IKR Publishers

IKR Journal of Agriculture and Biosciences
(IKRJAB)
Journal homepage: https://ikrpublishers.com/ikrjab/
Volume-1, Issue-4 (November-December) 2025

OPEN ACCESS
ISSN: 3107-5509 (Online)

Roadside Trees in the City of Yamoussoukro (Central Côte d'Ivoire): The Case of the N'Zuessi and Millionnaire Neighbourhoods

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DOI:*10.5281/zenodo.17862296*

ARTICLE INFO

Article history:
Received : 07-10-2025
Accepted : 09-11-2025
Available online : 08-12-2025

Citation: Nomel, G. J. R., Ambé, A. S. A., Kouadio, V.-P. G., & Kouassi, R. H. (2025). Roadside Trees in the City of Yamoussoukro (Central Côte d'Ivoire): The Case of the N'Zuessi and Millionnaire Neighbourhoods. *IKR Journal of Agriculture and Biosciences (IKRJAB)*, 1(4), 255-260.

ABSTRACT **Original Research Article**

The neighbourhoods of the city of Yamoussoukro in Côte d'Ivoire are densely populated with trees lining all roads. The aim of this study is to assess the diversity and carbon stock of trees in the Millionnaires and N'Zuessi neighbourhoods. To do this, an inventory of plant species was carried out using the itinerant survey method, and then we measured the height and DBH ≥ 2.5 cm of the trees. The biomass of individuals converted into carbon stock was estimated using allometric equations adapted to the urban environment. The area covered by trees along roadsides in both neighbourhoods has been estimated at 7.98 hectares. The results showed that these neighbourhoods are home to 30 species, comprising 1,900 individuals. The species *Terminalia mantaly* has the largest number, with 974 individuals. Exotic species are the most commonly planted, with 22 species, or 73% of the total. The total carbon stock is 1,365.01 tonnes, or 171.05 tonnes/hectare, with Terminalia mantaly containing the largest stock (104.02 tonnes/hectare). Trees therefore contribute to the reduction of greenhouse gases and deserve to be further developed in Africa.

Keywords: Roadside Trees, Carbon Stock, Côte d'Ivoire, Plant Diversity, Yamoussoukro.

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Introduction

Along main roads and sometimes in certain neighbourhoods of some cities, there are trees. All of these trees located along roadsides are called roadsides trees or roadsides plantings (Kouadio et al., 2016). This vegetation formation is one of the most important elements of the urban green network. It is very common in Western cities such as Paris (Reverdy, G., 1997; APUR, 2010), Alençon (Service des espaces verts, 2003), Copenhagen (Nilsson and Randrup, 1997), Strasbourg (CEP-CDPATEP, 2009), etc. These trees are not planted at random but are rigorously selected to meet specific needs. Planted at regular intervals, they offer a pleasant view of the city (Portero, G., 2018), shade during heatwaves (CDPNE, 2015), etc. As a result, roadsides trees have become an integral aesthetic component of the urban landscape.

In Africa, this practice only really began to develop in the 2000s and 2010s. These trees planted along roadsides are sometimes planted at regular intervals. These rows of trees are planted by local councils wishing to improve the living environment. Sometimes, the population or certain residents plant the trees themselves along roadsides to enjoy the benefits associated with their presence (Gomido, KX., 2012;Nomel et al., 2019).

In Côte d'Ivoire, two cities have real tree-lined avenues: Abidjan and Yamoussoukro, which are respectively the economic and political capitals. In Abidjan, these are the municipalities of Plateau, the business centre, and Cocody (Kouadioet al., 2016). In Yamoussoukro, all the streets in all neighbourhoods are lined with trees (Nomelet al., 2020). This is the case in the 220 or N'Zuessi neighbourhood, which is one of the oldest neighbourhoods in the city, and in the Millionaire neighbourhood, which, as its name suggests, is the most upmarket neighbourhood in the city with its luxury houses and flower-filled gardens. However, as in other neighbourhoods such as Assabou and Dioulakro, there has been a reduction in the number of trees due to road widening and the uncontrolled removal of various parts of trees by the population, slowly leading to their death. This results in a decrease in the carbon sequestration capacity of this urban forest, which is important in the fight against greenhouse gases. This study therefore aims to characterise the roadside trees in these two neighbourhoods. Specifically, it seeks to assess plant diversity and estimate the carbon stock of roadside trees in the N'Zuessi and Millionnaire neighbourhoods of the city of Yamoussoukro.

