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Inventory of Urban Trees in the City of Bunia, Case of the Mudzipela District, Ituri Province, DRC

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Abstract

The choice of this investigation was motivated by the fact that knowledge of urban forests seems to be of little interest to researchers, given its absence in the local literature. The general objective of this work is to contribute to a better understanding of the floristic diversity of the Mudzi-pela district. The meth

odological approach adopted made it possible to count and identify the trees planted along 13 avenues. After analysing the data collected in the area, we arrived at the following results: 361 trees, divided into 36 species and 30 families along the main avenues in the district. The average above-ground biomass for the avenues studied was 0.5730±0.0907 (CV: 15.82%), corresponding to an average of 0.28461 ± 0.045341 kg of sequestered carbon. This testifies to the compensatory role of the tree species in the Mudzi-pela district in the emissions of carbon dioxide resulting from human activities. The study environment is highly species-diverse, with the Simpsom 1-D index tending towards 1 in all the avenues studied.

Keywords: services; ecosystems; urban trees; Mudzi-pela.

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1. Introduction

Highly developed in the West, urban forests, also known as green spaces, are a major component of contemporary cities. Providing citizens with a sense of well-being, these green spaces contribute to the quality of life and attractiveness of cities [1]. The importance of urban trees is well established [2]. As a result, they play a vital role in human life in society, given the many services and functions they offer to city dwellers, particularly ecosystem services.

According to these authors, these include carbon sequestration, thermal regulation, biodiversity support and purification of atmospheric pollutants. These urban plant formations also serve as recreational areas. They can help mitigate the effects of climate change by fixing carbon via photosynthesis in the biomass or soil [3]. Nowadays, cities are home to a relatively large number of plant formations that are either planted or natural. These vegetated spaces are represented by parks, public or private gardens, roadside alignment plantations, vacant spaces and fulfil multiple functions for the inhabitants [4]. However, today's cities are densely populated and are facing gradual urbanisation as a result of the effects of unprecedented demographic growth in the world in general and in Africa in particular. Congolese towns in general, and those located in forest areas in particular, have always been strongly marked by accelerated and uncontrolled urban growth. This phenomenon has amplified and accelerated the reorganisation of urban space and has greatly contributed to accentuating the harmful effects on the environment [5]. In Ituri, the post-conflict period saw a change in lifestyle with a high concentration of the population in towns and commercial centres. The town of Bunia has seen a demographic explosion in recent decades as a result of multiple attacks and, above all, because it is more often invaded by people displaced by the war. With no other sources of energy available, the demand for space, firewood and charcoal has risen rapidly. Similarly, this high concentration has created a need for both hard and semi-durable construction, while these spaces are a means of conserving plants and improving the well-being of city dwellers [6]. Thus, the actions of man coupled with the hazards of climate change are disrupting and degrading the biological diversity of this ecosystem. This degradation of green spaces accentuates the atmospheric pollution of our cities due to the immobilisation of carbon [3]. This is why, if these green spaces are degraded, their ecosystem services are diminished and new strategies for the sustainable management of urban areas are needed. It was against this backdrop that the Mudzi-pela district attracted our attention and was selected as a suitable environment for identifying the composition of the urban flora found there. The general aim of this study is to contribute to a better understanding of the diversity of flora in the Mudzi-pela district.

2. Materials and Methods

This study focused on the Mudzi-pela district is located in the commune of Shari, to the north of the town of Bunia in the province of Ituri, in the DRC, and shares its borders: To the North with the Kasegwa district by the northern edge of the bishopric of the Bunia diocese and to the North-West by the Baboa Bokoe chiefdom, the Banjabulu grouping by the Kabazo stream; To the South with the Ngezi district by the Ngezi river; To the East with the Banjabulu grouping to the West with the Bigo district. [7]. The town of Bunia is located at Latitude: 29º 52′ East; Longitude: 120 27 ′ North, Average altitude: 1250 m; Rainfall: 1000 to 1200 mm/year and Its surface area is: 830 km² (Annual report 2015 of the town hall of the city of Bunia) [7]

Inventory, identification and measurement of reference diameters

A simple random inventory of a unit area was carried out using a sampling rate of 1% of the total area of 37,808m^2 for trees. The inventory was carried out in the following stages: identification of the species and measurement of the circumferences of the individuals. Only trees with a diameter greater than or equal to 10 cm were selected.

