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Research Article

Green Spaces in Yamoussoukro Secondary Schools (Ivory Coast)

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Abstract

The Scientific High School and Mamie Adjoua High School, the only secondary schools in the city of Yamoussoukro, have green spaces, but with of different compositions of different plant species. This study enabled us to assess the plant diversity of these green spaces and to estimate the carbon stock of tree species. To achieve this objective, a floristic inventory was carried out and diameter measurements at breast height (dbh ≥ 2.5 cm) were taken on the trees in order to estimate the carbon stock from the calculated biomass. A total of 110 species were counted, with a higher number in the Mamie Adjoua High School. *Caryota mitis* is the most important species in terms of individuals. The carbon stock of green spaces in these schools is 39.71 t/ha, with the highest value going to the species *Delonix regia* at 14.15 t/ha. There is also a strong preference for exotic species. Control should therefore be exercised to prevent the intrusion and establishment of invasive exotic species, even if these species are remarkable for their diversity. This study also showed that the green spaces in schools help to reduce greenhouse gases by playing an air purifying role appreciated by students and administrative staff in the city of Yamoussoukro.

Keywords

Diversity, Plant Species, Carbon Stock, High School, Yamoussoukro, Ivory Coast

1. Introduction

Education is a fundamental right, a powerful vector for development and one of the best ways of reducing poverty, raising levels of health and promoting gender equality. The aim of schools is to train the women and men of tomorrow, who will be able to lead their personal, civic and professional lives with full responsibility, and who will be capable of adaptation, creativity and solidarity. The school also has a role to play in the ongoing adaptation of men and women to social, technological and professional changes in our society [1].

Success at school is therefore closely linked to the education system. In fact, several factors must contribute to this success. These include the creation of a large number of schools and classrooms to avoid overcrowding. There are also laboratory rooms enabling learners to gain a better understanding of the phenomena around them, etc. According to [2], one of these many factors is the student's physical and psychological well-being. The school is therefore called upon to provide an effective environment that will promote the child's well-being

and high quality of life. The playground and its various facilities, of which the green space is the main element, can be considered a key element within the school. According to the Center for Studies on Networks, Transport, Urban Planning and Public Construction (CERTU), green spaces are planted areas, with or without trees, private or public, that are part of the urban fabric [3]. As a result, several species can make up a green space. These offer a wide range of benefits to people, such as visual beauty, shade, etc. [4, 5]. However, many schools in Africa in general, and in Ivory Coast in particular, lack green spaces. This state of affairs, which has been highlighted by several studies, has led government authorities to develop schools by incorporating green spaces so that learners can benefit from their advantages, particularly in Western countries such as France [6], Canada [7], the United States and Germany, to name but a few. In Africa in general, and in Ivory Coast in particular, very few schools have a green space. However, those that do do not have the same architecture and the species planted differ from one establishment to another. The general aim of this study, carried out in schools in Yamoussoukro, the political capital of Ivory Coast, is to assess plant diversity in Yamoussoukro's schools. Specifically, the aim was to determine the richness and composition of plant species and to estimate the carbon stock of trees in the green spaces of Yamoussoukro's schools.

