OPEN ACCESS

Haya: The Saudi Journal of Life Sciences
Abbreviated Key Title: Haya Saudi J Life Sci
ISSN 2415-623X (Print) | ISSN 2415-6221 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com

Original Research Article

Diversity and Carbon Stock of Abandoned Green Spaces in the City of Yamoussoukro (Ivory Coast)

Kouassi Roland Hervé[1], Nomel Gnagne Jules Richard[2*], Ambé Alain Serge Augustin[1], Koman Silvère Romuald[2], N'Guessan Kouakou Edouard[2]

[1]Laboratoire de Biologie Végétale, Département des Sciences et Technologies, Ecole Normale Supérieure d'Abidjan, 08 BP 10 Abidjan 08, Côte d'Ivoire
[2]Laboratoire des Milieux Naturels et Conservation de la Biodiversité, UFR Biosciences, Université Félix Houphouët-Boigny, 22 BP 582 Abidjan 22, Côte d'Ivoire

DOI: 10.36348/sjls.2021.v06i11.002 | **Received:** 08.09.2021 | **Accepted:** 12.10.2021 | **Published:** 06.11.2021

***Corresponding author:** Nomel Gnagne Jules Richard

Abstract

The city of Yamoussoukro has several abandoned green spaces that have been gradually nibbled away by city dwellers. The aim of the study carried out in this city was to evaluate the diversity of plant species present in these abandoned green spaces and to measure their carbon stock. To do this, a floristic inventory was carried out based on the surface survey plus the roving survey. The diameters at breast height (DBH) of individuals larger than 2.5 cm were measured. The biomass and carbon stock of the trees were assessed using a set of allometric equations from the literature. In total, 4687 individuals were counted, of which 1473 individuals have a DBH ≥ 2.5 cm. The number of species present in these areas is 328. The presence of species with conservation status and the relatively high carbon stock (302.11 t/h) show their importance in the urban environment.

Keywords: Abandoned green spaces, carbon stock, special status species, Yamoussoukro, Ivory Coast.

INTRODUCTION

Green spaces, a theme that first appeared in 1925, are undeveloped spaces managed by the green space departments of a municipality and open to the public [1]. These are spaces, regardless of their surface area, covered with natural or planted vegetation [2].

Given the many services provided by green spaces, they are very present in developed cities such as Paris, Oslo, London, Berlin, Sacramento, etc. The services provided by green spaces or ecosystem services are numerous. They include provisioning services [3,4], regulating services [5-7] and socio-cultural services [8-10].

In view of these invaluable contributions, studies are being conducted throughout Africa. These include studies by Gomido in Benin [11], Polorigni in Togo [12], Merimi and Boukrout in Morocco [13], etc. In Côte d'Ivoire, most studies on green spaces have been carried out in the Abidjan district [14-16].

Despite these multitudes of studies, green spaces all over the world are in clear regression. The main reason for this regression is urbanisation. Indeed, more than half of the population lives in cities [17] and the pressure on green spaces is increasing. The growth of cities leads to the conversion of old neighbourhoods or the development of new ones, resulting in reductions in the number of green spaces or the few existing ones that are not necessarily compensated for.

This is the case of the city of Yamoussoukro, the political capital of Côte d'Ivoire, which is undergoing the gradual destruction of its green spaces as a result of the gradual transfer of state structures, the development of the city and the increase in the local population, and the massive influx of other populations due to its position as a "crossroads city" conducive to commercial and craft activities, etc.

Moreover, the green spaces of the city of Yamoussoukro are made up of trees in line, private gardens and abandoned green spaces. The latter are in turn made up of teak plantations, coconut plantations, *Gmelina arborea* forests, Eucalyptus forests which are planted vegetation and patches of natural forest left voluntarily within the city. The abandoned green

spaces, which are the subject of our study, have been progressively nibbled away by the population since the 1990s and even destroyed for the construction of public and private buildings and roads. These areas, which should normally be monitored by the authorities, are being abandoned or "neglected" and are increasingly threatened by the growing population. Thus, the general objective of this study is to assess the plant diversity contained in neglected areas. More specifically, the aim is to determine the floristic richness and composition of abandoned green spaces and to evaluate their carbon stock.