Methodology

• Study Area

This study was conducted in the city of Yamoussoukro, the political and administrative capital of Côte d'Ivoire. Yamoussoukro comprises 14 neighbourhoods, including N'Zuessi, one of the oldest neighbourhoods, and Millionnaire, the city's most affluent neighbourhood (Nomelet al., 2019). These neighbourhoods have many trees lining all the roads. The city's climate is humid tropical transitional, characterised by two seasons: a long rainy season and a short dry season. Daytime temperatures are generally above 30°C and can even reach 35°C.

• Materials

- Inventory sheets.
- GPS for recording the geographical coordinates of trees in rows so that they can be plotted on a map.
- Measuring tape for measuring tree circumference.
- Camera for taking photographs.
- Interlocking stakes, each 3 meters long, for measuring tree height.

• Data collection

To achieve these objectives, an inventory was carried out using the itinerant method in the N'Zuessi and Millionnaires neighbourhoods, which have tree-lined streets. This method involved recording all the species identified while walking through a study area in all directions. All the trees lining the streets in the two neighbourhoods cover an area of 7.98 ha (Millionnaire: 2.65 ha; N'Zuessi: 5.33 ha). The coordinates of all the trees lining the streets were recorded so that they could be plotted on a map (Figure 1).

Figure 1: Location of avenue trees in the Millionnaires and N'Zuessi neighbourhoods of the city of Yamoussoukro

To measure carbon stocks based on biomass, DBH ≥ 2.5 cm measurements were taken. This minimum DBH allows for the inclusion of trees mature enough to store a significant amount of atmospheric carbon and to measure the height of palm trees and coconut trees, we used 3-metre-long interlocking stakes, which enabled us to estimate their height.

- **Data analysis**

This inventory enabled us to determine the richness and composition of the flora based on the work of Aké-Assi, L., (2001; 2002) and Raunkier, C., (1934). The origin of species (exotic and local) was made possible thanks to the list published by White, F., (1993) on the phytogeographical distribution of species.

To measure carbon stocks, we first calculated biomass using urban allometric equations known as UGES (Urban General Equations) established by Aguaron and McPherson (2012). Carbon stocks were then estimated by multiplying biomass by 0.5, in accordance with IPCC (2006) guidelines.

Results

The inventory identified 30 species divided into 23 genera and 16 families. The family with the greatest number of species is Fabaceae, with 8 species, or 26.66%. It is followed by Moraceae and Myrtaceae, with 3 species each, or 10%. In terms of species origin, the majority are exotic, with 22 species, or 73%. Local species account for only 27%, or 8 species. The total number of individuals is 1,900, lining the roads of the Millionnaire and N'Zuessi neighbourhoods (Table 1). The species *Terminalia mantaly*, *Ficus benjamina*, *Peltophorum pterocarpum* and *Ficus polita* have the highest numbers of individuals with 974 individuals (51.26% of individuals), 208 individuals (10.94% of individuals), 155 individuals (8.15% of individuals) and 142 individuals (7.47% of individuals) respectively.