2. Material and Method

2.1. Study Area

Yamoussoukro, a town in central Ivory Coast, has been the political capital since 22 March 1983 [8]. Located 250 km north-west of Abidjan, Yamoussoukro is at the crossroads of roads leading to the towns of Daloa, Bouaké, Oumé, Didievi and Sinfra. It is bordered to the north by the sub-prefectures of Lolobo and Kossou; to the west by the sub-prefectures of Bouaflé and Bazré; to the south by those of Oumé and Kokumbo; and to the east by the sub-prefectures of Toumodi and Attiégouakro. The town of Yamoussoukro, our study area, is located in the Yamoussoukro sub-prefecture (Figure 1).
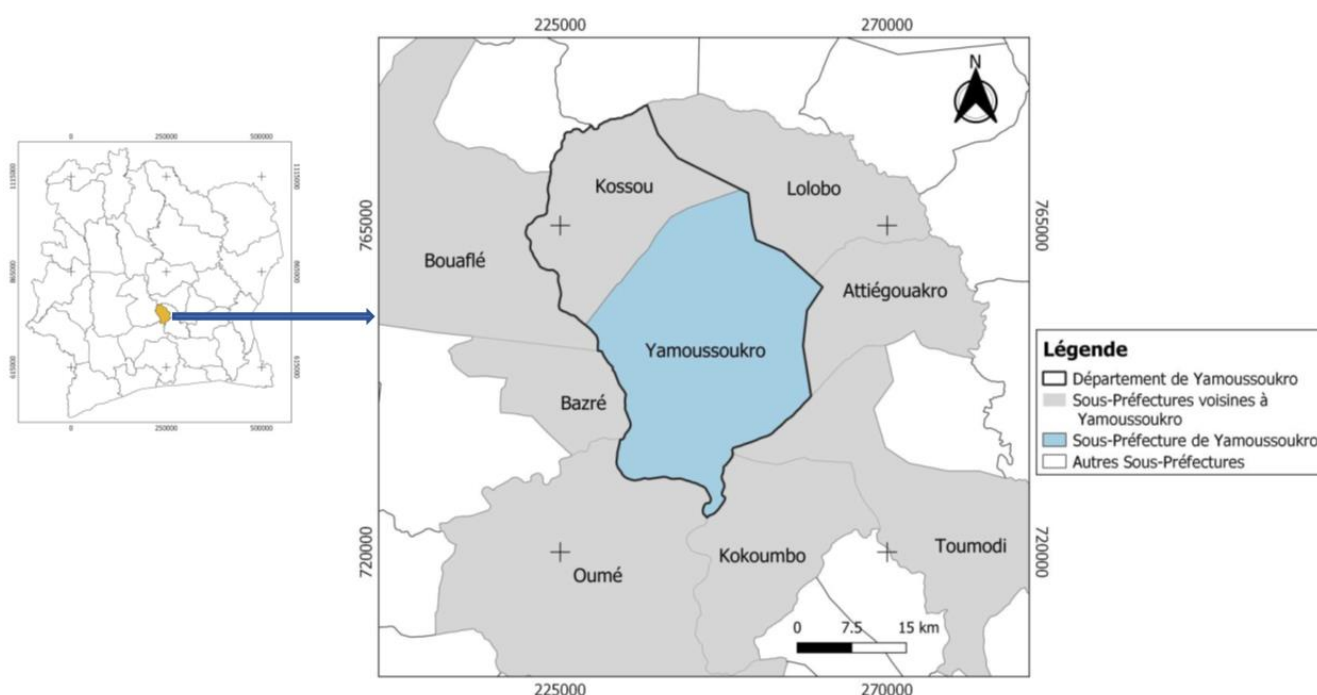
Figure 1. Location of the Yamoussoukro sub-prefecture in Ivory Coast.

Yamoussoukro has a transitional humid tropical climate, with two seasons: A rainy season with two peaks in June and September and a dry season from November to February. The schools included in this study are those that have a green space within their grounds. The schools visited were the Scientific High School and the Mamie Adjoua High School in Yamoussoukro, whose green spaces cover areas of 2 ha and 1.5 ha respectively.

2.2. Data Collection

To assess the diversity of plant species in the Scientific High School and Mamie Adjoua High School, a floristic inventory was carried out. This inventory consisted of listing all the plant species present in the green spaces of these two schools. The surface area occupied by each green space was considered as a unitary parcel within which all the species

were taken into account. This made it possible to record all the plant species by name and the number of individuals of each species. Diameters at breast height (DBH) greater than 2.5 cm were measured for all trees using a tape measure. For species not identified in the field, samples were taken and compared with those from the National Floristic Center (CNF) in Abidjan, located at the University Félix Houphouët-Boigny in Cocody, with a view to their identification.

2.3. Data Analysis

We used the lists of [9-12] to determine the families, phytogeographical types and biological types for each species surveyed. The biomass and carbon stock of tree species were estimated using allometric equations in an urban environment. These equations, known as UGES (Urban General Equations),

are divided into three equations depending on the type of species present, i.e. deciduous trees, conifers and palms [13]. From the calculated biomass, the carbon stock is obtained by multiplying it by 0.5 [14].

