NATIONAL UNIVERSITY OF RWANDA

FACULTY OF SCIENCE

BIOLOGY DEPARTMENT

BIODIVERSITY CONSERVATION

BIRD DIVERSITY AND DISTRIBUTION IN RELATION TO LANDSCAPE TYPES IN MUSANZE CITY, NORTHERN RWANDA

Thesis submitted in partial fulfillment of the requirements for the award of a MSc Degree in Biodiversity Conservation

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Huye, December 2012

DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and has not previously in its enterety or in part been submitted at any university for a degree.

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Signature Date

DEDICATION

This thesis is dedicated to my beloved husband Jean Léonard Seburanga, my lovely daudgters Raham Tess Teta and Raham Grace Ganza and my dear parents Sylvestre Mubashankwaya and Pulchérie Kamukera.

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ABSTRACT

A large number of wildlife survives outside protected areas on farmlands, pasturelands, and urban areas. Among all faunas, birds are one of most present wild animals in cities. Birds fulfill many ecological functions in their habitats, playing an important role in seed dispersal of fleshy fruit-producing plants. The landscape of the Musanze District has been undergoing major changes due to rapid urbanization driven by a fast growing human population. To ensure that bird-provided ecosystem services in Musanze City, Rwanda, are enjoyed by communities at an appropriate level for both current and next generation, a study of the effect of urban fabric lay out on its bird diversity and distribution was conducted. Linear mixed models (LMM) were used to assess whether landscape types have an effect on bird abundance and diversity. The Shannon's diversity index was used to identify the diversity of bird species in Musanze City. One Albertine Rift endemic bird species, the Ruwenzori double-collared sunbird (*Cinnyris stuhlmanni*) was recorded. Three migratory birds were found in Musanze City for the first time: the Common Sandpiper (*Actitis hypoleucos*), the Spotted Flycatcher (*Muscicapa striata*) and the Willow Warbler (*Phylloscopus trochilus*). Two bird species have not been previously reported in Rwanda: the Garden Warbler (*Sylvia borin*) and the Lesser Spotted Eagle (*Aquila pomarina*). An effect of city landscape types on the bird richness and relative abundance was also highlighted; residential neighborhood, institutional grounds and informal settlements were found to have highest species diversity indices compared to the rest of micro-landscape types. Riverside emerged as the landscape type with a specialized bird fauna, which are known to be restricted to the wetland environment. However, as a whole, built-up and open field categories had comparable results. Scavengers appeared to contribute more to biomass recycling than any other bird category. This study should help urban decision makers take into account the existence of a great diversity of avian fauna when developing and implementing land use plans, especially when villages and cities are in proximity of protected areas or natural reserves. Botanical gardens and public parks should be included in the master plan of the City.

Keywords: Bird diversity and abundance; Landscapes; Musanze city; Richness.

I. INTRODUCTION

With the majority of people expected to live in urban areas by the year 2050 all over the world (Loss et al., 2009), biological threats, inherent to such a rapid urbanization, raise concerns over the future of the already reduced diversity in peri-urban neighborhood settings (Evans et al., 2011). In particular, bird populations have been declining as a result of landscape change due to urban expansion (Coppedge et al., 2001; Evans et al., 2009; Strohbach et al., 2009). At the local level, major changes include high rates of land conversion into urban uses and increasing human pressure on biodiversity due to rapid population growth.

In many developing countries, a large number of wildlife survives outside protected areas on farmlands, pasturelands, and urban areas (Bolwig et al., 2006; Dunnett and Hitchmough, 2004). Among all faunas, birds are one of most present wild animals in cities (Austin and Smith, 1972). Due to the important role that birds play on earth, they receive special attention from people all over the world, who seek their protection and help to reduce environmental threats (Stevenson and Fanshawe, 2002).

