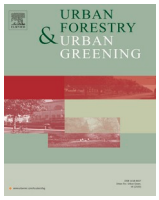
Urban Forestry & Urban Greening 63 (2021) 127220

Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

journal homepage: www.elsevier.com/locate/ufug



Review article

Diversity, use and management of household-located fruit trees in two rapidly developing towns in Southeastern D.R. Congo

Yannick Sikuzani Useni [a,b,*], François Malaisse [c], Jonas Mleci Yona [a], Theodore Mulembo Mwamba [d], Jan Bogaert [c]

[a] Ecology, Ecological Restoration and Landscape Unit, Faculty of Agricultural Sciences, University of Lubumbashi, Lubumbashi, Democratic Republic of the Congo
[b] Center of Competence in Planning and Urban Management, University of Lubumbashi, Lubumbashi, Democratic Republic of the Congo
[c] Biodiversity and Landscape Unit, Gembloux Agro-BioTech, University of Liège, Gembloux, Belgium
[d] Faculty of Agricultural Sciences, University of Lubumbashi, Lubumbashi, Democratic Republic of the Congo

ARTICLE INFO

Handling Editor: Tenley Conway

Keywords:
Ecosystem services
Fruit trees diversity
Household
Medium cities
Urban forestry

ABSTRACT

Recently, the growing need to complement rural and foreign sources of food and woodfuel is driving interest in urban forestry management in medium cities. The present study was designed to characterize the diversity of fruit trees in households of two rapidly developing cities in southeastern DR Congo (Lubumbashi and Kolwezi), and shed light on the sociological aspects of their management. Analyses of data collected through surveys carried out in planned and unplanned neighborhoods revealed noticeable botanical differences between the two neighborhoods within cities. In Lubumbashi, a greater number of fruit trees (6.5) and species (5.7) per 1000 m^2 was recorded in the unplanned neighborhood compared to the planned neighborhood (3.4 trees and 2.0 species). A similar trend was noted in Kolwezi, although with significantly reduced values (by more than half). Across the two cities, a total of 36 fruit trees species were listed, of which 8 were exclusively identified in unplanned neighborhoods of Lubumbashi, showing a comparatively greater species richness of the city. Coincidentally, the 8 specific species are characteristic of *Miombo* woodland, suggesting preexistence of *Miombo* vegetation in these areas. Overall, the listed flora of studied neighborhoods in the two cities is dominated by exotic species, with Rutaceae the most represented family. Straightforward differences in the use of fruit trees were noted between the two cities; medicinal uses stand out in Lubumbashi, whereas uses such as shading and properties boundary predominate in Kolwezi. As common trend in the two cities, however, fruit trees scarcely receive arboricultural care, partly explained by limited knowledge on the ecological requirements of fruit trees. Current results have provided important insights into the botanical richness of fruit trees and related sociological aspects of their management at household-scale, which may help in formulating guidelines and technical tools to assessing and monitoring urban forestry in Southeastern DR Congo.

1. Introduction

In recent decades, a remarkable pace of urbanization is witnessed in many regions around the world (Angel et al., 2011). At global scale, about 55 % of the world's population lived in urban areas in 2018, and this tally could reach 70 % by 2050 (United Nations, 2019, 2018). While urbanization was mostly characteristic of northern countries in the 20th century, it is currently a dominant process in developing countries as well, including sub-Saharan Africa (Bogaert et al., 2015), where a five-fold increase in the number of urban dwellers is forecast over the period from 2000 to 2050 (UN-Habitat, 2014). Likewise, due to the current rate of dedensification (2 %), the acreage of urbanized areas is predicted to increase from 26,500 km^2 to 325,500 km^2 over the same period (Angel et al., 2011).

Unfortunately, such expansion of cities in Sub-Saharan Africa is done anarchically, with unplanned housings gradually taking place in vacant spaces around cities, while interstitial spaces within cities experience considerable built-up densification (Vermeiren et al., 2012). Either way,

* Corresponding author at: Ecology, Ecological Restoration and Landscape Unit, Faculty of Agricultural Sciences, University of Lubumbashi, Lubumbashi, Democratic Republic of the Congo.
E-mail addresses: sikuzaniu@unilu.ac.cd (Y.S. Useni), malaisse1234@gmail.com (F. Malaisse), jonasmleci@gmail.com (J.M. Yona), mwamba.theo@yahoo.com (T.M. Mwamba), j.bogaert@uliege.be (J. Bogaert).

https://doi.org/10.1016/j.ufug.2021.127220
Received 8 September 2020; Received in revised form 8 June 2021; Accepted 11 June 2021
Available online 15 June 2021

urbanization in Sub-Saharan Africa is associated with marked loss of green spaces in and around cities (Etshekape et al., 2018), as exemplified by a loss of nearly 157 km^2 of green spaces in the space of 19 years (between 1987 and 2006) in the city of Abuja (Nigeria) (Fanan et al., 2011). Normally, the removal of green spaces leads to biodiversity erosion resulting in the loss of habitats and a disruption of the urban ecosystem functioning (Beatley, 2000; Kestemont et al., 2011; Beninde et al., 2015). Meanwhile, urbanization favors the creation of new disturbed habitats where exotic plant species are introduced (Williams et al., 2009; Kabir and Webb, 2008; Bigirimana et al., 2011). As a result, the proportion of exotic plant species exceeds 50 % of the flora in most African cities (Bernholt et al., 2009; Bigirimana et al., 2011; Rija et al., 2014).

Currently, restoration of natural landscape in urban areas is driving considerable attention. Indeed, the creation of new urban forests and green spaces, and the maintenance of existing ones, could help attenuating problems brought about by the environmental degradation associated with rapid and uncontrolled urbanization in African cities (Etshekape et al., 2018). Overall however, these reforestation efforts remain spatially variable. In many studied cases, the poorest neighborhoods are characterized by small amounts of green space, generally in a poor state of maintenance (Kaoma and Shackleton, 2014a, b; Shackleton et al., 2014). By contrast, planned settlements (inherited from the colonial period) generally present large plots of land, often with home gardens. But with the recent demographic explosion, planned neighborhoods are gradually attached to new unplanned settlements inhabited by populations of modest socio-economic conditions (Murwendo, 2011; Mensah, 2014). And, in their search for means to cope with the lack of basic infrastructure i.e. lack of electricity for cooking, populations from unplanned neighborhoods commonly target trees found in adjacent planned neighborhoods, thereby increasing threats on those resources. In South African municipalities for example, Shackleton et al. (2015) demonstrated a clear link between the mode of use of trees and level of development of the neighborhoods. Hence, in the new low-cost housing neighborhoods, trees are used more to provide shade and shelter, while residents in old township areas give priority to the aesthetic value of trees. It is not clear whether such trend could hold true for other African cities, like Lubumbashi and Kolwezi in south-eastern Democratic Republic of Congo (D.R. Congo) that were inherited from colonization.

The cities of Lubumbashi and Kolwezi, created in the first half of the 20th century, have a population density of around 3000 and 4700 inhabitants per km^2 respectively, which is the result of rural exodus and the influx of displaced people due to the socio-political crisis in D.R. Congo (Lebailly, 2010). Both cities are experiencing significant economic growth mainly associated to the liberalization of activities in the mining sector (Cabala et al., 2017; Useni et al., 2018a), but also due to commercial transactions facilitated by their proximity to southern and eastern African countries. Unsurprisingly, their spatial configuration underwent profound changes driven notably by built-up densification and uncontrolled periurbanisation, resulting in considerable negative impact on the vegetation cover (Dupin et al., 2013; Cabala et al., 2017; Useni et al., 2017a, b). Indeed, with the lack of rigorous legal provisions to protect public spaces, urban lands in the two cities are parceled out, enclosing green spaces, floodable land and even land reserved for agriculture.

To compensate for the loss of green spaces, rare projects for arteries greening exist in Lubumbashi since 2000 (Useni et al., 2019). Similarly in Kolwezi city, with its elevation to the rank of capital of the Lualaba province, projects for arteries greening have also been initiated (http://www.lualaba.gouv.cd/wp-content/uploads/2018/12/PROGRAMME-DUGOUVERNEMENT.pdf). In both Lubumbashi and Kolwezi however, the long dry season (5–7 months) limits the growth of street trees, hampering the ardor in greening arteries of these cities. Nonetheless, besides street trees, many residential plots in the two cities are home to an important flora of fruit trees that contribute to the overall greenness of these cities. Unfortunately, the diversity, origin and uses of these household-located trees remain largely unknown, making it difficult to infer on their actual ecological and socio-economic value.

