,202
Psidium guajava	0,999
Distemonanthus benthamianus	0,735
Terminalia catappa	0,692
Ficus exasperata	0,685
Alstonia boonei	0,662
Theobroma cacao	0,285
Dracaena arborea	0,241
Eucallyptus sp	0,228
Ficus Sp	0,186
Albizia zygia	0,146
Acacia sp	0,132
Mimosa sp.	0,035
Citrus limon	0,015
Thevetia neriifolia	0,012

Among the botanical families identified, Anacardiaceae holds the highest carbon stock, with 21.588 tonnes of carbon (tC). It is followed by Lauraceae, with 4.378 tC, and Combretaceae, with 2.654 tC (Figure 5).

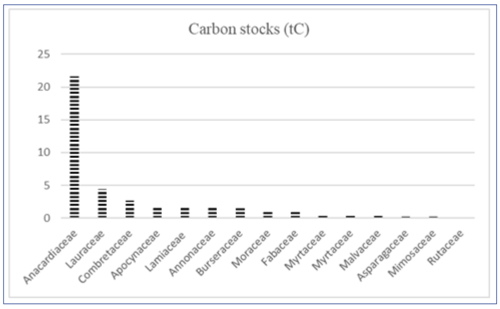

Figure 5: Distribution of carbon stocks by plant family

The carbon stock distribution curve by diameter class reveals that the [70-80 [range concentrates the majority of the stock, totaling 7.186 tC (Figure 6).

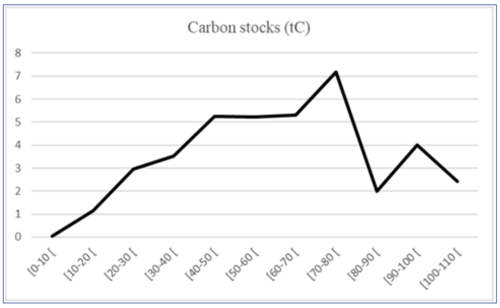

Figure 6: Carb stock curve by diameter class

Discussion

Floristic Inventory

The inventory conducted recorded 234 woody individuals with a DBH ≥ 10 cm, distributed across 20 species, 19 genera, and 14 families. The most frequent species were Mangifera indica (26%), Persea americana (16%), Psidium guajava (13%), Dacryodes edulis (9%), and Annona muricata (7%). These results reflect a strong presence of fruit-bearing species, often planted for their nutritional and economic value in urban environments. The study by Tchomcheni et al., carried out in a similar urban context, also highlighted the predominance of fruit species in the floristic composition. Mangifera indica, Psidium guajava, and Dacryodes edulis were among the most represented species, confirming their central role in urban planning practices and ethnobotanical uses [20].

The recorded taxonomic diversity, encompassing 14 botanical families, aligns with findings reported by Diop et al. in their study of woody species biodiversity across Sahelian and urban contexts [36]. These authors also highlighted the strong representation of the Apocynaceae, Fabaceae, Moraceae, and Myrtaceae families, which supports the trends observed in the present work.

Evaluation of diversity indices

The calculated Shannon index (H′ = 2.65), which falls below the threshold of 3 typically associated with high diversity, indicates moderate species diversity. This reflects a plant community dominated by a few species, notably Mangifera indica and Persea americana. A similar result was reported by Tchomcheni et al., who recorded a Shannon index of 2.58 in an urban district of Yaoundé, also highlighting limited species richness dominated by fruit-bearing trees [20].

The Pielou's evenness index (E = 0.86), close to the maximum value of 1, suggests a relatively balanced distribution of individuals among species, despite the dominance of a few. This level of evenness reflects good structural equity within the plant community. Comparable values were observed by Zergoun in the M'Zab Valley (E ≈ 0.85), indicating a stable species distribution in anthropized environments [37].

The Simpson diversity index (D = 0.89) indicates a high probability that two randomly selected individuals belong to different species. This value, very close to 1, reveals substantial diversity despite the dominance of certain taxa. This result is consistent with findings by Diop et al. (2021) on woody biodiversity in West Africa, where Simpson values above 0.85 were recorded in urban areas with dense vegetation cover.