These species were chosen because the objective of forest inventories in general is to assess mature varieties [8]. The circumference of the species surveyed was then measured at chest height from a distance of 1.30 m above the ground. To carry out all this work, we needed a Bic pen to write down the information; a Botao tape to measure the circumference; a notebook to keep the information or data collected in the field; a Samsung camera to capture the images so that we could identify certain species that seemed unknown to us; a 100 m tape for measuring horizontal distances when taking circumference measurements; a wooden stick to indicate the 1.30 m level of the ground; a marker or chalk to number the trees already measured and the biological material used in this study is made up of various trees found in alignment. Along the avenues with diameters <10 cm; between 10-20 cm; between 20-30 cm and more. It should be noted that for certain trees with special features (buttresses, stilt roots, knots, branches, bends, etc.), the circumference is measured differently. In the case of trees with buttresses or stilt roots, the measurement is taken 30 cm above the buttresses or roots, whereas in the case of forked trees the circumference is obtained after measuring and adding together the circumferences of each of the branching stems.

After these various measurements, the species sampled were identified from the database made available by the botanical conservatories on the Internet. Identification consisted of determining the scientific name of each tree, its trade name and the family to which it belongs. The criteria mainly concerned the leaves, fruit and sometimes the bark. For our part, the leaves alone were sufficient for identification, but the fruit also helped us to avoid confusion for certain species with similar leaves.

Data encoding, processing and analysis

The data recorded on the inventory sheets were transferred to a database for processing using Microsoft Office Excel and R software. The qualitative variables were the neighbourhood and the sample avenues. The R software helped us to calculate the Shannon H, Simpson 1-D and equitability J indices. The various parameters calculated are described as follows:

- Species richness (S) is the number of species present along the avenue studied.

- Relative species richness is the number of species per unit of distance (m); it is used to compare the species richness of the different avenues studied.

- Relative frequency (RF) is calculated as the ratio of the number of individuals of a species or responses (n) to the total number of species surveyed or responses obtained for a variable (N): $RF = (n \times 100)/N$.

- The Shannon diversity index (H) is the most commonly used in the literature: $H = - \Sigma\, p_i \log_2 p_i$; it varies as a function of both the number of species present and the relative proportion of individuals of the various species, generally between 0 and H max ≈ 5 bits, and sometimes beyond; pi (between 0 and 1) is the relative proportion of the number of individuals of a species i in the total number of individuals of all the species concerned (pi = ni /Σ ni where ni is the number of individuals of species i and Σ ni is the total number of individuals of all species).

- Piélou's equitability (R) often accompanies Shannon's diversity index to assess the equi-repartition of species. This index reflects the degree of diversity achieved by a plantation, and corresponds to the ratio between the effective diversity (H) and the theoretical maximum diversity (H max): R = . Equitability varies between 0 and 1; it tends towards 0 when the quasi-

lg^2S

The equitability tends towards 1 when each species is represented by the same number of individuals.

3. Results and discussions

Table 1: Inventoried species

SPECIES	FAMILY
Ailanthus altissima (Mill.) Swingle	Anacardiaceae
Albizia julibrissin. Durazz	
Annona muricana. Linné	Annonaceae
*Artocarpus heterophyllus.*Lam	
Bambousa eutuldoides. Schrad	Apocynaceae
Brugmansia suaveolens (Humb, Bbonpl. Ex Willd) Bercht. J.Presl	Bignoniaceae
Calliandra calothyrsus. Meisn	
Callistermon viminalis (Gaertn) G.Don	Casuarinaceae
Cascabela thevtia (Linne) Lippold	
Cassia fistula. Linné	Combretaceae
Casuarina cunninghamiana.	
Euphorbia turicalii. Linne	Malvaceae
Ficus etrangleur. Linne	
Ficus thonningie.	Meliaceae