The present study was designed to fill this gap, aiming at characterizing the diversity of fruit trees and their management as well as their uses in Lubumbashi and Kolwezi cities. We hypothesized that, due to the fragmentation of parcels commonly practiced in the two cities, and owing to the extension of buildings within parcels, the low availability of space in planned neighborhoods would have led to a lowering of the diversity and the use of fruit trees as compared to the situation in unplanned neighborhoods. It is further presumed that irrespective of the type of neighborhood, the preference of residents for fruit trees would be dictated by their multiplicity of use or facility for their maintenance.

2. Study sites and context

The study was conducted in Lubumbashi (Upper Katanga province) and Kolwezi (Lualaba province, Fig. 1). Lubumbashi city, where the altitude varies between 1200 m and 1300 m, is subdivided in seven municipalities and forty-three neighborhoods, covering an area of about 747 km^2 (Nkuku and Rémon, 2006), mostly dominated by red and yellow lateritic soils (Leblanc and Malaisse, 1978). Kolwezi city extends over 213 km^2 acreage with an average altitude of 1448 m, and is divided into two municipalities. The soil of Kolwezi is clay-sandy with subsoil rich in mineral deposits, mainly copper and its derivatives (Atibu et al., 2013). The two cities record a humid subtropical climate (Cw type of the Köppen classification system, Bultot, 1950; Harjoaba and Malaisse, 1978; Malaisse et al., 1978), with one rainy season (November–March) and one dry season (May–September), separated by October and April as transition months. The average annual rainfall of Lubumbashi city is close to 1200–1300 mm, and the annual average temperature approaches 20 °C (Leblanc and Malaisse, 1978). Much like Lubumbashi, the average annual precipitation of Kolwezi varies between 1200 and 1600 mm, and its average annual temperature ranges from 18 to 22 °C (Kikufi and Lukoki, 2008). At the beginning of the past century, the vegetation in and around these two cities was dominated by the *Miombo* woodland. Due to diverse anthropogenic activities, this woodland was progressively replaced by a wooded savannah and then by a shrubby and ultimately a grassy savannah (Malaisse, 2010; Dupin et al., 2013; Cabala et al., 2017). The economic activities of both cities consist of industrial and artisanal mining, general trade, agriculture (subsistence), and informal trade.

The selection of the two cities for study is based firstly on their population size, averaging 2.5 million for Lubumbashi and one million for Kolwezi. Moreover, their situation in the *Miombo* ecoregion within the Katangese copperbelt area (Cabala et al., 2017), and the existence of a clear demarcation between planned and unplanned neighborhoods, make these cities interesting units for studying fruit trees diversity, uses and management. In fact, the studied neighborhoods were selected based on the level of planning, leading to their separation in three groups following Leblanc and Malaisse (1978) *i.e.* residential neighbourhood, planned neighbourhood and informal neighbourhood. In this study, residential and planned neighborhoods are included in the category of planned neighborhoods, while informal neighborhoods are part of the unplanned neighborhoods. Table 1 summarizes the main biophysical and socio-economic characteristics of each neighborhood and the local municipality they belong to.

3. Methods

Exploratory visits to the field sites were carried out from 9 to 14 January 2019 to locate the sites of study and interact with local authorities. The designated sites were selected in a way to separately represent planned (Gambela 1 and Gambela 2 for Lubumbashi; Dilungu for Kolwezi) and unplanned neighborhoods (Kalubwe and Kigoma for Lubumbashi; Kasulo and Latin for Kolwezi). And then, series of surveys

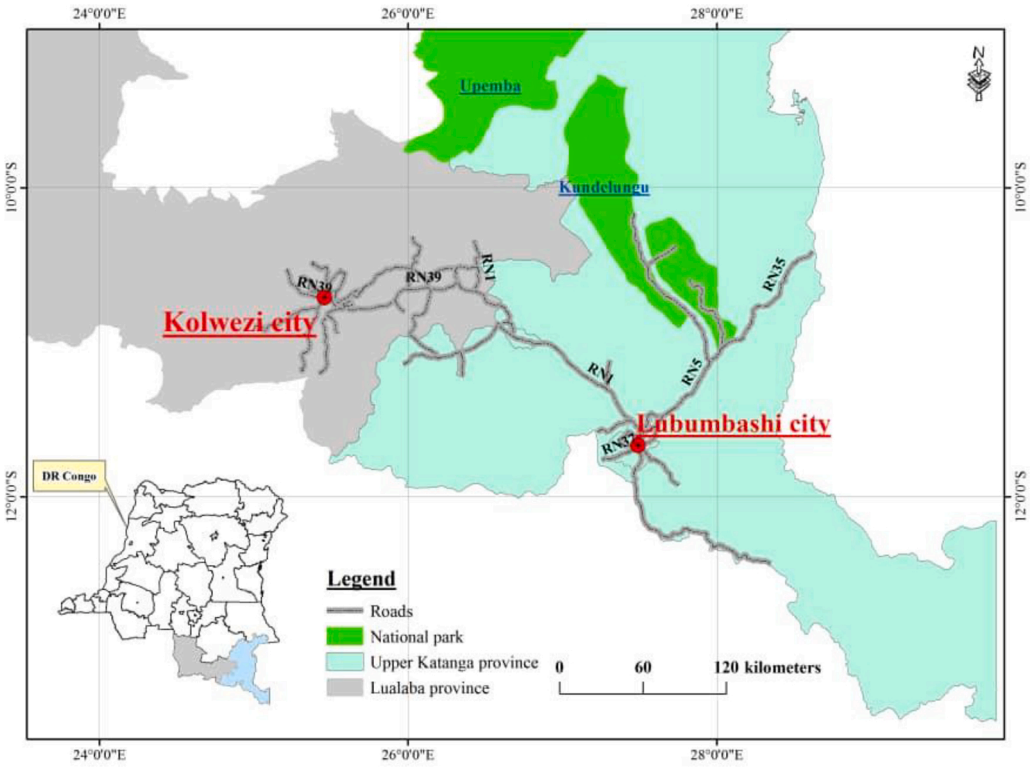


Fig. 1. Location of study sites in the provinces of Lualaba (Kolwezi city) and Upper Katanga (Lubumbashi city) in southeastern D.R. Congo.

Table 1
Main characteristics of the planned and unplanned neighborhoods studied in Lubumbashi and Kolwezi cities. The demographic data for Lubumbashi city and Kolwezi are from 2009 and 2017/2018 respectively.

Neighborhood (City)	Location	Area (km^2)	Population	Main characteristics
Gambela I (Lubumbashi)	11°38′11.12″S 27°29′12.07″E	3.00	20,080	Composed of a planned part with the presence of paved roads, spacious plots, good sanitation conditions and quality of electricity, low presence of informal activities, easy accessibility, presence of a public park and two private wooded green spaces, high standard of living of the inhabitants. The extension of the neighborhood is unplanned and occupies a large part. The total estimated number of streets is 45.
Gambela II (Lubumbashi)	11°38′35.04″S 27°29′53.16″E	5.25	27,500	Composed of a planned part with the presence of some paved roads, not very spacious plots, medium sanitation conditions and quality of electricity, presence of informal economic activities, easy accessibility, presence of two private wooded green spaces, average to high standard of living of the inhabitants. The extension of the neighborhood is unplanned and occupies a large part. The total estimated number of streets is almost 50.
Kalubwe (Lubumbashi)	11°37′44.66″S 27°27′38.53″E	5.32	37,242	Generally informal districts and dilapidated streets; only the main road is paved; serious problems of sanitation and electricity of average quality, a strong presence of informal economic activities, presence of dust in the dry season, insufficient infrastructure, presence of two private green spaces, acceptable standard of living of the inhabitants. The total estimated number of streets is more than 100.
Kigoma (Lubumbashi)	11°37′21.65″S 27°30′08.04″E	12.00	45,058	Low income residents, lack of urbanization, important informal activities, anarchic and chaotic constructions, weak or lack of public infrastructure, difficult access, presence of dust in the dry season, absence of public green spaces. The total estimated number of streets is more than 100.
Kasulo (Kolwezi)	10°41′09.90″S 25°30′01.32″E	~16.00	~75,000	Low income residents, lack of urbanization, important informal activities, anarchic and chaotic constructions, weak or lack of public infrastructure, easy access, presence of dust in the dry season, presence of private green spaces. The total estimated number of streets is 82.
Quartier Latin (Kolwezi)	10°42′09.93″S 25°31′44.33″E	~6.00	13,650	Lack of urbanization, some informal activities, anarchic constructions, weak or lack of public infrastructure, easy access, presence of dust in the dry season, acceptable standard of living of the inhabitants, absence of public green spaces. The total estimated number of streets is 56.
Dilungu (Kolwezi)	10°42′46.27″S 25°31′44.33″E	~1.20	7850	Neighborhood composed of a planned part with the presence of some paved roads, not very spacious plots, medium sanitation conditions and quality of electricity, low presence of informal economic activities, easy accessibility, presence of private wooded green spaces, average to high standard of living of the inhabitants. The extension of the neighborhood is unplanned and occupies a large part. The total estimated number of streets is 23.