Table 1: Summary of specific richness and composition

Neighbourhoods	Species	Families	Individuals	Individuals ≥2,5 cm	Origin of species	
					Local	Exotic
Millionnaire	24	13	650	628	6	18
N'Zuessi	16	11	1250	1250	3	13
Total	30	16	1900	1878	8	22

The maximum dbh of the trees surveyed is 162.1 cm (or 509 cm in circumference). The distribution of diameter classes shows that the classes with more than 500 individuals are the classes]30;40],]40;50] and]50;60], with a peak in the class]50;60], which contains the largest number of individuals, namely 587. The class]60;70] is a class that contains between 400 and 500 individuals. The class that contains between 300 and 400 individuals is the class]20;30]. The class]10;20] has between 200 and 300 individuals. The classes [2.5;5], [5;10], [70;80], [80;90], [90;100] and [100; [have fewer than 100 individuals, with the class [2.5;5] having the smallest number, i.e., 14 individuals. When we look at each neighbourhood individually, we see that the number of individuals per diameter class is higher in the N'Zuessi neighbourhood than in the Millionaire neighbourhood, with the exception of classes [2.5;5], [20 ;30] and [80 ;90], where the number of individuals is roughly the same in both neighbourhoods (Figure 2). Also, in Millionnaire, the diameter class with the highest number of individuals is the class [20 ;30] with 119 individuals, while the classes with the lowest number of individuals are the classes [2.5;5] and [5 ;10] with 4 individuals each. In the N'Zuessi neighbourhood, the class]50 ;60] has the largest number of individuals with 304 individuals. The class [2.5;5] has the smallest number of individuals (3 individuals) (Figure 2).

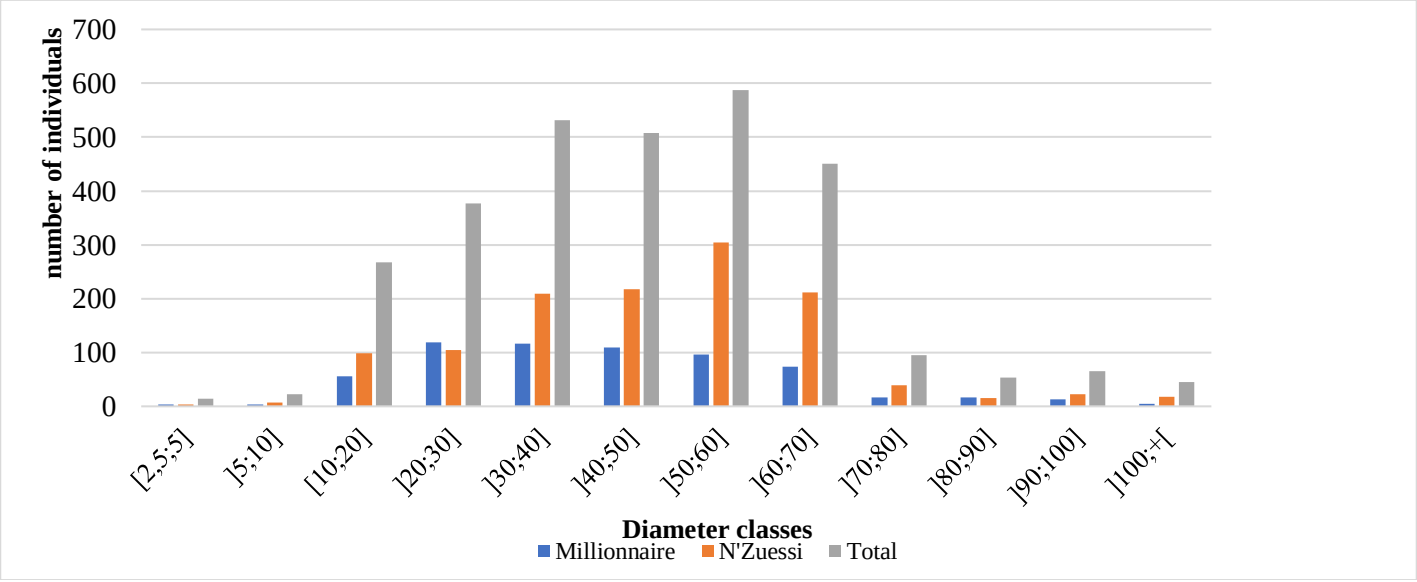

Figure 2: Representation of the number of individuals counted by diameter class

The total dry biomass of the trees lining the streets in the Millionaire and N'Zuessi neighbourhoods is 2,730.02 tonnes, or 342.1 tonnes per hectare. The equivalent carbon stock is 1.365.01 tonnes, or 171.05 tonnes per hectare. The trees in the N'Zuessi neighbourhood capture more carbon than those in the Millionaire neighbourhood. Their values are 902.85 tonnes, or 169.39 tonnes/ha, and 462.15 tonnes, or 174.39 tonnes/ha, respectively (Table 2).