MATERIAL AND METHOD

Study Area

The city of Yamoussoukro is located in central Côte d'Ivoire, 250 km northeast of the city of Abidjan [18]. Yamoussoukro is at the crossroads of roads leading to the cities of Daloa, Bouaké, Oumé, Didievi and Sinfra. Yamoussoukro 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; to the east by the sub-prefectures of Toumodi and Attiégouakro (Figure 1).

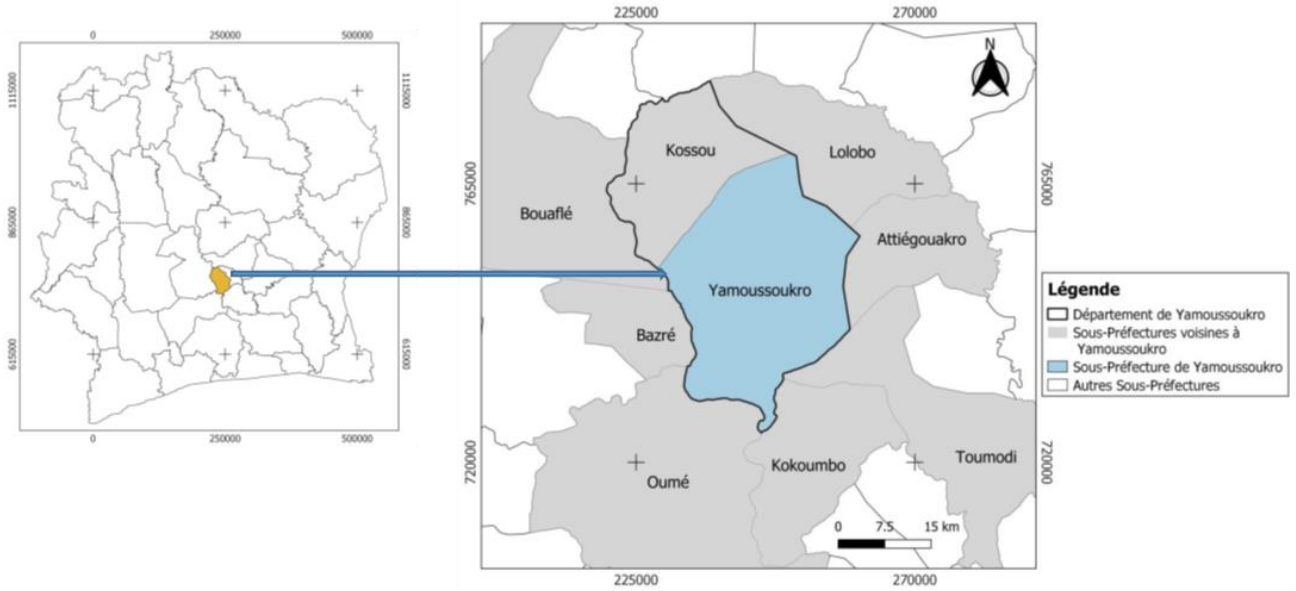

Figure 1: Location of the city of Yamoussoukro

Data Collection

For the inventory of plant species in derelict areas, the area survey was used. This consists of recording all plant species in plots of a fixed area. In this study, plots of 400 m^2 were installed and their geographical coordinates were recorded with a GPS. In these plots we identified the species, counted their number, the number of individuals for each species and recorded them on survey sheets. The circumferences of tree species with a diameter greater than 2.5 cm were measured with a tape measure. For species not identified in the field, herbarium samples were taken for comparison with samples from the National Floristic Centre (CNF) of the University of Félix Houphouët-Boigny in Cocody, allowing their identification. In total, 14 neglected areas were inventoried out of the twenty or so in the city.

Data Analysis

For the determination of botanical families of plant species, we used the catalogue of vascular species of Aké-Assi [19, 20]. For the identification of phytogeographical types, we used the major chorological subdivisions of White [21]. The APG IV [22] classification was used. For species of conservation value, we used the list of endemic species of Guillaumet [23] and Aké-Assi [24, 25, 19, 20], the IUCN red list [26] and that of Aké-Assi [27].