Miq	
Citrus aurantiifolia. (Christm.) Swingle	Connaraceae
Codieaum variegatum. (Linne) A. Juss	
Coffea arabica. Linné	Cupressaceae
Cola acuminata (P. Beauv.) Schoot , Endl	
Croton gratissimus. Bruch	Euphorbiaceae
Cupressus sempervirens. Linné	
Delonix regia (Bojer ex Hook) Raf.	Fabaceae
Duranta erecta. Linné	Juglandaceae
Elaeis guinensis. Jacq	
Eriobotrya japonica (Thunb.) Lindl	Lauraceae
Eucalyptus botryoides (S.m)	
Eucalyptus sp	Leguminosae
Eugenia uniflora. Linne	
Ephorbia hyberna. Linne	Lythraceae
Euphorbia pulcherrima. Linne	

Blume	
Fluegga virosa (Roxb ex. Willd).Royle	
Glycyrrhiza glabra. Linne	Moraceae
Grevilea robusta. A.Cunn ex. R.BR	
Hibiscus rosa-sinensis. Linne	Moringaceae
Hibiscus tiliaceus. Linne	
Jatropha curca. Linne	Myrtaceae
Juglans nigra. Linne	
Khaya senegalensis (Desr).A.Juss	Oleaceae
Leucena leucocephala (Lam) de wit	
Mangifera indica. Linne	Phyllanthaceae
Melia azedarach. Linne.	
Moringa oleifera. Lam	
Morus sp. Linne	Proteaceae
Persea americana. Moulin	
Plumeria alba. Linne	Rosaceae
Psidium guajava.	

Linne	
Punica granatum. Linne	Rubiaceae
Salix babylonia.Linne	
Senna spectabilis (DC.) H.S Irwin ; Barneby	Rutaceae
Spathodea campanulata. P. Beauv	
Syzyngium cumini. (Linne). Skeels	Simaroubaceae
Sysyngium malaccense (Linne) Merr; L.M. Perry	Slicaceae
Tamarindus indica. Linne	Solanaceae
Terminalia ivorensis. A.Chev	Verbenaceqe

Notices: EVA: Assessing the richness of flora in landscaped green spaces, CV: Coefficient of Variation, kg: Kilogram, T/ha: tonne per hectare.

Table 2: Morphological condition of trees

Tree morphology status	AMANDO	CANDIP	CATHERDRALE	EVECHE	KABAZO	KATALE	KOLOMANI	MATHYSEN	Mgr UKEC	Mont CARMEL	NGEZI	SINGOMA	VANHOEF	Total
Shrub (< 10 cm)	13	8	7	22	4	5	9	4	9	4	8	5	12	**110**
Tree (≥ 10 cm)	11	18	11	33	18	19	25	16	27	12	18	18	25	**251**
Total	**24**	**26**	**18**	**55**	**22**	**24**	**34**	**20**	**36**	**16**	**26**	**23**	**37**	**361**

Pearson Chi-square test (X-squared = 13.191, df = 9, p-value = 0.1541)

Out of a total of 361 tree individuals inventoried in the Mudzi-pela neighbourhood, 110 stems of Dhp <10cm is obtained; and 251 stems of Dhp ≥10cm. The avenues with a large number of Dhp ≥10cm trees are: Evêché with (33 individuals), Mgr.Ukec with (27), Kolomani with (25 individuals) and Vanhoef with (25 individuals) than the other avenues. Trees with a large number of DBH <10cm are observed in the avenues: Evêché with (22 individuals), Amando with (13 individuals); and Vanhoef with (12 individuals) than the other avenues. According to the Pearson Chi-square Test X-squared = 13.191, df = 9, p-value = 0.1541, which is strictly above the significance threshold of 0.05, i.e. 5%, it can be said that there is no significant difference in terms of tree density between the avenues considered.