In terms of plant species across both neighbourhoods, the most important species in terms of carbon stock are *Terminalia mantaly* (104.02 t/ha), *Ficus benjamina* (24 t/ha) and *Peltophorum pterocarpum* (19.24 t/ha). This trend in plant species carbon stock is also observed when each neighbourhood is considered individually (Table 2).

Table 2: Summary of biomass and carbon stock of trees in the two neighbourhoods

	Total	Neighbourhoods	Plant species
Biomass (t/ha)	342.1	Millionnaire (348.78)	*Terminalia mantaly* (97.1)
			Ficus benjamina(71.71)
			Peltophorum pterocarpum (44.06)
		N'Zuessi (338.78)	*Terminalia mantaly* (263.2)
			Ficus benjamina (36.22)
			Peltophorum pterocarpum (35.7)
Carbon stock (tC/ha)	171.05	Millionnaire (174.39)	*Terminalia mantaly* (48.55)
			Ficus benjamina (35.85)
			Peltophorum pterocarpum (22.03)
		N'Zuessi (169.39)	*Terminalia mantaly* (131.6)
			Ficus benjamina (18.11)
			Peltophorum pterocarpum (17.85)

Discussion

• Plant Diversity

Although the number of trees in the city of Yamoussoukro has declined, it remains relatively high in certain neighbourhoods such as Millionnaire and N'Zuessi. The N'Zuessi neighbourhood has a higher number of trees than the Millionnaire neighbourhood. This could be explained by the fact that N'Zuessi is larger than Millionnaire (twice the size of Millionnaire). This means that there are more tree-lined streets in the N'Zuessi neighbourhood than in the Millionnaire neighbourhood. It is with this in mind that researchers such as Nowak et al. (2008) and Riboulot-Chetrit, M., (2015) argue that there is a link between the size of the area occupied by trees and their number. Indeed, the larger the area, the higher their number, although this is not always the case when considering species that are more prevalent in the Millionaire neighbourhood than in the N'Zuessi neighbourhood. This contrast in species can be explained by the fact that Millionaire is the most upmarket neighbourhood in the city, and the desired variety of species makes the neighbourhood more "chic" and roughly corresponds to the standard of upmarket neighbourhoods. Hence the consideration of surface area and the desired effect when comparing the number of individuals and species in a given area.

In terms of families, Fabaceae is the most important. This large family includes three subfamilies, namely Papilionaceae, Mimosaceae and Caesalpiniaceae, making it a super family that encompasses numerous plant species and, by extension, numerous individuals. Fabaceae are found on every continent and grow in a variety of soils, even poor ones. In fact, species in this family do not need fertiliser. Their roots have special cells (nodules) that harbour bacteria which capture nitrogen from the air and thus enrich the soil (Giraud, E., 2007; Amicale des jardiniers du Puy-Mézier, 2015). Furthermore, according to Aké-Assi E. et al.(2010), this family includes species whose individuals provide a large amount of shade when they reach a certaine size.

The *Terminalia mantaly* species has by far the largest number of individuals. This can be explained by the fact that this species has foliage with horizontal, shelf-like branches that spread out and provide shade (Deas and Sansoni, 2024).According to these authors, it is a tree that improves the fertility of difficult soils that are either very wet or very dry. *Terminalia mantaly* is a versatile species, well suited to dry, windy tropical conditions and poor or degraded soils. It prefers areas with good sun exposure and can tolerate a wide range of soil conditions.