The floristic indices of Shannon [28] and Pielou [29] were calculated to measure diversity. To highlight the preponderance of species, we calculated the species importance index (SII) by highlighting both the number of individuals, the occurrence of their records and their importance in relation to the basal area occupied by each species [30].

Densities of tree species were measured for each plot by counting individuals per hectare. Basal areas were also determined. Histograms of the distribution of tree individuals in diameter classes were constructed to show the variation in tree diameter in the abandoned green areas.

Biomass was estimated from allometric equations in order to preserve the tree species in the green areas. These allometric equations are those of Arifin [31] for bananas, Brown [32] for coconuts, palms and roasters, Shin *et al*., [33] for bamboo and Chave *et al*., [34] for other species in semi-deciduous tropical

forest areas. It is expressed in t/ha. This biomass is converted into carbon stock by multiplying it by the coefficient 0.5.

RESULTS

Floristic richness, composition and diversity

The number of individuals counted in all the abandoned green spaces in the city of Yamoussoukro is 4687 individuals. Among these individuals, those with a DBH ≥ 2.5 cm are 1473. These individuals belong to 328 species grouped in 241 genera and 80 families (Table 1). The genera *Euphorbia*, *Cassia* and *Albizia* are the most represented. The average number of species is 23.11 ± 9.24. The most represented species in terms of individuals (DBH ≥ 2.5 cm) are *Azadirachta indica* with 269 individuals (18.3 %), *Eucalyptus camaldulensis* with 208 individuals (14.1 %), *Cocos nucifera* with 158 individuals (10.7 %) and *Senna siamea* with 152 individuals (10.3 %). The most preponderant botanical families are the Fabaceae with 49 species or 15 %, the Euphorbiaceae with 22 species or 6.7 % and the Apocynaceae with 22.

Table 1: Floristic richness of abandoned green spaces

	Number
Individual	4687
Individual à DHP ≥ 2,5 cm	1473
Species	328
Genus	241
Family	80
Shannon	1,97 ± 0,6
Equitabilité de Pielou	0,85 ± 0,08

In terms of biological types, microphanerophytes (mp) with 35% of species while hydrophytes (Hyd) are the least numerous with 1% of species (Figure 2). Regarding phytogeographic types, exotic species (i) are the most abundant with 36.9% of species while species from the Sudanese region (SZ) are the least represented with a proportion of 3% (Figure 3).

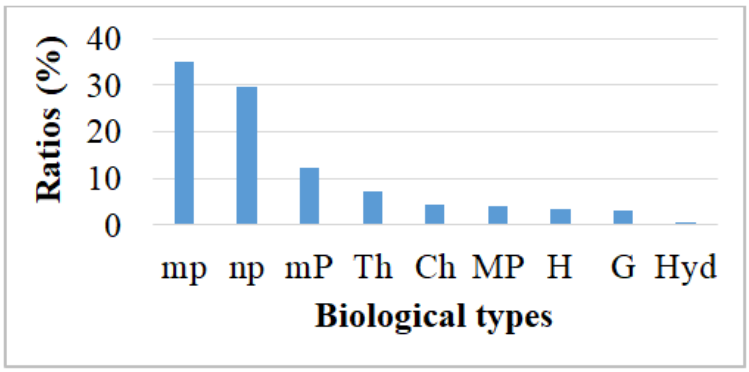

Figure 2: Distribution of biological types of abandoned spaces

Legend: mp: macrophanerophyte; np: nanophanerophyte; mP: mesophanerophyte; Th: Therophyte; Ch: Chamaephyte; MP: Megaphanerophyte; H: Hemicryptophyte; Hyd: Hydrophyte; G: Geophyte; rh: rhizome; Sto: Stolon.