3. Results

3.1. Floristic Richness

The total number of individuals counted on the green spaces of the 2 establishments is 390 individuals. Of these, 286 individuals have a DBH $\geq$ 2.5 cm and 104 individuals have a DBH < 2.5 cm. These individuals represent 110 species and 38 families (Table 1). There were variations between these establishments.

Table 1. Number of species and individuals recorded per green space.

Green spaces	Surface area (ha)	Species	Individuals	Individuals with DBH≥ 2.5 cm	Individuals with DBH < 2,5 cm
Scientific High School	2	72	185	144	41
Mamie Adjoua High School	1,5	86	205	142	63
Total	3,5	110	390	286	104

In the Scientific High School green space, 185 individuals were counted, with 144 individuals having a DBH $\geq$ 2.5 cm and 41 having a DBH < 2.5 cm (Table 1). These individuals belong to 72 species and 31 families. The most represented species in terms of individuals (DBH $\geq$ 2.5 cm) are *Caryota mitis* with 37 individuals (25.7%), *Elaeis guineensis* with 20 individuals (13.8%), *Delonix regia* with 12 individuals (8.3%) and *Peltophorum pterocarpum* with 10 individuals (7%).

In the Mamie Adjoua High School green space, 205 individuals were counted, with 142 individuals having a DBH $\geq$ 2.5 cm compared with 63 having a DBH < 2.5 cm (Table 1). These individuals belong to 86 species and 35 families. The most represented species in terms of individuals were *Tectona grandis* with 43 individuals (30.3%), *Delonix regia* with 17 individuals (12%) and *Gmelina arborea* with 15 individuals (10.6%).

3.2. Morphological Types
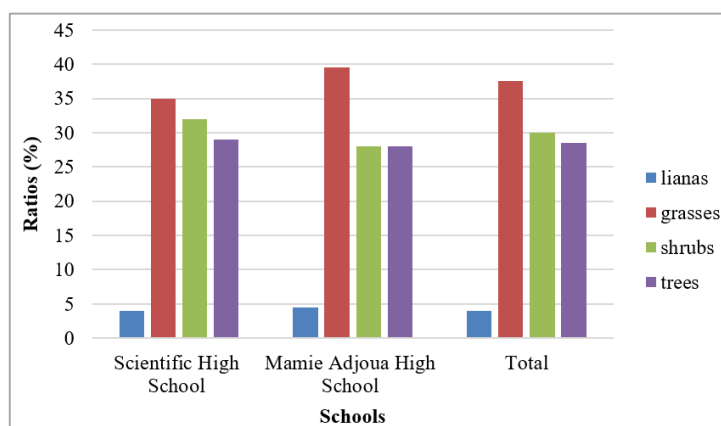
Figure 2. Distribution of morphological types by green space.

Of all the green spaces in the 2 establishments, grasses are the most numerous, with 41 species or 37.3%. Shrubs followed with 34 species (31%). Lianas are the least numerous with 4 species or 3.6% (Figure 2). The same trend can be seen when we look at the green spaces in each establishment. Grasses are the most dominant, with a proportion of over 34% in the 2 establishments. Creepers are the least numerous, accounting for less than 5% in the 2 establishments.

3.3. Biological Types

Nine biological types were identified in all the green spaces visited. Microphanerophytes (mp) and nanophanerophytes (np) are the most represented, with proportions of 34.5% and 27% respectively (Figure 3). The other 7 types have proportions of less than 10%, with Megaphanerophytes (MP) the type with the lowest proportion (4.5%).
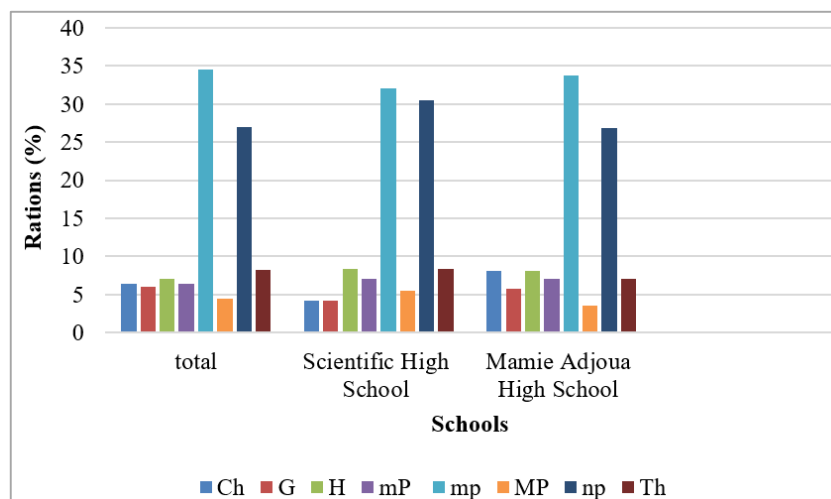