• Origin of Species

Most of the trees planted are exotic species. These exotic species, which come from various backgrounds, are captivating due to the variety of colours of their foliage, shapes and flowers (Fomell, CT., 2003). Another reason for their high rate is that these exotic species have extraordinary adaptability and rapid growth capacity (Nowak, DJ., 1994; Dieng et al., 2019). Among the predominant species, particularly in the N'Zuessi neighbourhood, the presence of Ficus polita is due to the population's particular fondness for it, according to a study conducted by Kouassi et al. (2019). A fast-growing species, it develops large, compact foliage that prevents sunlight from reaching the ground. According to these authors, this encourages small traders to set up shop there.

• Distribution of Diameter Classes

The distribution of individuals by diameter class follows a bell curve, showing that individuals with large diameters are in the majority. This explains the very low number of trees in the classes below 10 cm. The distribution of individuals by diameter class follows a bell curve, showing that individuals with large diameters are in the majority. Indeed, this bell shape shows that there is very little or no regeneration due to population pressure and regular maintenance of these roadside trees. It is with this in mind that Glèlè Kakaïet al. (2016) assert that in the case of tree plantations, the diameter

structure often hasa bell shape that should adjust to a normal distribution.

- **Carbon Stock**

The relatively high carbon stock in these two neighbourhoods (1,365.01 tonnes) is thought to be due to the density and large number of large-diameter trees. It is in this context that Dube and Senecal (2006) stated that the larger a tree is (and the greater its basal area), the more carbon it stores. It can also be explained by the high presence of fast-growing exotic species. According to Beckett et al. (1998) and Georgi and Zafiriadis (2006), these plant species are responsible for a large part of the biomass in a given area. Thus, the carbon stock of these two neighbourhoods (1,365.01 tonnes) is greater than that of the trees in the entire city of Daloa, estimated by Kouassi et al. (2018) at 158.9 tonnes. This significant difference can be explained by the density of trees along the roads. In their study in Daloa, Côte d'Ivoire, the authors noted the low density of roadside trees in this city due to their removal during road resurfacing and asphalting works. In Yamoussoukro, our study area, roadside tree planting was designed and implemented by the first president of Côte d'Ivoire, a nature lover, during the development of the city, with roads that are still solid and trees planted every 5 to 8 metres depending on the length of the roads. If we examine each of the neighbourhoods studied, the carbon stock is higher in N'Zuessi than in Millionnaire. This is due to the larger area of the N'Zuessi neighbourhood. However, when calculated per hectare, the carbon stock is higher in Millionnaire. This means that the Millionnaire neighbourhood is denser per hectare. These roadsides trees of Yamoussoukro help reduce greenhouse gases by storing carbon dioxide in their organs and deserve to be developed in all cities across the country.

Conclusion

This study showed that the roadsides trees of the N'Zuessi and Millionnaires neighbourhoods of the city of Yamoussoukro comprise 30 species. There are 1,900 trees in these two neighbourhoods, more than half of which are located in the N'Zuessi neighbourhood. Terminalia mantaly accounts for more than 51% of the trees surveyed. Exotic species account for 73% of the species recorded. The trees lining the streets of these neighbourhoods contribute to the reduction of greenhouse gases with an estimated carbon stock of 171.05 t/ha, *Terminalia mantaly* (104.02 t/ha), *Ficus benjamina* (24 t/ha) and *Peltophorum pterocarpum* (19.24 t/ha) being the plant species that store the most carbon. Therefore, roadside trees should be extended to all towns and motorways in Côte d'Ivoire in the context of increasing global warming. As trees are crucial in the fight against greenhouse gas reduction, it would be important to assess their health so that they can continue to play their role as carbon sinks.

Acknowledgment

We would like to thank the authorities of the city of Yamoussoukro. In particular, the town hall and the Autonomous District of Yamoussoukro, which provided us with all the necessary authorisations to carry out this study. Our thanks also go to the Yamoussoukro State Nursery, which provided us with information on the planting of avenue trees.

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