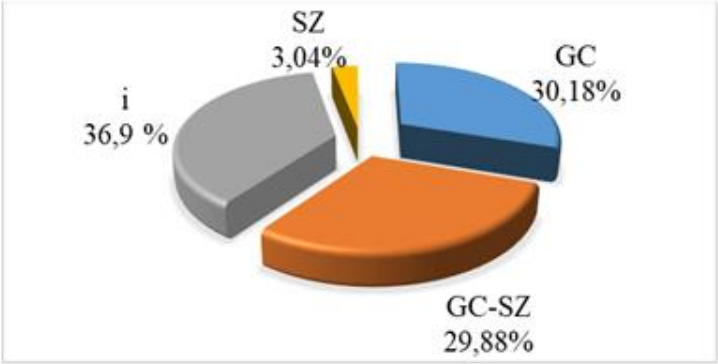

Figure 3: Distribution of phytogeographic types of abandoned areas

For morphological types, shrubs are the most abundant with 34.1 %. While lianas are the least abundant with 13.7 % (Figure 4).

From the point of view of species diversity, the average Shannon index is equal to 1.97 ± 0.6 bits. As for the Pielou equitability index, it is equal to 0.85 ± 0.08 (Table 1).

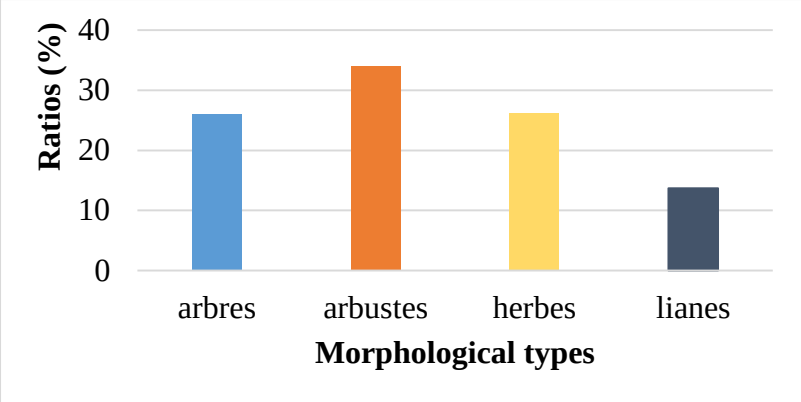

Figure 4: Distribution of morphological types of abandoned spaces

Special Status Species

In all of the abandoned areas, 6 special-status species were identified. Among these species, 4 are endemic and 4 are rare and/or threatened with extinction. The endemic species are *Hypocratea vignei* Hoyle (Hippocrateaceae), *Cola caricaefolia* (G. Don) K. Schum. (Malvaceae) and *Syzygium guineense* (Willd.) DC. (Myrtaceae) all from the West African forest block (GCW) and *Terminalia ivorensis* A. Chev. (Combretaceae), a species from Upper Guinea (HG). Rare and/or endangered species include *Albizia ferruginea* (Guill. & Perr.) Benth (Fabaceae), *Khaya senegalensis* (Desv.) A. Juss. (Meliaceae) and *Terminalia ivorensis* (Combretaceae). All these species are qualified as vulnerable species (Vu) on the IUCN red list. On the Aké-Assi list, one species has been identified, namely *Syzygium guineense* (Willd.) DC which is a Myrtaceae qualified as Rare Plant, which has become rare and endangered (PRE).

Stand Structure

Across all the abandoned areas, 1473 individuals ≥ 2.5 cm were counted. Thus, the density is 433.23 individuals/ha. When individuals in the plots are considered, the average density is equal to 428.48 ± 164.41 individuals/ha. As for the basal area, it is 40.33 m^2/ha, or an average of 21.65 ± 24.17 m^2/ha in the different plots.

In these abandoned areas, the diameter class containing the greatest number of individuals is the class]10-20] with 120 stems/ha. This class is followed by the classes]20-30] and]5-10] with 90.58 and 68.82 stems/ha respectively. While the least represented are the classes]70-80] and]80-90] with 3.82 and 3.52 stems/ha respectively (Figure 5).

Biomass and Carbon Stock

The total expressed plant biomass of the tree species in the abandoned green spaces is 2054.41 t or 604.23 t/ha. The carbon stock corresponding to this biomass is equal to 302.11 t/ha. The average biomass, when considered in the different plots, is equal to 166.34 ± 191.72 t/ha or an average carbon stock equal to 83.17 ± 95.86 t/ha. The most important plant species in terms of plant biomass and carbon stock are *Eucalyptus camaldulensis* (93.08 t/ha), *Terminalia mantaly* (63.1 t/ha) and *Hildegardia barteri* (41.45 t/ha).