Birds fulfill many ecological functions in their habitats. For instance, they are bio-indicators of healthy ecosystems (Mistry et al., 2008; Slabbekoorn and Ripmeester, 2008). Insectivorous and raptors regulate disease-vectors including mosquitoes and rodents. Scavenger birds such as the pied crow (*Corvus albus*) contribute to biomass recycling and to some degree they reduce the amount of disposable wastes. Frugivorous birds play an important role in seed dispersal of fleshy fruit-producing plants (Stevenson and Fanshawe, 2002). Birds are also important in pollination like sunbirds who participate in cross-breeding of flowering plants, especially those with bird-pollination syndrome (Judd et al., 2008). To ensure that the above-mentioned bird-provided ecosystem services are available to communities at an appropriate level for both current and next generation, there is a pressing need to study the dynamics and socio-economics of bird diversity outside protected areas, especially in urban areas.

The landscape of the Musanze District in the Northern Province of Rwanda has been undergoing major changes due to rapid urbanization driven by a fast growing human population (Weber,

1987). Up to 1,000 people live per km^2 in some areas (Sabuhoro and Bush, 2008) and the high rate of land use conversion into urban in Musanze is threatening the wild avian diversity as it is the case for other fast growing cities in the world (Staniforth, 2002). More than half of the total Rwandan population is expected to live in urban areas in less than 40 years (Sano, 2007).

While wild avian diversity has been a subject of research in natural habitats of the Northern Province, especially in the Parc National des Volcans (VNP) and the Buhanga Eco-Park, the biodiversity of the neighboring Musanze City, like many other anthropogenic landscapes, remain understudied. This study aimed to address the issue of ecological bias in bird diversity and distribution in fast growing cities and to propose strategies for effective conservation of birds in urban areas of Rwanda, in general, and of Musanze City, in particular. It provides policy makers and conservationists with scientific information about the ecological status of birds in Musanze City and how species are distributed in the city in relation to the urban fabric layout.

Therefore, the main objective of this study was to assess the diversity and distribution of birds in urban landscape types of the Musanze City. Specifically, the study aimed (1) to identify bird species that live in or visit Musanze City; (2) to identify bird feeding guilds as well as bird abundance and diversity in different landscape types in Musanze (3) to locate areas of the city that show high bird diversity, hereafter referred to as 'urban bird hotspots'; and finally (4) to compare the bird diversity in Musanze City with the bird diversity found in the VNP and Buhanga Eco-park, which are two important ecological zones in the administrative district where Musanze City is located.

II. MATERIALS AND METHODS

II.1 Study area

Musanze District is situated in the northwestern highlands of Rwanda and is one of five administrative districts of the Northern Province. The study was carried out within MusanzeCitywhich comprises four sectors: Muhoza, Cyuve, Musanze and Kimonyi and covering a total area of 61.97 km² (Fig. 1). Musanze Cityis one of the largest and fast growing urban centers in Rwanda. It is a central hub for businesses, trade and tourism. The VNP with its famous mountain gorillas, the Buhanga eco-park and the Ruhondo Lake found in the same district make the City popular destination for national and international tourists (www.musanze.gov.rw, 30.12.2012).

II.2 Landscape Stratification

Landscapes of Musanze City can be classified into two major categories, open fields and built-up areas. Open fields consist of agricultural fields, cemeteries, wastelands, stream banks, forests, and the aerodrome. Built-up areas include business centers, institutional grounds, settlements, and residential neighborhoods.

Agricultural fields refer to cultivated lands that are located within Musanze peri-urban areas, with maize and beans being the most common crops. Cemeteries are places where deceased people are buried. In this study, two cemeteries were included in our sampling sites, in Muhoza (Nyamagumba) and Cyuve sectors. Wastelands are places dedicated to household solid waste disposal. Two wastelands were considered for the study, one close to Musanze business center and another in Cyuve. Stream banks encompass habitats on both sides of permanent or seasonal river flows. Forests included areas covered by tree plantations, mainly Eucalypts. Natural forests were not found within the city boundaries. The Musanze aerodrome is a non-paved strip covered by a regularly mown lawn of about 1.5km length.