were undertaken from January to April 2020 for collection of both qualitative and quantitative data. For reliability of data, the number of investigated streets was set to be representative of at least 20 % of the total estimated number of streets in the studied neighborhood. Hence, in Lubumbashi city, 19 streets were studied in the planned neighborhoods, 9 in Gambela 1 (out of almost 45 streets) and 10 in Gambela 2 (out of almost 50 streets). Through random selection, a total of 15 houses (Gambela 1) and 13 houses (in Gambela 2) were surveyed for each

investigated street. Seven houses were selected at the beginning and end of each street, with the remainder (8 in Gambela 1 and 6 in Gambela 2) were chosen in the middle of the street, on the left and on the right side. In Kalubwe and Kigoma neighborhoods (unplanned), 32 streets for each neighborhood (out of more than 100 streets) were surveyed, and 6 houses per street were surveyed, two at the beginning and the end of the street, and two in the middle. For Kolwezi city, 10 streets (out of 23 streets) covering the planned part of the neighborhood (Dilungu) were studied, and in each avenue, 5 houses were studied at the beginning of the street, 5 in the middle and 4 at the end of the street. In the unplanned neighborhoods, 32 (out of 82 streets for Kasulo) and 25 (out of 56 streets for Latin) streets were studied respectively. In each street, 3 houses were surveyed at the beginning of the street, 2 in the middle and 3 at the end of each street. Where an unoccupied household was found without fruit trees, or in case of unwillingness of household members to participate to the study, the next available household was sampled.

Investigative studies were applied to two different sets of units: the plot and the householder. The selected householders were subjected to structured interviews (open- and closed-ended questions) with the help of a translator. To accommodate the working hours of some interviewees, periods for data collection were extended to weekends and public holidays.

Geographical coordinates of each studied residential plot were obtained with a GPS, and the corresponding area of the plot was determined through digitization of plots polygons on Google Earth imagery followed by conversion into vector format using the Quantum GIS 2.10.1 software. In each residential plot, fruit trees species were taxonomically identified using available floras (Lebrun and Stork, 1991–2015) and specialized literature (Bigirimana et al., 2011; Rija et al., 2014; Useni et al., 2018b, 2019). The origin status of species was determined following Pyšek et al. (2004) who defines exotic species as the ones that are not indigenous to a specific geographic area (in Africa), and following Bigirimana et al. (2011) who classifies Afro-Asian species as indigenous. Information regarding the number of fruit trees and their mode of use by household members were also collected as complementary data. The following categories of fruit trees uses are considered in this study: (i) commercial use (selling of fruits), (ii) medicinal use, (iii) direct consumption, and (iv) other uses, including shade, aesthetic, and properties boundary. A recent survey in South Africa indicated notable agricultural care accorded to trees by household members (Shackleton et al., 2015). For this reason, we collected information about the type and frequency of agricultural care accorded to trees, as well as the qualification of people engaged in execution of the task. Finally, the interviews allowed collecting information on knowledge of residents about ecological requirements of fruit trees present in their plots.

For analysis of the household survey data, counts of responses were produced for quantitative data in each neighborhood, and then one-way Anova tests followed by Tukey's post-hoc comparisons of data between neighborhood types and cities were performed. Significant differences were recorded at $p \leq 0.05$. The relative frequency of species of surveyed residential plot, and that of uses and management of fruit trees was calculated following the formula: Frequency = n/N (where n is the number of plots in which the variable where observed, and N the total number of plots). The diversity of fruit trees was assessed based on species richness (number of tree species per zone), and on Shannon (H) and Simpson (D) indexes, which are most popularly used in community ecology for biodiversity quantification (Nagendra and Gopal, 2010). A comparison of species richness frequencies between neighbourhood types and between cities was performed using the Sørensen-Dice index or Beta diversity (Socolar et al., 2016).

4. Results

4.1. Main characteristics of plots and specific richness of fruit trees

Obtained results on demographic data demonstrate that regardless of the type of neighbourhood, Lubumbashi presents a younger population as compared to Kolwezi. It was also found that a greater proportion of married people exists in planned than unplanned neighbourhoods of Lubumbashi, but an inverse trend was noted in Kolwezi. In most planned neighbourhoods studied in Lubumbashi and Kolwezi, more than half of household heads hold a high school degree. In unplanned neighbourhoods however, the proportion merely reaches 20 %. Similarly, the proportion of household heads holding a high school degree remains higher in planned (50–80 %) than unplanned neighborhoods (40–45 %) in the two cities. And broadly, the proportion of household heads with primary school level is very low (10 %). A clear difference between cities emerges however regarding the proportion of salaried employees that is higher (more than 50 %) in studied neighbourhoods in Kolwezi than those of Lubumbashi (less than 20 %). Moreover, results indicate that more than 80 % of heads of households in planned and unplanned neighbourhoods of Lubumbashi are engaged in informal work occupation (Table 2).

In general, results revealed bigger plots in investigated neighborhoods in Lubumbashi, as compared to Kolwezi. Comparing the type of neighborhood in Lubumbashi, an average area of 1048m^2 was recorded for the planned neighborhood, exceeding the plot area of the unplanned neighborhoods by almost 50m^2. Conversely, in Kolwezi, larger plots were observed in the unplanned neighborhoods (nearly 929m^2 compared to (~903m^2 in planned neighborhoods). To facilitate comparison between cities and neighborhoods, the average plots area was standardised to 1000m^2. Thus, it was clarified that Lubumbashi presents more tree stands and species per 1000m^2 compared to Kolwezi city. Besides, irrespective of city, current results revealed a reduced number of species and trees per 1000m^2 in planned neighborhoods as compared to unplanned neighborhoods where slightly higher values were recorded (Table 2).

Table 2
Main characteristics of studied plots (average area, number of households and residents), number of trees and tree species per plot in the planned and unplanned neighborhoods of Lubumbashi and Kolwezi cities. UP: unplanned; P: planned.

	Lubumbashi		Kolwezi		P value
	UP (n = 390)	P (n = 390)	UP (n = 360)	P (n = 140)	
Age range of heads of households	20–60	25–65	34–79	40–80	–
Male heads of household (%)	72.7	81.3	60.0	70.0	–
Marital status married (%)	68.2	60.3	55.0	70.0	–
Head of household with higher education qualifications (%)	19.1	56.5	55.0	50.0	–
Head of household with secondary education qualifications (%)	40.3	77.3	45.0	50.0	–
Head of household with primary education qualifications (%)	4.5	0.0	0.0	0.0	–
Number of households	2.90 ± 2.3a	3.10 ± 2.9a	2.70 ± 7.3a	2.0 ± 0.9b	0.026
Number of residents	13.2 ± 8.1a	14.9 ± 8.5a	12.8 ± 7.3a	9.4 ± 4.4b	0.019
Average area (m^2) of plot	992.6 ± 746.4b	1048.1 ± 651.7a	928.9 ± 580.2c	902.5 ± 398.2d	0.04
Number of fruit trees per 1000m^2	6.5 ± 5.4a	5.7 ± 4.5a	3.4 ± 1.9b	2.0 ± 1.0c	0.001
Number of species per 1000m^2	3.2 ± 2.1a	2.8 ± 1.7a	2.5 ± 1.2b	1.7 ± 0.8c	0.0019

Data are mean ± standard deviation. Different letters within rows indicate significant difference between means.

The average number of households per plot is about 3 in both neighborhoods in Lubumbashi. In Kolwezi, it is 3 in the unplanned neighborhoods and drops to 2 in the planned neighborhoods. Unsurprisingly, Lubumbashi city records a higher number of residents per plot in the studied neighborhoods. Planned neighborhoods in Lubumbashi city have a high average number of residents per plot (15) compared to unplanned neighborhoods (13). In Kolwezi city, an inverse trend was noted. While the average number of residents per household in the unplanned neighborhoods approached 13, it dropped to 9 in the planned neighborhoods (Table 2).