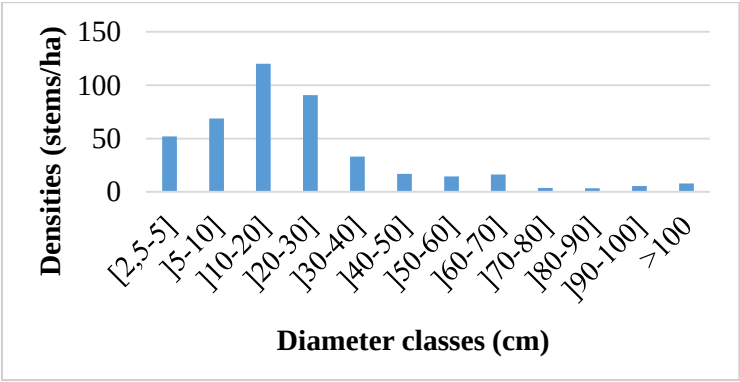

Figure 5: Number of individuals counted by diameter class in the abandoned areas

DISCUSSION

The abandoned green spaces in the city of Yamoussoukro are quite diverse. Indeed, they include tree plantations such as coconut plantations (*Cocos nucifera*), teak plantations (*Tectona grandis*), *Eucalyptus camaldulensis* plantations, *Gmelina arborea* and portions of natural forest. This denotes a relatively abundant specific richness (328 species) due to a variety

of habitats. It is in this sense that Raymond and Simon [35] stated that habitat diversity and mesological characteristics are factors that promote plant and animal diversity in urban areas. This richness is lower than that of private gardens in the same city, whose richness was estimated at 378 species by Nomel *et al*., [36]. This difference can be explained by the private nature of these gardens, which prohibits any incursion by the population. Thus, these spaces are monitored by their owners. The inventories allowed to count 1473 individuals ≥ 2.5 cm (443.23 individuals/ha). This relatively high density per hectare is due to the numerous spaces planted with trees. Indeed, when planting trees, local authorities voluntarily planted trees with very little space between them whether in coconut groves, teak groves, *Gmelina arborea* plantations and *Eucalyptus* plantations. However, the low number of large-diameter trees compared to small-diameter trees could be explained by the cutting of trees by the population. These spaces, very little monitored by the authorities, are frequented by the population who, in search of wood, cut large-diameter trees [37] hence the bell-shaped appearance of the diameter classes showing an antrhopized environment. This is true when a significant number of small diameter trees (DBH ≥ 2.5 cm) are counted with 68.57% of the individuals counted. For the reforestation of some spaces, species such as *Cocos nucifera*, *Gmelina arborea*, *Eucalyptus camaldulensis*, *Tectona grandis*, *Peltophorum pterocarpum* and *Hopea odorata* were selected. They are all exotic species of the phytogeographic regions. According to Cauchat *et al*., [38], these species have the particularity of being fast growing and do not require specific maintenance. Nevertheless, these species, even if their importance [39,40] has been demonstrated, can have consequences on biodiversity as well. Indeed, it is clear that the introduction of exotic species modifies the composition and functioning of ecosystems in a radical way [41]. They compete with native species for space and nutrients and thus can negatively impact the distribution of other species [42]. The presence of special-status species shows that green spaces are very good environments for biodiversity conservation. Similar studies have shown the role of urban green spaces as a refuge for biodiversity [43, 44]. Regarding the relatively high biomass and carbon stock, these rates are mainly due to monospecific plantations (teakeraies, coconut groves, Gmelina arborea plantations, etc.) which are numerous in the city and some large-diameter species still spared such as *Hildegardia barteri* and *Terminalia mantaly*. In addition, the predominance of fast-growing exotic species promotes this high biomass and carbon stock [45]. Compared to the value of the carbon stock of abandoned spaces in the city of Abidjan, it is higher. Indeed, Kouadio [46] in his study on the abandoned spaces of the said city found a value of 12.94 t/ha. This very large difference is due to the poverty of large diameter trees in the green spaces of the city of Abidjan which are constantly attacked by the populations. On the other hand, this value of carbon stock in Yamoussoukro is low compared to the carbon stock of private gardens in the same city, whose value is 882.21 t/ha. This difference could be explained by the very large diameter trees in private gardens that are left voluntarily by their owners to benefit from their shade. The green spaces of the city of Yamoussoukro, which were once maintained, have been neglected due to the lack of interest shown by local authorities. All the monospecific or mixed tree plantations were made during the lifetime of the first President of Côte d'Ivoire, the late Felix Houphouët-Boigny. However, these islands of forest, which are very numerous in the city, have been spectacularly reduced due to their approximate management and the transfer of state structures to the city, the political and administrative capital of Côte d'Ivoire. Recently, the State of Côte d'Ivoire has initiated a vast reforestation program in the city. This is to be encouraged. Nevertheless, it must involve botanists in the choice of species used for reforestation and especially rely on local species or an association of exotic species and local species for mutual benefit.