In all the areas inventoried in the Mudzi-pela district, out of a total of 361 tree individuals inventoried in the Mudzi-pela district, 110 stems of Dhp <10cm is obtained; and 251 stems of Dhp ≥10cm. The avenues with a large number of Dhp ≥10cm trees are: Evêché with (33 individuals), Mgr.Ukec with (27), Kolomani with (25 individuals) and Vanhoef with (25 individuals) than the other avenues, this could be explained by the fact that old avenues, managed by the Catholic Church of Mudzi-pela which would prevent anthropogenic pressure.

[9]. in their study of a total of 3168 individuals in the whole of the study area in the two districts of Assabou and Dioulakro in Abidjan Côte d'Ivoire, with 28 species divided into 23 genera and 16 families obtained a higher result than the one we obtained because in our study we were interested only in individuals with Dhp ≥ 10cm, which was not the case for their study which took account even of individuals with Dhp ≤ 10cm; however, the total of 361 individuals spread over an average of 37 species and 31 families in the avenues of the Mudzi-pela district. This number of individuals, species and families is much lower from the point of view of individuals than 705 individuals divided into 29 species and 17 families, found by [10]. In the communes of COCODY and Plateau in Abidjan (Côte d'Ivoire). The same case of inventory was observed by [11]. which identified 742 individuals of

Dhp ≥ 10 cm distributed among 127 species and 39 families in the botanical garden of Bingerville. The comparison between our result and these two results quoted above, by adding the information as provided in table (n02), confirm our hypothesis according to which Nowadays, several species of tree would have disappeared following the deforestation caused by the anthropic actions due to the demographic explosion which the town of Bunia knew.

Table 3: Specific diversity of avenue line plantings

INDICES	AMANDO	CANDIP	CATHERDRALE	EVECHE	KABAZO	KATALE	KOLOMANI	MATHYSEN	Mgr UKEC	Mont CARMEL	NGEZI	SINGOMA	VANHOEF
Taxa (S)	17	16	15	31	13	13	26	12	15	7	14	16	22
Individuals	24	26	18	55	22	24	34	20	36	16	26	23	37
Dominance (D)	0.0729	0.0769	0.0803	0.0393	0.095	0.101	0.0502	0.105	0.0818	0.156	0.0917	0.078	0.0679
Simpson (1-D)	0.9271	0.9231	0.9198	0.9607	0.905	0.899	0.9498	0.895	0.9182	0.844	0.9083	0.923	0.9321
Shannon (H)	2.73	2.665	2.63	3.33	2.453	2.42	3.139	2.363	2.594	1.895	2.505	2.668	2.885
Equitability (J)	0.9636	0.961	0.9713	0.9696	0.9562	0.943	0.9633	0.951	0.9579	0.974	0.949	0.962	0.9333

From the point of view of diversity, examination of Table 3 shows that the study environment is highly diverse in terms of species because the Simpsom 1-D index tends towards 1 in all the avenues studied. In addition, the species are evenly distributed across the avenues studied (Equitability is ≈ 0.9713).

Finally, the Shannon index in turn varies according to the avenues if they are considered separately. It is greatest at Eveche (3.33) and Kolomani (3.139) and the one that represents a low value is Mont carmel avenue (1.895). Similarly, [13]. carried out a census in the MBUNYA commune of a total of 1689 stems of Dhp ≥ 10cm, compared with our results above (the Simpsom_1-D index tends towards 1. It is 0.97 at BANKOKO, 0.95 at HOHO, 0.92 at OPASI and 0.96 at YAMBI YAYA). The high diversity and equitability values observed in Evêché and Kolomani avenues can be explained by the fact that these avenues have been reforested several times by the local population and are also one of the oldest avenues. Depending on this diversity and the distribution of species, local people benefit from the goods and services provided by the neighbourhood's avenue trees.