4.2. Qualitative analysis of the fruit tree flora

The taxonomic spectrum of the fruit tree flora in the planned and unplanned neighborhoods of Lubumbashi and Kolwezi cities is presented in Table 3. In Lubumbashi, overall 25 fruit trees species distributed in 16 families and 21 genera were identified in planned neighborhoods. However, a higher number of species (33), was recorded in unplanned neighborhood, belonging to 24 families and 29 genera, showing greater taxonomical diversity of these neighborhoods compared to counterpart planned neighborhoods within the city. Different from the situation in Lubumbashi, planned and unplanned neighborhood in Kolwezi exhibit identical number of species (9), genera (7) and families (7) (Table 3). It is clear that fruit tree flora of Lubumbashi city displays a wider taxonomical diversity with values ranging from two to four times higher than those observed in Kolwezi. Shannon index values confirm that there is a high diversity of fruit trees in Lubumbashi compared to Kolwezi (Table 3). Within cities (Lubumbashi or Kolwezi), the values of the Shannon index are lower in the planned neighbourhoods than the unplanned ones, possibly due to their low species richness clusters. Comparing cities, the greater Shannon index recorded for Lubumbashi clearly demonstrates a higher diversity of fruit tree species (Table 3). Logically, this indicates existence of dominant species in Kolwezi, in this case *C. sinensis*. However, the Simpson index shows that the diversity of these different sites is not so variable, since the values obtained show only small differences.

The list of species recorded in Lubumbashi and Kolwezi cities is given in Table 4. Summing up fruit tree species inventoried within city, a total of 36 species was recorded across planned (67 %) and unplanned neighbourhoods (89 %) in Lubumbashi. A significantly lower number (24 %) was recorded in Kolwezi. Most importantly, all species observed in Kolwezi were also present in Lubumbashi, clearly highlighting the comparatively poor taxonomical richness of fruit trees in Kolwezi. Among species exclusively identified in Lubumbashi, 8 proved to be characteristic of the *Miombo* woodland. Of these 8 species, two were identified in both planned and unplanned neighborhoods (*Strychnos cocculoides* and *Syzygium guineense*), and the remaining 6 species i.e. *Anisophyllea boehmii, Azanza garckeana, Cochlospermum angolense, Ficus* sp., *Landolphia kirkii* and *Parinari curatellifolia* were specifically found in the unplanned neighborhoods. It was further found that 23 species (63.8 %) out of the 36 species listed in Lubumbashi were exotic, with only 36.2 % of species (13 out of 36 species) found to be indigenous. In Kolwezi, only one out of the 9 fruit tree species listed in this flora is indigenous (Table 4).

For the city of Lubumbashi, *Mangifera indica* and *Persea americana* are present in planned and unplanned neighborhoods, with a frequency of 50 %, whereas other species are less present (<50 %) in both areas. Among the 36 species listed, 4 are absent in unplanned neighbourhoods (*Annona squamosa, Averrhoa carambola, Prinus* sp. and *Vitis* sp.), and for fruit species, 12 are absent in residential neighbourhood plots (*Anisophyllea boehmii, Landolphia kirikii, Cochlospermum angolense, Dacryodes edulis, Parinari curatellifolia, Garcinia mangostana, Azanza garckeana, Ficus* sp, *Punica granatum, Malus, Coffea canephora, Cola acuminata*). As for the city of Kolwezi, all 9 identified species are present in both planned and unplanned neighborhoods. However, in the unplanned neighborhoods, *Mangifera indica*, *Annona muricata*, *Elaies guineensis*, *Carica papaya and Persea americana* were found in more than half of the plots. In planned neighbourhoods, only *Annona muricata* and *Citrus sinensis* have a relative frequency greater than 50 % (Table 4). Consequently, the similarity of species richness between the two cities was estimated at 40 %, as revealed by the Beta diversity index. Likewise, a 50 % similarity was estimated between residential neighbourhoods across cities, while comparison between unplanned neighbourhoods of the two cities shows a 40 % similarity.

In Lubumbashi, the six taxonomical families identified i.e. Rutaceae, Moraceae, Myrtaceae, Rosaceae, Annonaceae and Arecaceae, possess more than one species, thus encompassing about 46 % of the 36 species identified, in this order: Rutaceae (10.8 %) followed by Moraceae, Myrtaceae and Rosaceae (8.1 % each), then Annonaceae and Arecaceae (5.4 % each; Table 5). The remaining families (20) listed in Lubumbashi flora are Anacardiaceae, Anisophyllaceae, Apocynaceae, Bixaceae, Bombacaceae, Bursearaceae, Caricaceae, Chrysobalanaceae, Clusiaceae, Lauraceae, Loganiaceae, Malvaceae, Moringaceae, Musaceae, Oxalidaceae, Passifloraceae, Punicaceae, Rubiaceae, Sterculiaceae and Vitaceae, each representing 2.7 % of fruit tree species listed in the flora characterized within the city (Lubumbashi). In Kolwezi, only 7 families out of these 26 are represented. Similar to Lubumbashi, Rutaceae is also the most represented taxonomical family in the fruit tree flora of Kolwezi, accounting for one third of the recorded species. Other families identified in Kolwezi, each represented by a single species, are Anacardiaceae, Annonaceae, Arecaceae, Caricaceae, Lauraceae and Myrtaceae.

4.3. Management and multiple uses of fruit trees in planned and unplanned neighborhoods of Lubumbashi and Kolwezi

The results related to the perception of residents on the interest of fruit trees in the planned and unplanned neighborhoods of Kolwezi and Lubumbashi are shown in Table 6. In Kolwezi, commercial interest was expressed in 46 % and 28 % of observations respectively in the planned and unplanned neighborhoods, while they approached 35 % regardless of neighborhoods in Lubumbashi. Strikingly, medicinal interest of fruit trees stands out in Lubumbashi where scores of 63 % and 44 % were recorded in unplanned and planned neighborhoods respectively. Conversely, significantly lower scores were noted in Kolwezi (12 % and 18 % respectively in unplanned and planned neighborhoods). On the other hand, other interests (shade, aesthetic, and properties boundary, etc.) were of higher frequency (70 %) in Kolwezi (in all the neighborhoods) compared to 38 % and 16 % in the planned and unplanned neighborhoods in Lubumbashi. The interest for fruit consumption was manifest in all surveyed plots in both Lubumbashi and Kolwezi, regardless of the type of neighborhood. Finally, results revealed that tree maintenance by the residents is performed in less than half of studied plots, with 47 % and 44 % score noted respectively in the planned neighborhoods of Lubumbashi and Kolwezi cities versus 30 % and 17 % respectively in unplanned neighborhoods of Lubumbashi and Kolwezi. In all the neighborhoods studied either in Lubumbashi or Kolwezi, the essential care accorded to trees consists in organic fertilization and

Table 3
Distribution by families, genus and species of fruit trees in the plots of Lubumbashi and Kolwezi cities and related diversity indices. UP: unplanned (n = 390 in Lubumbashi and 360 in Kolwezi); P: planned (n = 390 in Lubumbashi and 140 in Kolwezi).

Indices	Lubumbashi		Kolwezi	
	UP	P	UP	P
Species	32	24	5	5
Genus	21	20	7	7
Family	24	16	7	7
Simpson_1-D	0.8	0.8	0.6	0.7
Shannon_H	2.1	2.2	1.1	1.5

Table 4
Relative frequency (%) of specific richness and origin status of fruit tree species in the planned and unplanned neighborhoods of Lubumbashi and Kolwezi cities.