CONCLUSIONS

The neglected or abandoned green spaces of the city of Yamoussoukro are rich in 328 species divided into 241 genera and 80 families. All the individuals counted are 4687 of which 1473 individuals have a DBH ≥ 2.5 cm.

Shrubs, microphanerophytes and exotic species are the most representative. *Azadirachta indica*, *Eucalyptus camaldulensis*, *Cocos nucifera* and *Senna siamea* are the species with the highest number of stems. These green spaces have within them 6 species of special status namely *Hypocratea vignei*, *Cola caricaefolia*, *Syzygium guineense*, *Terminalia ivorensis*, *Albizia ferruginea* and *Khaya senegalensis*.

The total plant biomass sequestered by the trees in the green spaces is equal to 2054.41 t or 604.23 t/ha, i.e. a carbon stock equivalent to 302.11 t/ha. Eucalyptus camaldulensis (93.08 t/ha), Terminalia mantaly (63.1 t/ha) and Hildegardia barteri (41.45 t/ha) are the species with the highest biomass.

Thus, these green spaces play a role in the conservation of biodiversity and especially shows its importance in reducing greenhouse gases in the city of Yamoussoukro.

REFERENCES

1. Merlin, P., & Choay, F. (2009). Dictionnaire de l'urbanisme, Presse Universitaires de France, Paris, 963 p.
2. St-Arnaud, M. (2008). Les espaces verts en milieu urbain au Québec: avantages, problématiques et recommandations. Essai de maîtrise en