Carbon Stock Estimation

The total carbon stock estimated in the surveyed areas of Yaoundé VI Subdivision amounts to 38.991 tonnes of carbon (tC), with an average of 0.386 tC/ha. This relatively modest level reflects the typical characteristics of sparsely wooded urban environments, were fragmented green spaces and low tree density limit carbon sequestration capacity. In comparison, more densely vegetated environments show significantly higher performance. For instance, in the sacred forest of Kouoghap (Western Cameroon), Chimi et al. recorded carbon stocks of up to 70.2 tC/ha in Eucalyptus plantations and 45.6 tC/ha in live hedges, illustrating the high potential of structured forested systems. Conversely, some urban areas can demonstrate remarkable performance [38]. This is the case of Biyem-Assi South-West, which stands out with 20.896 tC over 32 hectares, yielding an average of 0.653 tC/ha. This value, higher than the overall average for Yaoundé VI, is likely due to a greater concentration of mature trees and more effective urban vegetation management.

In both studies conducted in Yaoundé, Mangifera indica stands out as the species with the highest carbon sequestration potential. In the present survey, it accounts for a total of 21.588 (tC), making it the most significant contributor to the overall carbon stock in the Yaoundé VI subdivision. This predominance is corroborated by the findings of Tchomcheni et al. (2023), who also identified Mangifera indica among the leading sequestration species, alongside Persea americana and Dacryodes edulis. However, the absolute values reported in their study are comparatively lower, which can be attributed to a smaller survey area and a relatively low vegetation density in the Elig-Effa West neighborhood.

The Anacardiaceae family overwhelmingly dominates the carbon stock in the surveyed areas, with a total of 21.588 tC, followed by the Lauraceae (4.378 tC) and the Combretaceae (2.654 tC). These results align with the findings of Diop et al. (2021), who highlighted the strong representation of fruit-bearing and ornamental plant families in Sahelian urban zones, largely due to their utilitarian and aesthetic value to local populations. The predominance of Anacardiaceae, which includes species such as Mangifera indica and Anacardium occidentale, clearly illustrates this trend, as does the notable presence of Lauraceae, often associated with evergreen ornamental species.

In Yaoundé VI, the [70–80 mm] diameter class accounts for the largest share of the carbon stock, totaling 7.186 tC. This dominance reflects a significant presence of mature trees, indicative of a relatively well-established vegetation structure. In contrast, Tchomcheni et al. observed a predominance of the [30–50 mm] diameter classes in the Elig-Effa West neighborhood, revealing a younger or less developed vegetation profile, typical of informal urban areas or zones undergoing densification [20].

Conclusion

Urban areas, in constant expansion, represent both a major challenge for managing carbon emissions and a strategic opportunity to strengthen ecological resilience through vegetation. The findings from the neighborhoods of Elig-Effa West and Biyem-Assi South-West, located in Yaoundé VI Subdivision, clearly illustrate this duality. In Elig-Effa West, the total estimated carbon stock is 18.095 tonnes over 68.9 hectares, averaging 0.263 tC/ha, while in Biyem-Assi South-West, it reaches 20.896 tonnes over 32 hectares, with a higher average density of 0.653 tC/ha. This difference reflects a greater concentration of mature trees and a more developed vegetation structure in Biyem-Assi. In both neighborhoods, fruit tree species such as Mangifera indica, Persea americana, and Dacryodes edulis stand out for their high sequestration potential, confirming their strategic role in urban greening policies. Mangifera indica, in particular, proves to be the most significant contributor, with 21.588 tonnes of carbon recorded across Yaoundé VI alone. Although the estimates are based on indirect methods and limited sampling, they provide a valuable reference baseline for future research on carbon sequestration in informal urban settings. They also highlight the need to preserve, enhance, and strengthen existing tree populations, whether established through public initiatives or private efforts. In the absence of standardized protocols for directly measuring CO_2 uptake by urban trees, these results offer a solid foundation for developing reference emission scenarios and for effectively integrating vegetation into sustainable urban planning and climate change mitigation strategies.

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