Family	Species	Lubumbashi		Kolwezi		Origin Status
		UP (n = 390)	P (n = 390)	UP (n = 360)	P (n = 140)	
Anacardiaceae	*Mangifera indica* L.	79.2	99.0	80.0	19.8	Ex
Anisophylleaceae	**Anisophyllea boehmii* Engl.	16.0	0.0	0.0	0.0	In
Annonaceae	*Annona muricata* L.	17.5	15.0	58.8	64.0	Ex
Annonaceae	*Annona squamosa* L.	0.0	19.8	0.0	0.0	In
Apocynaceae	**Landolphia kirkii* Dyer	20.0	0.0	0.0	0.0	In
Arecaceae	*Cocos nucifera* L.	14.8	12.8	0.0	0.0	Ex
Arecaceae	*Elaeis guineensis* Jacq.	40.4	36.6	79.2	19.8	In
Bixaceae	**Cochlospermum angolense* W.	11.5	0.0	0.0	0.0	In
Bombacaceae	*Bombacopsis glabra* (Pasquale) A. Robyns	19.8	13.6	0.0	0.0	Ex
Burseraceae	*Dacryodes edulis* (G. Don) H.J. Lam.	18.0	0.0	0.0	0.0	In
Caricaceae	*Carica papaya* L.	16.5	39.6	79.2	19.8	Ex
Chrysobalanaceae	**Parinari curatellifolia* Planch. ex Benth	17.5	0.0	0.0	0.0	In
Clusiaceae	*Garcinia mangostana* L.	19.8	0.0	0.0	0.0	Ex
Lauraceae	*Persea americana* M.	62.5	59.4	59.4	40.5	Ex
Loganiaceae	**Strychnos cocculoides* Baker.	14.3	19.8	0.0	0.0	In
Malvaceae	**Azanza garckeana* (F. Hoffm.) Exell & Hillc.	17.5	0.0	0.0	0.0	In
Moraceae	**Ficus* sp.	39.6	0.0	0.0	0.0	In
Moraceae	*Morus nigra* L.	20.0	16.0	0.0	0.0	Ex
Moraceae	*Artocapus heterophyllus* Lam.	15.0	18.8	0.0	0.0	Ex
Musaceae	*Musa* sp.	41.6	39.6	0.0	0.0	Ex
Myrtaceae	*Syzygium jambos* (L.) Alston	17.5	12.8	0.0	0.0	Ex
Myrtaceae	**Syzygium guineense* (Wild.) DC subsp *guineense*	16.0	6.9	0.0	0.0	In
Myrtaceae	*Psidium guajava* L.	35.6	38.9	39.6	16.8	Ex
Oxalidaceae	*Averrhoa carambola* L.	0.0	20.0	0.0	0.0	Ex
Passifloraceae	*Passiflora edulis* Sims.	20.0	16.0	0.0	0.0	Ex
Punicaceae	*Punica granatum* L.	18.0	0.0	0.0	0.0	Ex
Rosaceae	*Eriobotrya japonica* (Thunb.) Lindl.	17.8	12.0	0.0	0.0	Ex
Rosaceae	*Malus* sp.	17.0	0.0	0.0	0.0	Ex
Rosaceae	*Prunus* sp.	0.0	16.0	0.0	0.0	Ex
Rubiaceae	*Coffea canephora* Pierre ex A. Froehner.	17.2	0.0	0.0	0.0	In
Rutaceae	*Citrus limon* L.	40.0	18.0	99.0	39.6	Ex
Rutaceae	*Citrus maxima* (Burm.) Merr.	18.0	16.0	0.0	0.0	Ex
Rutaceae	*Citrus reticulata* Blanco.	15.0	12.5	18.5	19.8	Ex
Rutaceae	*Citrus sinensis* L.	18.9	20.0	20.5	59.4	Ex
Sterculiaceae	*Cola acuminata* (P. Bauv.) Shott et Endl.	17.8	0.0	0.0	0.0	In
Vitaceae	*Vitis* sp.	0.0	19.8	0.0	0.0	Ex

UP: Unplanned; P: planned; In = Indigenous; Ex = Exotic. Species preceded by * are characteristic of *Miombo* woodland (Malaisse, 2010; Meerts, 2016).

Table 5
Distribution (by families) of fruit tree species found in Lubumbashi and Kolwezi cities.

N°	Family	Lubumbashi		Kolwezi	
		Number of species	% of family	Number of species	% of family
1	Anacardiaceae	1	2.7	1	11.1
2	Anisophyllaceae	1	2.7	0	0.0
3	Annonaceae	2	5.4	1	11.1
4	Apocynaceae	1	2.7	0	0.0
5	Arecaceae	2	5.4	1	11.1
6	Bixaceae	1	2.7	0	0.0
7	Bombacaceae	1	2.7	0	0.0
8	Bursearaceae	1	2.7	0	0.0
9	Caricaceae	1	2.7	1	11.1
10	Chrysobalanaceae	1	2.7	0	0.0
11	Clusiaceae	1	2.7	0	0.0
12	Lauraceae	1	2.7	1	11.1
13	Loganiaceae	1	2.7	0	0.0
14	Malvaceae	1	2.7	0	0.0
15	Moraceae	3	8.1	0	0.0
16	Musaceae	1	2.7	0	0.0
17	Myrtaceae	3	8.1	1	11.1
18	Oxalidaceae	1	2.7	0	0.0
19	Passifloraceae	1	2.7	0	0.0
20	Punicaceae	1	2.7	0	0.0
21	Rosaceae	3	8.1	0	0.0
22	Rubiaceae	1	2.7	0	0.0
23	Rutaceae	4	10.8	3	33.3
24	Sterculiaceae	1	2.7	0	0.0
25	Vitaceae	1	2.7	0	0.0
Total	26	37	100.0	9	100.0

Table 6
Management and uses of fruit trees in planned and unplanned neighborhoods of Kolwezi and Lubumbashi.

	Lubumbashi		Kolwezi	
	UP(n = 390)	P(n = 390)	UP(n = 360)	P(n = 140)
Uses of fruit trees				
Commercial (%)	35.0	34.5	27.5	46.4
Medical (%)	63.0	44.0	12.3	17.9
Other (%)	15.5	38.0	70.4	70.0
Fruit consumption (%)	100.0	100.0	100.0	100.0
Knowledge about fruit trees requirements of fruit trees	0.0	0.0	0.0	0.0
Care of fruit trees (%)	47.3	29.9	44.3	17.1
Types of cares				
Organic fertilization (%)	100.0	100.0	100.0	100.0
Pruning (%)	100.0	100.0	100.0	100.0
Regularity of care on fruit trees (%)	0.0	0.0	0.0	0.0

P: Planned neighborhoods; UP: Unplanned neighborhoods.

pruning, performed irregularly though.

5. Discussion

5.1. Neighborhood types, plot characteristics and trees abundance

In D.R. Congo, the public land administration is characterized by unclear definition of the role of each administration, a lack of capacity

and a poorly supervised staff. This, coupled with the systematic lack of public budgeting, make it difficult to rigorously plan the expansion of cities (UN-Habitat, 2009; Useni et al., 2020). In this context, excessive urban sprawl become common place in the cities of Lubumbashi and Kolwezi, two rapidly-growing cities in the southeastern part of the country. This leads to a progressive replacement of *Miombo* woodland by built-up areas, thus the loss of trees in the urban environment (Useni et al., 2019). To compensate for such loss and that related to the scarcity of wooded green spaces, residents generally plant fruit trees or decide to keep inherited wild trees in their plots (Leblanc and Malaisse, 1978). For historical reasons (colonization) and due to the current difficulty for planners to properly manage green spaces (Gwedla and Shackleton, 2019), urban trees are generally unevenly distributed between and within cities.

Current results show that both Lubumbashi and Kolwezi cities possess a very young population, although people's age could not influence the preference or the presence of fruit trees (Etshekape et al., 2018). In the context of this study, planned neighborhoods are characterized by large plots, particularly in Lubumbashi. The superiority observed in Lubumbashi over Kolwezi may be linked to the presence of white population who once inhabited these sites during the colonial period. Conversely, the city of Kolwezi was created as a workers' city, explaining its relatively smaller residential plots (Leblanc and Malaisse, 1978; Nkuku and Rémon, 2006). Previously, a report by Sambiéni et al. (2018) suggested that there are a few large plots remaining in unplanned neighborhoods, and that the availability of spaces is favorable to the rapid densification of residential areas. In accordance with the view that plot size can influence the number of trees per plot (Hope et al., 2003) through the availability of space (Bernholt et al., 2009), current results revealed a significantly higher abundance of fruit trees in Lubumbashi than Kolwezi. Although residential plots are recognized as important places for tree conservation in urban areas (Goddard et al., 2010; Beninde et al., 2015), the number of people in a plot, especially the presence of children, influences their preservation through maintenance. Indeed, thanks to the availability of family labor, households with many children are more likely to plant or maintain fruit trees, especially in unplanned neighborhoods where the majority of households own properties (Etshekape et al., 2018), and where our results revealed a higher number of trees per 1000m^2.

5.2. Fruit trees flora in household plots

Current results have identified a total of 36 fruit tree species in Lubumbashi, which is significantly higher compared to the botanical diversity observed in Kolwezi (9 species). Plausibly, the edapho-climatic conditions of Kolwezi (soils majorly sandy and very cold dry seasons) that are less favorable to the establishment of most fruit species (Malaisse, 2010), may be raised to explain such poor tree diversity in this city. It is worth noting that the fruit tree species richness noted in Lubumbashi (36) remains a record when compared to previous results by Makumbelo et al. (2005) in Kinshasa (19 species) or by Salako et al. (2014) in Benin (9–11 species). Differences in climate, soil and socio-economic conditions could also explain these differences in reported results (Bernholt et al., 2009; Etshekape et al., 2018). For the city of Lubumbashi, compared to the study by Useni et al. (2019), the fruit tree species inventoried in our study in residential plots represent almost 42 % of the total tree flora studied in the city.