environnement, Université de Sherbrooke, Sherbrooke, Québec, 79 p.
3. Kuchelmeister, G. (1991). Urban and Peri-Urban Multipurpose Forestry in Development Cooperation: Experience, Deficits and Recommandations, Rapport ronéo, Allemagne, 164p.
4. Oueslati, W., Salanié, J., & Choumert, J. (2006). Modes d'approvisionnement en végétaux: Enseignement de la modélisation économique. Actes des 11ème Assises du CNVVF, 30 novembre et 1er décembre, Vichy, 11p.
5. Powe, N. A., & Willis, K. G. (2004). Mortality and morbidity benefits of air pollution (SO2 and PM10) absorption attributable to woodland in Britain. *Journal of Environmental Management*, 70, 119-128.
6. Nowak, D. J., Hoehn, R. E., Crane, D. E., Stevens, J. C., & Walton, J. T. (2007). Assessing urban forest effects and values, San Francisco's urban forest. Newtown Square, Department of Agriculture, Forest Service, 22 p.
7. Gill, S. E., Handley, J. F., Ennos, A. R., & Pauleit, S. (2007). Adapting cities for climate change: the role of the green infrastructure. *Built Environment*, 33, 115-133.
8. Dunnett, N., Swanwick, C., & Woolley, H. (2002). Improving urban parks, play areas and open spaces. Urban Research Report, London, 217 p.
9. Llewelyn-Davies, Y. (2007). Urban Design Compendium, 2nd Edition, English Partnerships, London, 125 p.
10. Peters, K., Elands, B., & Buijs, A. (2010). Social interactions in urban parks: Stimulating social cohesion? *Urban Forestry and Urban Greening*, 9, 93-100.
11. Gomido, K. X. (2012). Foresterie urbaine dans la ville d'Azovè (Commune d'Aplahoué). Mémoire de Maitrise Flash/UAC, Bénin, 84 p.
12. Polorigni, B., Radji, R., & Kokou, K. (2014). Perceptions, tendances et préférences en foresterie urbaine: cas de la ville de Lomé au Togo. *European Scientific Journal*, 10(5), 261-277
13. Merimi, J., & Boukroute, A. (1996). Inventaire et état sanitaire des arbres d'alignement dans la ville d'Oudja (Maroc). Activité de l'Institut Agronomique et Vétérinaire, 16(1), 41-47.
14. Vroh, B. T. A., Tiebre, M. S., & N'Guessan, K. K. (2014). Diversité végétale urbaine et estimation du stock de carbone: cas de la commune du Plateau, Abidjan, Côte d'Ivoire. *Afrique Science*, 10(3), 329-340.
15. Kouadio, Y. J. C., Vroh, B. T. A., Gone Bi, Z. B., Adou Yao, C. Y., & N'Guessan, K. E. (2016). Evaluation de la diversité et estimation de la biomasse des arbres d'alignement des communes du Plateau et de Cocody (Abidjan - Côte d'Ivoire). *Journal of Applied Biosciences* 97: 9141–9151.
16. Monssou, E. O., Vroh, B. T. A., Goné, B. Z. B., Adou Yao, C. Y., & N'Guessan, K. E. (2016). Evaluation de la diversité et estimation de la biomasse aérienne des arbres du jardin botanique de Bingerville (district d'Abidjan, Côte d'Ivoire), *European Scientific Journal* 12(6), 185–201.
17. FAO. (2012). Etude sur la foresterie urbaine et périurbaine de N'Djamena, Tchad. Rôle et place de l'arbre en milieu urbain et périurbain Appui à la formulation d'une stratégie et un plan d'action de la foresterie urbaine et périurbaine à N'Djamena, république du Tchad. Document de travail sur la foresterie urbaine et périurbaine, n°6, Rome, Italie, 95 p.
18. N'guessan, K. A., Kouassi, A. M., Gnaboa, R., Traoré, K. S., & Houenou, P. V. (2014). Analyse de phénomènes hydrologiques dans un bassin versant urbanisé: cas de la ville de Yamoussoukro (centre de la Cote d'Ivoire). *Larhyss Journal*, pp 135-154.
19. Aké-Assi, L. (2001). Flore de la Côte d'Ivoire 1, Catalogue, systématique, biogéographie, écologie. Boisera 57, Conservatoire et jardin botanique de Genève, Suisse, 396 p.
20. Aké-Assi, L. (2002). Flore de la Côte d'Ivoire 2, Catalogue, systématique, biogéographie et écologie. Conservatoire et Jardin Botanique, Genève, Suisse, 441 p.
21. White, F. (1993). The AETFAT chorological classification of Africa: history, methods and applications. *Bull. Jard. Bot. Nat. Belg, 62, 225-281*.
22. APG IV. (2016). An update of the Angiosperm phylogeny group classification for the orders and families of flowering plants: APG IV. *Botanical Journal of Linnaean Society*, 256, 105-121.
23. Guillaumet, J. L. (1967). Recherche sur la végétation et la flore de la région du Bas Cavally (Côte d'Ivoire). Mémoire ORSTOM, 20, Paris (France), 200p.
24. Aké-Assi, L. (1984). Flore de la Côte d'Ivoire. Thèse de doctorat, Université de Cocody, Abidjan, Côte d'Ivoire. 1206p.
25. Aké-Assi, L. (1988). Espèces rares et en voie d'extinction de la flore de la Côte d'Ivoire. Monographie Systématique Botanique. *Missouri Botanical Garden*, 25, 461-463.
26. IUCN. (2018). IUCN Red List of Threatened Species. Version 2018.1.www.iucnredlist.org consulté le 15 janvier 2019.
27. Aké-Assi, L. (1998). Impact de l'exploitation forestière et du développement agricole sur la conservation de la biodiversité biologique en Côte d'Ivoire. *Le Flamboyant*, 46 : 20-21.
28. Shannon, C. E. (1948). A mathematical theory of communications. Bell. *System Technical Journal*, 27, 379-423.
29. Piélou, E. C. (1966). The measurement of diversity in different types of biological collections *Journal of Theorical Biology*, 1, 131-144.