Figure 3. *Distribution of biological types for all green spaces at the two establishments.*

Legend: Ch: Chamephyte; G: Géophyte; H: Hémicrytophyte; mP: mesophanérophyte; MP: Mégaphanérophyte; mp: microphanérophyte; np: nanophanérophyte; Th: Thérophyte

3.4. Local and Exotic Species in Green Spaces

In green spaces as a whole, there were 64 exotic species (58.2%) and 46 local species (41.8%). The same trend was observed in the Scientific High School and Mamie Adjoua High School green spaces, where exotic species dominated with 57% and 54% respectively (Figure 4).

In terms of morphological types, the majority of exotic species are trees and shrubs, with 40.6% each. Lianas are the least numerous (Table 2). In terms of local species, grasses are in the majority with 67.4% of species.
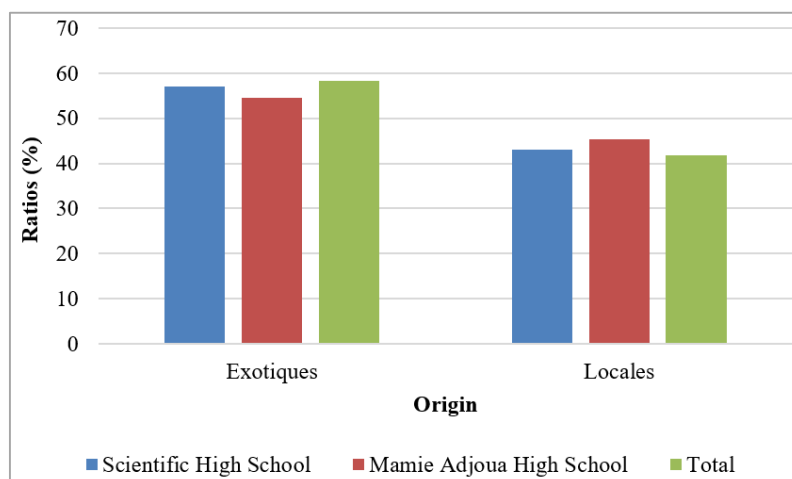

Figure 4. *Distribution of species origin in the green spaces of the two establishments.*

Table 2. *Breakdown of species origin according to green spaces.*

	Exotic species				Local species			
	trees	Shrubs	grasses	Lianas	trees	shrubs	grasses	Lianas
Scientific High School	16	19	5	1	5	4	20	2
Mamie Adjoua High School	22	16	7	2	2	8	27	2
Total	26	26	10	2	5	8	31	2

3.5. Biomass and Carbon Stock of Tree Species in Green Spaces

The total biomass expressed in all the green spaces of the 2 establishments is equal to 79.43 t/ha, i.e. a carbon stock of 39.71 t/ha. The most important plant species in terms of carbon stock are *Delonix regia* with 14.15 t/ha, *Terminalia mantaly* with 7.10 t/ha and *Peltophorum pterocarpum* with 2.86 t/ha. Thus, the biomass expressed in the Scientific High School green space is equal to 47.15 t/ha, i.e. a carbon stock of 23.57 t/ha. The most important species in terms of carbon stock are *Delonix regia* (8.37 t/ha), *Peltophorum pterocarpum* (7.89 t/ha) and *Mangifera indica* (the mango tree) with 5.33 t/ha. The biomass of the green space at the Mamie Adjoua High School is 122.48 t/ha, giving a carbon stock of 61.24 t/ha. The most important species in terms of carbon stock are *Delonix regia* (21.87 t/ha), *Terminalia mantaly* (15.68 t/ha) and *Tectona grandis* (5.56 t/ha).