In the fruit tree flora listed across the two cities, Rutaceae remained the most represented family. In fact, this family exhibits a strong adaptation to a wider range of ecological conditions, thanks to the grafting technique regularly applied to them (Snoussi, 2013). Moreover, the Rutaceae family offers multiple uses *i.e* ornamental use, shading, fruit production, etc., an attribute favorable for their widespread presence in the two studied cities, which is also supported by data of current study. We may assume that the high frequency recorded for other fruit tree species like *Mangifera indica* in Lubumbashi or *Citrus limon* in Kolwezi could be a result of human preference as well, stemming from the ecosystem services provided by these species including shade, edible fruits, or ornamental flowers. For *M. indica* particularly, additional services are gained from the use of its leaves and bark as ingredients in traditional medicine; hence, this plant species is steadily becoming popular, despite his tag as an introduced species. Besides *M. indica and C. limon*, fruit trees listed in this study include safou (*Dacryodes edulis*), avocado (*Persea americana*), mangosteen (*Garcinia mangostana*) and papaya (*Carica papaya*) that produce fruits, seeds and nuts for domestic consumption and commercialization in the region and abroad. The other fruits listed in the present study are consumed as snacks and are highly traded as well. In this context, it is apparent that the urban vegetation in the two cities was gradually shaped by humans to meet their different needs. This view is shared by Bernholt et al. (2009) and Makumbelo et al. (2008) who also concluded that plots in African cities very often contain introduced species, useful for cultural, socio-economic and ecological purposes.

Generally, by shaping urban vegetation in accordance with their needs, humans inadvertently allow dominance of exotic species over native species. The latter are therefore ecologically threatened with the extension of cities (McKinney, 2008; Savard et al., 2000). To avoid this and to maintain botanical diversity, it is advisable to preserve local fruit trees species inherited in the plots (Davenport et al., 2011; Jamnadass et al., 2011), particularly during the process of extension and densification of built-up. In this sense, the presence of some *Miombo* woodland species in unplanned neighborhood of Lubumbashi city may be considered as plausible evidence of a certain level of integrity or regeneration of some species (Useni et al., 2019). In this study, a higher number of *Miombo* fruit trees per plot was found in unplanned neighborhoods. Mainly located in periurban areas, unplanned neighborhoods present hybrid ecological conditions of the *Miombo* woodland that surrounded the city and disturbed (urban) habitats (Bogaert et al., 2015).

The urbanization process in the cities of Kolwezi and Lubumbashi creates heterogeneous urban terrains with new environmental conditions that can allow only adapted species to survive (Williams et al., 2009). In unplanned neighborhoods, these fruit trees could be rapidly damaged following spatial changes due to uncontrolled building expansion (Shackleton et al., 2015). In planned neighborhoods where residents are tenants, the lack of security of tenure and limited space (André et al., 2014) could be mentioned as deterrents to activities of trees planting. Compared to planned neighborhoods, residents in unplanned neighborhoods could be in majority owners of their land, hence they are more likely to plant trees in their plots (McConnachie et al., 2008; Shackleton and Blair, 2013). This echoes the findings of Shackleton et al. (2015) suggesting that residents who own their homes are more likely to plant trees than residents who do not own their homes. And in the context of the city of Kinshasa, the lack of land ownership was identified as one of main constraints to planting fruit trees in urban and peri-urban areas (Etshekape et al., 2018).

5.3. Multiple benefits of fruit trees and their management

In unplanned neighborhoods, the systematic cutting of trees during the construction of houses, combined with the absence of paved roads, increases the sensitivity of these areas to dust, wind and high temperatures. For these reasons, planting fruit trees in plots of these areas contributes in improving the living environment by regulating the microclimate or capturing dust (Atangana et al., 2014). According to Etshekape et al. (2018), fruit production and shade supply are regarded as the main reasons for social acceptability of fruit tree planting in the peri-urban areas of Kinshasa. For the present study, beyond food services (observed at 100 % in both cities), fruit trees in residential plots are also destined to commercial activities. In fact, following the socio-political instability in D.R. Congo (1997–2004), Lubumbashi and Kolwezi cities experienced sustained demographic growth, worsening the unemployment rate (Lebailly, 2010). Urban agriculture and urban forestry have

always been a refuge sector offering means for additional incomes for poor households. This clearly justifies the commercial and food role of fruit trees (Kalaba et al., 2009; Murwendo, 2011). In both Lubumbashi and Kolwezi, fruits harvested during the rainy season (mangoes, guavas, etc.) are sold in front of the plots and/or in urban markets. Similar local fruit trades have also been noted in the city of Kisangani and Kinshasa (D.R. Congo) (Makumbelo et al., 2005; Termote et al., 2012). Likewise, Kaoma and Shackleton (2015) found that up to 33 % of household income in poor neighborhoods in the municipalities of Bela Bela, Tzaneen and Zeerust (South Africa) could be gained from the sale of products from trees in public and private urban green spaces.

Due to the high cost of access to modern health services, traditional medicine is gaining importance in African cultures, reflected by the attention accorded to multipurpose trees with medicinal properties in residential plots (Kahumba et al., 2015). The interest for medicinal trees was also demonstrated by current results in both Lubumbashi and Kolwezi cities. However, their extent of use varies across cities, with Kolwezi showing a lower number of residents using traditional medicine. Contrast to Lubumbashi were informal and low-income activities predominate, Kolwezi benefits from formal employment activities, guaranteeing decent salary and easy access to modern health care, thus obviating the need to rely on traditional medical care. This may explain the differential trend observed between the two cities.

Results of this study further delineated that irrespective of the city or the type of neighborhood, the use of different fruit trees for care is well known by local population. Makumbelo et al. (2008) also showed that 64 % of respondents in Kinshasa city were aware of at least one medicinal recipe from fruit tree species, to treat mainly diseases of the digestive and the respiratory systems.

Normally, the interest shown by plot owners for ecosystem services provided by fruit trees would imply their regular maintenance (Ngur--Ikone, 2010; Cameron et al., 2012). Despite such awareness however, it was puzzling that the investigated populations in Lubumbashi or Kolwezi lacked sufficient knowledge about the ecological requirements of planted fruit trees. Consequently, the exploitation of the leaves and roots of fruit trees often lead to a deterioration of their physiological status. The low proportion of residents involved in fruit tree maintenance observed in planned neighborhoods (generally with high aesthetic prestige) is thought to be connected to the relatively high financial possibilities to hire gardeners (Iverson and Cook, 2000; Pedlowski et al., 2003; André et al., 2014; Shackleton et al., 2014; Useni et al., 2017b). Deterred by the high cost related to tree maintenance, the essential of fruit trees maintenance in investigated neighborhoods consisted in organic fertilization, probably favored by the practice of yard sweeping providing opportunity to piling household waste at the foot of trees. Besides organic fertilization, trees pruning was identified as another low-cost activity of trees maintenance, mostly observed in planned neighborhoods where fruits trees have been inherited, and are currently at an advanced age (Dapilah et al., 2019). It is worth noting that due to water scarcity, maintenance care such as watering was quasi unmentioned in the context of the current study, corroborating the opinion that water scarcity is a major constraint to the planting and maintenance of trees in the plots during the dry season (Shackleton et al., 2015). Although some households may possess wells, the considerable drop in water level during the dry season still makes tree watering a difficult task. And under some circumstances, the poor quality of water (i.e. higher concentration of trace metals) makes the task even worthless (Atibu et al., 2013; Balloy et al., 2019).

6. Conclusion

The present study provides insights into the use of urban fruit trees in relation to the level of land use planning in neighborhoods of Lubumbashi and Kolwezi, two rapidly urbanizing cities in the Southeastern part of D.R. Congo. Obtained results revealed a multiplicity of services provided by the listed floras in investigated neighborhoods, including urban food forestry, medicinal use and a number of environmental benefits. Further, results demonstrated notable variation in the diversity of fruit trees between the type of neighborhoods (planned and unplanned), and between the two studied cities (Lubumbashi and Kolwezi), which is mainly driven by differences in socio-economic conditions of populations and ecological conditions of investigated sites. As a common trend however, majority of species identified in the two cities were found to be exotic, suggesting a tendency to homogenisation of urban vegetation at the expense of native fruit tree species, although some *Miombo* woodland species were identified in unplanned neighborhoods of Lubumbashi city notably. Overall, current results call for measures to preserve the last *Miombo* woodland in Lubumbashi, while adopting a master plan for their sustainable integration and management in the two studied cities. Moreover, measures to promote urban forestry with native species and to limite the expansion of exotic species are needed.

Author contributions

Conceptualization: YUS, TMM, FM & JB; Data collection: YUS & JYM; Formal analysis: YUS; Funding acquisition: YUS & JB; Investigation: YUS & JYM; Methodology: YUS, FM, JYM, & JB; Project administration: YUS & JB; Resources: YUS & JB; Software: YUS, TMM & JYM; Supervision: YUS & JB; Validation: YUS, FM, JYM, TMM & JB; Writing - original draft: YUS; Writing - review & editing: YUS, FM, JYM, TMM & JB.

Declaration of Competing Interest

The authors report no declarations of interest.

Acknowledgements

The authors are grateful to the local authorities of Kolwezi and Lubumbashi cities who helped them to conduct the study. The research was funded by the ARES-CCD (Belgium), via CHARLU project.