30. Cottam, G., & Curtis, J. T. (1956). The use of distance measures in phytosociological sampling. *Ecology*, 37, 451-460.
31. Arifin, J. (2001). Estimasicadangan C pada berbagai sistem penggunaan lahan di Kecamatan Ngantang, Malang. Skripsi-S1. Unibraw, Malang, 25p.
32. Brown, S. (1997). Estimating biomass and biomass change of tropical forest. Food and Agriculture Organisation (FAO), 134, 93p.
33. Shin, M. Y., Miah, M. D., & Lee, K. (2007). Potential contribution of the forestry sector in Bangladesh to carbon sequestration. *Journal of Environnemnt and Management*, 82, 260-276.
34. Chave, J., Brown, S., Cairns, M. A., Chambers, J. Q., Eamus, D., Folster, H., Fromard, F., Higuchi, N., Kira, T., Lescuyer, J. P., Nelson, B., Ogawa, H., Puig, H., Reira, B., & Yamakura, T. (2005). Tree allometry and improved estimation of carbon stock and balance in tropical forest. *Oecologia*, 145, 87-99.
35. Raymond, R., & Simon, L. (2012). Biodiversité : les services écosystémiques et la nature en ville. Revue Forestière Française. LXIV, 3, 339-350.
36. Nomel, G. J. R., Kouassi, R. H., Ambé, A. S. A., Doumbia, M., & N'Guessan, K. E. (2020). Étude de la végétation des jardins privés de la ville de Yamoussoukro (Centre, Côte d'Ivoire). *Revue Nature et Technologie*, 13(1), 91-98.
37. Kouassi, R. H., Nomel, G. J. R., Ambé, A. S. A., Doumbia, M., & N'Guessan, K. E. (2019). Perception, Attitude et Attentes des Résidents à l'égard des Espaces Verts Urbains de Yamoussoukro (Côte d'Ivoire). *European Scientific Journal January*, 3(15), 389-405.
38. Cauchat, H., & Touzard. M. (1991). La représentation de l'arbre d'ornement et l'horizon temporel, Paris Ministère de l'Environnement, Paris (France), 594p.
39. McIntyre, S., & Hobbs, R. J. (1999). A framework for conceptualizing human effects on landscapes and its relevance to management and research models. *Conservation Biology*, 13, 1282-1292.
40. Hunter, I. R. (2001). What do people want from urban forestry? The Europe experience. *Urban Ecosystems*, 5, 277-284
41. McKinney, M. L. (2006). Urbanization as a major cause of biotic homogenization. *Biological Conservation, 127, 247-260*.
42. Nomel, G. J. R., Vroh, B. T. A., Gone Bi, Z. B., Adou Yao, C. Y. & N'guessan, K. E. (2017). Caractéristiques floristiques et structurales des espaces aménagés au niveau des échangeurs de la ville d'Abidjan (Côte d'Ivoire), *Journal de la Recherche Scientifique*, Université Lomé (Togo), 19(3), 119-131.
43. Ville de Gatineau. (2011). Projet de plan de gestion des arbres et des boisés, Gatineau, 25p.
44. Nomel, G. J. R., Kouassi, R. H., Ambé, A. S. A., Doumbia, M., & N'Guessan K. H. (2021). Etude de la végétation des jardins privés de la ville de Yamoussoukro (centre, Côte d'Ivoire). *Revue Nature et Technologie*, 13(1), 91-98. https://www.asjp.cerist.dz/en/Articles/47
45. Georgi, N. J., & Zafiriadis, K. (2006). The impact of park trees on microclimate in Urban Areas. *Urban Ecosystem*, 9, 195-209.
46. Kouadio, Y. J. C. (2016). Diversité végétale, services écosystémiques et valeur économique de la végétation urbaine de la ville d'Abidjan (Côte d'Ivoire). Thèse de Doctorat UFHB. Laboratoire Botanique, Foresterie urbaine, 218p.