4. Discussion

Various species are present in the green spaces of the Scientific High School and Mamie Adjoua High School schools in Yamoussoukro. The green space at the Scientific High School covers 2 ha, while that at the Mamie Adjoua High School is 1.5 ha. However, in terms of species, the Mamie Adjoua High School has more than the Scientific High School. This could be explained either by the study period coinciding with maintenance of the Scientific High School green space. This maintenance has the effect of reducing the number of 'undesirable' species in the Scientific High School green space. The Scientific High School green space is very densely grassed, whereas the Mamie Adjoua High School green space is very densely planted. This explains the different species densities (57.33 species/ha at Mamie Adjoua High School and 36 species/ha at LS). The number of species is not always linked to surface area, particularly for urban green spaces. For some authors, such as [15, 16], the larger the surface area, the more species there are. However, this assertion is not always true, particularly for urban green spaces where humans often intervene to achieve various objectives. In these two types of green space, there is a high proportion of trees and shrubs. This is due to the fact that, because of its geographical position, the city of Yamoussoukro is exposed to high temperatures of up to 30°C and often close to 35°C throughout the day. Thus, these two morphological types offer shade that is appreciated by the pupils and staff of these secondary schools. This result is similar to that achieved by [17] who stated that in African countries, trees and shrubs are the most planted to benefit from their shade because in these countries, the climate tends to get warmer. In the same vein, [18] state that this is one of the many roles played by tree species in urban environments. The high rate of exotic species of these two morphological types. For some authors, these species have the advantage of being extremely fast-growing [19]. Hence their planting in these schools in order to benefit quickly from their advantages. This explains the high numbers of *Caryota mitis*, *Tectona grandis*, *Delonix regia* and *Peltophorum pterocarpum*. Other studies have also shown that exotic species are highly prized. These include the study by [17] in Lomé, Togo, where the species *Azadirachta indica* (nime) was the most planted; and the [20] in Chad, where the most planted species were exotic species. These were *Azadirachta indica*, *Terminalia mantaly* (badamier) and *Mangifera indica* (mango).

The total biomass expressed is 79.43 t/ha, giving a carbon stock of 39.71 t/ha. These relatively high values are due to the large number of individuals with a diameter at breast height (DBH) greater than 2.5 cm. Thus, the biomass and carbon stock values for the Mamie Adjoua High School are higher than those for the Scientific High School because there are more trees in the Mamie Adjoua High School than in the Scientific High School. With this in mind, [21] stated that the larger and/or more numerous the trees, the higher the biomass and carbon stock values. In addition, the high proportion of fast-growing exotic species has an influence on carbon stock productivity. In fact, these species are responsible for the large amount of plant biomass [22]. This high biomass in our study can also be explained by the high proportion of introduced species. These fast-growing species are responsible for the large amount of above-ground plant biomass in standing trees. This high biomass and carbon stock is responsible for good air quality, as the air is free of impurities.

5. Conclusion

This study was carried out in the green spaces of schools in the town of Yamoussoukro. Of all the city's secondary schools, only two have a green space: the Scientific High School and the Mamie Adjoua High School. These are the Scientific High School and the Mamie Adjoua High School. The aim of this study is to take stock of the various plants present and the perceptions of pupils and staff regarding them. A total of 110 plant species were identified. The most abundant plant species in terms of numbers were Caryota mitis, *Elaeis guineensis*, *Delonix regia*, *Tectona grandis* and *Peltophorum pterocarpum*. Exotic species (58.2%) are more abundant than local species (41.8%). The total carbon stock expressed is 39.7 t/ha/. The most important species in terms of carbon stock are *Delonix regia*, *Terminalia mantaly* and *Peltophorum pterocarpum*. This study has shown the usefulness of green spaces in schools and also their contribution to reducing greenhouse gases.

Abbreviations

APUR	Parisian Urban Planning Workshop
CERTU	Center for Studies on Networks, Transport, Urban Planning and Public Construction
CNF	National Floristic Center
DBH	Diameters at Breast Height
FAO	Food and Agriculture Organization
LMA	Lycée Mamie Adjoua
LS	Lycée Scientifique
MEA	Millenium Ecosystem Assessment
UGES	Urban General Equations
UFR	Training and Research Unit

Conflicts of Interest

The authors declare no conflicts of interest.

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