References

André, M., Mahy, G., Lejeune, P., Bogaert, J., 2014. Vers une synthèse de la conception et d'une définition des zones dans le gradient urbain-rural. Biotechnol. Agron. Soc. Environ. 18 (1), 61–74.

Angel, S., Parent, J., Civco, D.L., Blei, A.M., 2011. Making Room for a Small Planet of Cities. Lincoln Institute of Land Policy, Cambridge, MA, USA.

Atangana, A., Khasa, D., Chang, S., Degrande, A., 2014. Tropical Agroforestry. Springer, 380 pages with Index.

Atibu, K.E., Devarajan, N., Thevenon, F., Mwanamoki, P.M., Tshibanda, J.B., Mpiana, P. T., Prabakar, K., Mubedi, J.I., Wildi, W., Poté, J., 2013. Concentration of metals in surface water and sediment of Luilu and Musonie Rivers, Klowezi-Katanga, Democratic Republic of Congo. Appl. Geochem. 39, 26–32.

Balloy, M.P., Katond, J.-P., Hanocq, P., 2019. Evaluation de la qualité physico chimique et bactériologique des eaux de puits dans le quartier spontané de Luwowoshi (RD Congo). Tropicultura [En ligne] 37 (2019). Numéro 2.

Beatley, T., 2000. Preserving biodiversity. Challenges for planners. J. Am. Plann. Assoc. 66 (1), 5–20.

Beninde, J., Veith, M., Hochkirch, A., 2015. Biodiversity in cities needs space: a meta-analysis of factors determining intra-urban biodiversity variation. Ecol. Lett. 18, 581–592.

Bernholt, H., Kehlenbeck, K., Gebauer, J., Buerkert, A., 2009. Plant species richness and diversity in urban and peri-urban gardens of Niamey, Niger. Agrofor. Syst. 77, 159–179.

Bigirimana, J., Bogaert, J., De Cannière, C., Lejoly, J., Parmentier, I., 2011. Alien plant species dominate the vegetation in a city of Sub-Saharan Africa. Landsc. Urban Plan. 100, 251–267.

Bogaert, J., Biloso, A., Vranken, I., André, M., 2015. Peri-urban dynamics: landscape ecology perspectives. In: Bogaert, J., Halleux, J.-M. (Eds.), Territoires périurbains: développement, enjeux et perspectives dans les pays du sud. Les presses agronomiques de Gembloux, Gembloux, Belgique, pp. 63–73.

Bultot, F., 1950. Carte des régions climatiques du Congo Belge établies d'après les critères de Köppen. Bureau climatique, Institut National pour l'Etude Agronomique au Congo-Belge, Bruxelles, Belgique.

Cabala, K.S., Useni, S.Y., Sambiéni, K.R., Bogaert, J., Munyemba, K.F., 2017. Dynamique des écosystèmes forestiers de l'Arc Cuprifère Katangais en République Démocratique du Congo. I. Causes, transformations spatiales et ampleur. Tropicultura 35 (3), 192–202.