Table 4: Above-ground biomass and organic carbon

Avenue	Biomass (t)	CO (t)
AMANDO	0.256493	0.128247
CANDIP	0.500306	0.250153
CATHERDRALE	0.28937	0.144685
EVECHE	0.936724	0.468362
KABAZO	0,491474	0.245737
KATALE	0.547097	0.282957
KOLOMANI	0.891979	0.444599
MATHYSEN	0.442639	0.221319
Mgr UKEC	0.888358	0.444179
Mont CARMEL	0.355481	0.17774
NGEZI	0.586744	0.30111
SINGOMA	0.458272	0.229136
VANHOEF	0.723698	0.361849
Total	**6.877161**	**3.700073**
Average ± Ec	**0.573097±0.090683**	**0.284621±0,045341**
CV(%)	**15.82**	**15.93**

Table 4 above shows that the average above-ground biomass for the avenues studied is 0.573097 ± 0.090683 (CV: 15.82%), which corresponds to an average of 0.28461 ± 0.0453 kg of carbon sequestered per avenue. The total above-ground biomass of the areas surveyed amounts to 6.8772 kg of dry matter, which corresponds to a sequestered carbon stock of 3.700073 kg. Of the total carbon sequestered, Avenue de l'Evêché sequestered the greatest quantity, followed by Avenue Kolomani and Monseigneur UKEC, with 0.8928 tonnes and 0.8884 tonnes of carbon respectively, while Avenue Cathédrale and Avenue Amando sequestered the least, with 0.2565 tonnes and 0.2894 tonnes respectively. The total amount of carbon sequestered corresponds to 13.5793 tonnes of CO2 equivalent.

The quantities of biomass differ considerably from one avenue to another. They are a total of 6.877161 t/ha for a corresponding carbon stock of 3.700073 tC/ha (table 4). And on average they vary between 0.573097± 0.090683 for a corresponding carbon stock varying between 0.284621tC ± 0.045341Tc. This result is slightly larger than those found by [3]. in the city of Bobo Dioulasso in Burkina Faso, who obtained the following result: The quantities of biomass (varying from 6.44 t/ha) as well as the carbon stock (3.22 tC/ha per EVA), differ considerably from one EVA to another. This result is significantly lower than those found by [11]. in the Jardin Botanique de Bingerville, where biomass values range from 21 to 381.4 t/ha. It is also lower than the biomass values for gardens in the Commune of Plateau in Abidjan, which vary from 19.25 to 181.60 t/ha according to the results of work by [12]. For avenues and boulevards in the Plateau and Coccody communes, [10]. found 562.33 ± 819.39 t/ha and 266.09 ± 363.48 t/ha respectively. These biomass values are low compared with the 6.877161 t/ha recorded in the Mudzi-pela district in the town of Bunia. These differences are linked to the methodological approach used to collect the data. While our study only took into account trees with a diameter (DBH ≥ 10 cm), the other authors mentioned above considered trees with a diameter ≤ 10 cm. Thus, this information confirms our second hypothesis according to which the quantity of biomass and aerial carbon sequestered by trees and shrubs in the Mudzi-pela district is considerable.

Considering all the EVAs in the town of BoboDioulasso, the Ka-ya-Wooto scrubland contains the largest carbon stock, at 356.98 tc/ha. The high density (2372.88 stems/ha) and the large pool of large-diameter individuals in this EVA could justify the superiority of its carbon volume compared with the others. As noted by [13]. carbon stocks depend on several parameters, including the quality and quantity of trees. Similarly, the high contribution of large-diameter trees to total biomass stocks has been demonstrated by other studies [9].

4. Conclusion

This study provided information on the floristic composition of the avenues in the town of Bunia, specifically from the Shari commune to the Mudzi-pela district.

The methodological approach adopted made it possible to count and identify the trees planted along 13 avenues.

After analysing the data collected in the area, we arrived at the following results: 361 trees, divided into 36 species and 30 families along the main avenues in the district. The average above-ground biomass for the avenues studied was 0.5730±0.0907 (CV: 15.82%), corresponding to an average of 0.28461 ± 0.045341 kg of sequestered carbon. This testifies to the compensatory role of the tree species in the Mudzi-pela district in the emissions of carbon dioxide resulting from human activities.

The study environment is highly species-diverse, with the Simpsom 1-D index tending towards 1 in all the avenues studied.

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