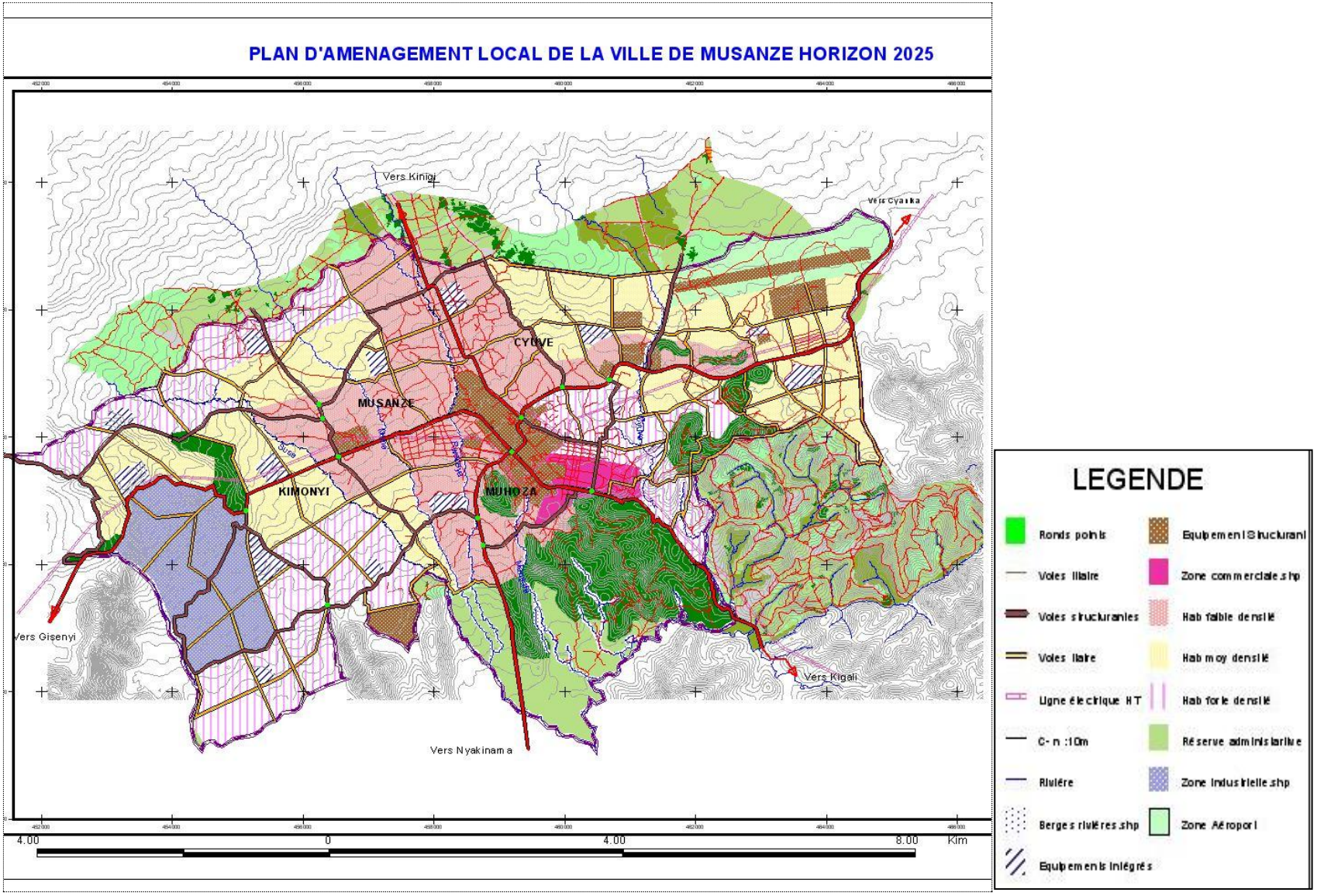


Figure 1. Musanze City map (PIGU, 2005)

In this study, business centers include market places and areas with a high concentration of shops. Institutional grounds comprise gardens of large institutions such as the district office and Musanze hospital, one university and a high school, as well as the city animal slaughterhouse. Informal and non-formal settlements include organized village settlements and rural type scattered settlements, where banana plantations are the most common crop in the home gardens. Residential neighborhoods are high standard settlement areas of the city.