Cameron, R.W.F., Blanusa, T., Taylor, J.E., Salisbury, A., Halstead, A.J., Henricot, B., Thompson, K., 2012. The domestic garden—its contribution to urban green infrastructure. Urban For. Urban Green. 11, 129–137.
Dapilah, F., Nielsen, J.Ø., Akongbangre, J.N., 2019. Peri-urban transformation and shared natural resources: the case of shea trees depletion and livelihood in Wa municipality, Northwestern Ghana. Afr. Geogr. Rev. 38 (4), 374–389.
Davenport, N.A., Gambiza, J., Shackleton, C.M., 2011. Use and users of municipal commonage around three small towns in the Eastern Cape, South Africa. J. Environ. Manage. 92, 1449–1460.
Dupin, L., Nkono, C., Burlet, C., Muhashi, F., Vanbrabant, Y., 2013. Land cover fragmentation using multi-temporal remote sensing on major mine sites in Southern Katanga (Democratic Republic of Congo). Adv. Remote Sens. 2 (2), 127–139.
Etshekape, P.G., Atangana, A.R., Khasa, D.P., 2018. Tree planting in urban and peri-urban of Kinshasa: survey of factors facilitating agroforestry adoption. Urban For. Urban Green. 30, 12–23.
Fanan, U., Dlama, K.I., Oluseyi, I.O., 2011. Urban expansion and vegetal cover loss in and around Nigeria Federal Capital City. J. Ecol. Nat. Environ. 3 (1), 1–10.
Goddard, M.A., Dougill, A.J., Benton, T.G., 2010. Scaling up from gardens: biodiversity conservation in urban environments. Trends Ecol. Evol. 25, 90–98.
Gwedla, N., Shackleton, C.M., 2019. Perceptions and preferences for urban trees across multiple socio-economic contexts in the Eastern Cape, South Africa. Landsc. Urban Plan. 189, 225–234.
Harjoaba, I., Malaisse, F., 1978. Le régime journalier des précipitations et les types de pluies à Lubumbashi. Geo-Eco-Trop 2 (4), 401–414.
Hope, D., Gries, C., Zhu, W., Fagan, W.F., Redmanm, C.L., Grimm, N.B., Nelson, C.M., Kinzig, A., 2003. Socioeconomics drive urban plant diversity. Proc. Natl. Acad. Sci. U. S. A. 100, 8788–8792.
Iverson, L.R., Cook, E.A., 2000. Urban forest cover of the Chicago region and its relation to household density and income. Urban Ecosyst. 4, 105–124.
Jamnadass, R.H., Dawson, I.K., Franzel, S., Leakey, R.R.B., Mithöfer, D., Akinnifesi, F.K., Tchoundjeu, Z., 2011. Improving livelihoods and nutrition in sub-Saharan Africa through the promotion of indigenous and exotic fruit production in smallholders' agroforestry systems: a review. Int. For. Rev. 13 (3), 338–354.
Kabir, E., Webb, E.L., 2008. Floristics and structure of southwestern Bangladesh homegardens. Int. J. Biodivers. Sci. Ecosyst. Serv. Manag. 4 (1), 54–64.
Kahumba, J., Rasamiravaka, T., Okusa Ndjolo, P., Bakari, S.A., Bizumukama, L., Kiendrebeogo, M., Rabemenantsoa, C., El Jaziri, M., Williamson, E.M., Duez, P., 2015. Traditional African medicine: from ancestral knowledge to a modern integrated future. Science 350 (6259 Suppl), S61–S63.
Kalaba, F.K., Chirwa, P.W., Prozesky, H., 2009. The contribution of indigenous fruit trees in sustaining rural livelihoods and conservation of natural resources. J. Hortic. For. 1, 1–6.
Kaoma, H., Shackleton, C.M., 2014a. Collection of urban tree products by house-holds in poorer residential areas of three South African towns. Urban For. Urban Green. 13, 244–252.
Kaoma, H., Shackleton, C.M., 2014b. Homestead greening is widespread amongst the urban poor in three medium-sized South African towns. Urban Ecosyst. 17, 1191–1207.
Kaoma, H., Shackleton, C.M., 2015. The direct-use value of urban tree non-timber forest products to household income in poorer suburbs in South African towns. For. Policy Econ. 61, 104–112.
Kestemont, B., Frendo, L., Zaccai, E., 2011. Indicators of the impacts of development on environment: a comparison of Africa and Europe. Ecol. Indic. 11 (3), 848–856.
Kikufi, B.A., Lukoki, L.F., 2008. Aperçu de la végétation des sites miniers de Kolwezi au sud Katanga. Rev. Cong. Sci. Nucl. 23 (1), 21–32.
Lebailly, P., 2010. Rapide évaluation de l'impact de la crise du secteur minier de la zone Lubumbashi-Likasi-Kolwezi de la province du Katanga (RD Congo) et des potentialités en terme de promotion de l'emploi. La problématique agricole. Rapport Final. BIT. https://www.gembloux.ulg.ac.be/economie-et-developpement-rural/wp-content/uploads/sites/34/2018/10/2013_LEBAILLY_Rapide-%c3%a9valuation-de-l-impact-de-la-crise-du-secteur-minier-emploi-Katanga.pdf.
Leblanc, M., Malaisse, F., 1978. Lubumbashi, un écosystème urbain tropical. Centre International de Sémiologie, Université Nationale du Zaïre, 166p.
Lebrun, J.-P., Stork, A.L., 2015. Enumération des plantes à fleurs d'Afrique tropicale et Tropical African Flowering Plants: Ecology and Distribution, vol. 1–7. Conservatoire et Jardin botaniques de la Ville de Genève.
Makumbelo, E., Paulus, J.J., Luyindula, N., Lukoli, L., 2005. Apport des arbres fruitiers à la sécurité alimentaire en milieu urbain tropical: cas de la commune de Limete à Kinshasa, R.D Congo. Tropicultura 23 (4), 245–252.
Makumbelo, E., Lukoli, L., Paulus, J.J., Luyindula, N., 2008. Stratégie de valorisation des espèces ressources des produits non ligneux de la savane des environs de Kinshasa: II. Enquête ethnobotanique (aspects médicinaux). Tropicultura 26 (3), 129–134.
Malaisse, F., 2010. How to live and survive in Zambezian open forest (miombo ecoregion). Les Presses agronomiques de Gembloux, Gembloux(Belgique), 422p.
Malaisse, F., Malaisse-Mousset, M., Schorochoff, G., 1978. Analyse de la pluviosité à Lubumbashi et dans ses environs immédiats. Contribution à l'étude de l'écosystème forêt claire (Miombo). Geo-Eco-Trop 2 (3), 301–315.
McConnachie, M.M., Shackleton, C.M., McGregor, G.K., 2008. The extent of public green space and alien plant species in 10 small towns of the Sub-Tropical Thicket Biome, South Africa. Urban For. Urban Green. 7 (1), 1–13.
McKinney, M.L., 2008. Effects of urbanization on species richness. A review of plants and animals. Urban Ecos. 11 (2), 161–176.
Meerts, P., 2016. An annotated checklist to the trees and shrubs of the Upper Katanga (D. R. Congo). Phytotaxa 258 (3), 201–250.
Mensah, C.A., 2014. Urban green spaces in Africa: nature and challenges. Int. J. Ecosyst. 4 (1), 1–11.
Murwendo, T., 2011. Improving urban livelihoods at household level through sustainable utilisation of peri-urban forests in Masvingo City. J. Sustain. Dev. Africa 13, 299–313.
Nagendra, H., Gopal, D., 2010. Street trees in Bangalore: density, diversity, composition and distribution. Urban For. Urban Green. 9 (2), 129–137.
Ngur-Ikone, J., 2010. La politique publique de la gestion des espaces verts par l'hôtel de ville de Kinshasa. Afrique dev. 35 (3), 13–46.
Nkuku, C., Rémon, M., 2006. Stratégies de survie à Lubumbashi (R-D Congo). Enquête sur 14000 ménages urbains. Archive congolaise, Harmattan, Paris, 2006.
Pedlowski, M.A., Da Silva, V.A., Adell, J.J., Heynen, N.C., 2003. Urban forest and environmental inequality in Campos dos Goytacazes, Rio de Janeiro. Brazil. Urban Ecosyst. 6, 9–20.
Pyšek, P., Richardson, D.M., Rejmanek, M., Webster, G.L., Williamson, M., Kirschner, J., 2004. Alien plants in checklists and floras: towards better communication between taxonomists and ecologists. Taxon 53, 131–143.
Rija, A.A., Said, A., Mwamende, K.A., Hassan, S.H., Madoffe, S.S., 2014. Urban sprawl and species movement may decimate natural plant diversity in an Afro-tropical city. Biodivers. Conserv. 23, 963–978.
Salako, V.K., Fandohan, B., Kassa, B., Assogbadjo, A.E., Idohou, A.F.R., Gbedomon, R.C., 2014. Home gardens: an assessment of their biodiversity and potential contribution to conservation of threatened species and crop wild relatives in Benin. Genet. Resour. Crop Evol. 61 (2), 313–330. https://doi.org/10.1007/s10722-013-0035-8.
Sambiéni, K.R., Biloso, M.A., Scholastique, T.M., Occhiuto, R., Bogaert, J., Dossou, B., 2018. La végétation arborée domestique dans le paysage urbain et périurbain de la ville de Kinshasa, République Démocratique du Congo. Afrique Sci. 14 (2), 197–208.
Savard, J.P.L., Clergeau, P., Mennechez, G., 2000. Biodiversity concepts and urban ecosystems. Landsc. Urban Plan. 48, 131–142.
Shackleton, C.M., Blair, A., 2013. The abundance of urban public green space influences residents' perceptions, uses and willingness to get involved in two small towns in South Africa. Landsc. Urban Plan. 113, 104–112.
Shackleton, C.M., Hebinck, P., Kaoma, H., Chishaleshale, M., Chinyimba, A., Shackleton, S.E., Gambiza, J., Gumbo, D., 2014. Low-cost housing developments in South Africa miss theopportunity for household level urban greening. Land Use Policy 36, 500–509.
Shackleton, S., Chinyimba, A., Hebinck, P., Shackleton, C., Kaoma, H., 2015. Multiple benefits and values of trees in urban landscapes in two towns in northern South Africa. Landsc. Urban Plan. 136, 76–86.
Snoussi, H., 2013. Diversité Génétique Intra et Interspécifique des Porte-greffes d'Agrumes utilisés en Tunisie. Apport des marqueurs SSRs nucléaires, des *InDel* mitochondriaux et de la diversité allélique de gènes candidats pour la tolérance à la salinité. Institut National Agronomique de Tunisie. PhD thesis.
Socolar, J.B., Gilroy, J.J., Kunin, W.E., Edwards, D.P., 2016. How should beta-diversity inform biodiversity conservation? Trends iEcol. Evol. 31 (1), 67–80.
Termote, C., Meyi, M.B., Djailo, B.D., Huybregts, L., Lachat, C., Kolsteren, P., Van Damme, P., 2012. A biodiverse rich environment does not contribute to a better diet: a case study from DR Congo. PLoS One 7, e30533.
UN-Habitat, 2009. Document des programmes pays : République Démocratique du Congo. Publication de l'UN-Habitat, 24p.
UN-Habitat, 2014. The state of African cities 2014. Re-imagining sustainable urban transition. Human Settlements Programs. United Nations, 273p.
United Nations, 2018. The World's Cities in 2018—Data Booklet (ST/ESA/ SER.A/417).
United Nations, 2019. World Population Prospects 2019: Highlights (ST/ESA/SER.A/423).
Useni, S.Y., Malaisse, F., Cabala, K.S., Munyemba, K.F., Bogaert, J., 2017a. Le rayon de déforestation autour de la ville de Lubumbashi (Haut-Katanga, R.D. Congo): synthèse. Tropicultura 35 (3), 215–221.
Useni, S.Y., Cabala, K.S., Malaisse, F., Nkuku, K.C., Amisi, M.Y., Bogaert, J., Munyemba, K.F., 2017b. Vingt-cinq ans de monitoring de la dynamique spatiale des espaces verts en réponse à l'urbanisation dans les communes de la ville de Lubumbashi (Haut-Katanga, R.D. Congo). Tropicultura 35 (4), 300–311.
Useni, S.Y., Cabala, K.S., Halleux, J.-M., Bogaert, J., Munyemba, K.F., 2018a. Caractérisation de la croissance spatiale urbaine de la ville de Lubumbashi (Haut-Katanga, RD Congo) entre 1989 et 2014. Tropicultura 36 (1), 99–108.
Useni, S.Y., Sambiéni, K.R., Maréchal, J., Ilunga, W.I.E., Malaisse, F., Bogaert, J., Munyemba, K.F., 2018b. Changes in the spatial pattern and ecological functionalities of green spaces in Lubumbashi (the Democratic Republic of Congo) in relation with the degree of urbanization. Trop. Conserv. Sci. 11, 1–17.
Useni, S.Y., Malaisse, F., Cabala, K.S., Kalumba, M.A., Mwana, Y.A., Nkuku, K.C., Bogaert, J., Munyemba, K.F., 2019. Tree diversity and structure on green space of urban and peri-urban zones: the case of Lubumbashi City in the Democratic Republic of Congo. Urban For. Urban Green. 41, 67–74.
Useni, S.Y., Boisson, S., Cabala, K., Nkuku, K.C., Malaisse, F., Halleux, J.-M., Munyemba, K.F., Bogaert, J., 2020. Dynamique de l'occupation du sol autour des sites miniers le long du gradient urbain-rural de la ville de Lubumbashi, RD Congo. Biotechnol. Agron. Soc. Environ. 24 (1), 1–14.
Vermeiren, K., Van Rompaey, A., Loopmans, M., Serwajja, E., Mukwaya, P., 2012. Urban growth of Kampala, Uganda: pattern analysis and scenario development. Landsc. Urban Plan. 106 (2), 199–206.
Williams, N.S.G., Schwartz, M.W., Vesk, P.A., McCarthy, M.A., Hahs, A.K., Clemants, S. E., Corlett, R.T., Duncan, R.P., Norton, B.A., Thompson, K., McDonnell, M.J., 2009. A conceptual framework for predicting the effects of urban environments on floras. J. Ecol. 97 (1), 4–9.