II.3 Data Collection

During March 2012, data were collected within plots using the point count method (Gibbons and Gregory, 2006). The sampling design consisted of a series of points, referred to as point count or circular-plot survey units at which birds were counted within a defined radius (Johnson, 1995). Forty 50m-radius plots were established; 20 in open fields and other 20 in built-up areas (Tab. 1). A global positioning system (GPS) unit was used to locate sampling plots on the ground. Two to five plots were selected to each micro-landscape type (Tab. 1) within a 0.4x0.4km grid at a rate of one plot per grid cell. Each plot was visited four times each time for a 10min-observation period (Haslem and Bennett, 2008), making160 visits in total. The visits at each plot were equally distributed across four day time periods: early morning (6:30-8:30), late morning (9:00-11:00), early evening (15:00-17:00) and late evening (17:30-18:30). Since the weather can influence the occurrence of birds (Rurangwa, 2011), working during rain or strong wind was avoided.

Table 1. Distribution of plots across micro-landscape types and administrative sectors

Landscape types	Category	Sectors	Number of plots
Aerodrome	Open field	Muhoza	2
Agro-fields	Open field	Muhoza,Cyuve	5
Business centers	Built-up	Musanze, Muhoza, Cyuve	5
Cemeteries	Open field	Muhoza	2
Forests	Open field	Musanze, Muhoza, Cyuve	5
Institutional grounds	Built-up	Musanze, Muhoza	5
Residential neighborhood	Built-up	Muhoza	5
Riversides	Open field	Muhoza	2
Informal settlements	Built-up	Kimonyi, Muhoza	5
Streamsides	Open field	Musanze	2
Wastelands	Open field	Muhoza, Cyuve	2

A bird expert was present in most of our field visits. A pair of 8x42 resolution binoculars (Olympus mark) and a field guide book were also used to identify birds (Stevenson and Fanshawe, 2002). Once at the plot, the center of the plot was chosen whenever possible to observe bird movements within the plot's radius and 5minutes were spent before data collection in order to let birds to resettle. The following records were taken during each 10-min observation period: number of plot, micro-landscape type, arrival time, departure time, species names of birds observed, number of individuals by bird species, weather conditions, vegetation cover, and any kind of disturbance such as noises from vehicles or machines and human presence.

Birds encountered outside of our study plots were noted only when it was a new species never observed before. However, these were excluded from statistical analysis. Instead, these records were considered for compiling a bird checklist of Musanze City. When a bird could not be identified in the field, photos and descriptive notes were taken for a later identification by a bird expert. Photos were taken using an EOS 600D Canon digital camera.

II.5 Data Analysis

The Linear Mixed Models (LMM) method was used to analyze relationships between landscape types and bird abundance and species richness. LMM became recently a most useful tool used to analyze continuous repeated measures data from a sample of individuals in different areas (Arellano-Valle et al., 2005). It is a statistical model that consists of both fixed effects and random-effects terms (Bates, 2005). In this study, LMM were used to assess whether urban landscape types have an effect on bird abundance and species richness. Landscape types (macro and micro-landscape types) were fixed effects (covariates) while sampling plots were treated as random effect to handle repeated measure on plots. Bird species richness and relative abundance were dependent variables assessed in different LMMs.

The Shannon's diversity index [$H' = -\Sigma p_i \log p_i$, where p_i is the proportion of individuals belonging to the i^{th} species] was used to identify the α-diversity of bird species both at city and landscape

type levels, while the Bray-Curtis Cluster Analysis (Single Link) method was used to assess the level of similarity in bird composition between landscape types (Magurran, 2004).

Referring to Tuyisingize and Fawcett (2011), from which we retrieved the checklist of birds of the VNP and Buhanga Eco-Park, Musanze City was compared with the two natural ecosystems in terms of bird species richness and composition using the hierarchical clustering method.

To detect relationship between bird species and food availability in the city, bird species were categorized according to their feeding guilds. The completeness of the survey was assessed by analyzing patterns of the species accumulation curves (Peterson and Slade, 1998). The accumulation curves of species richness in different micro-landscape types have globally reached their plateau (Fig. 2), which prompted to conclude that the sampling has covered the majority of species in Musanze.

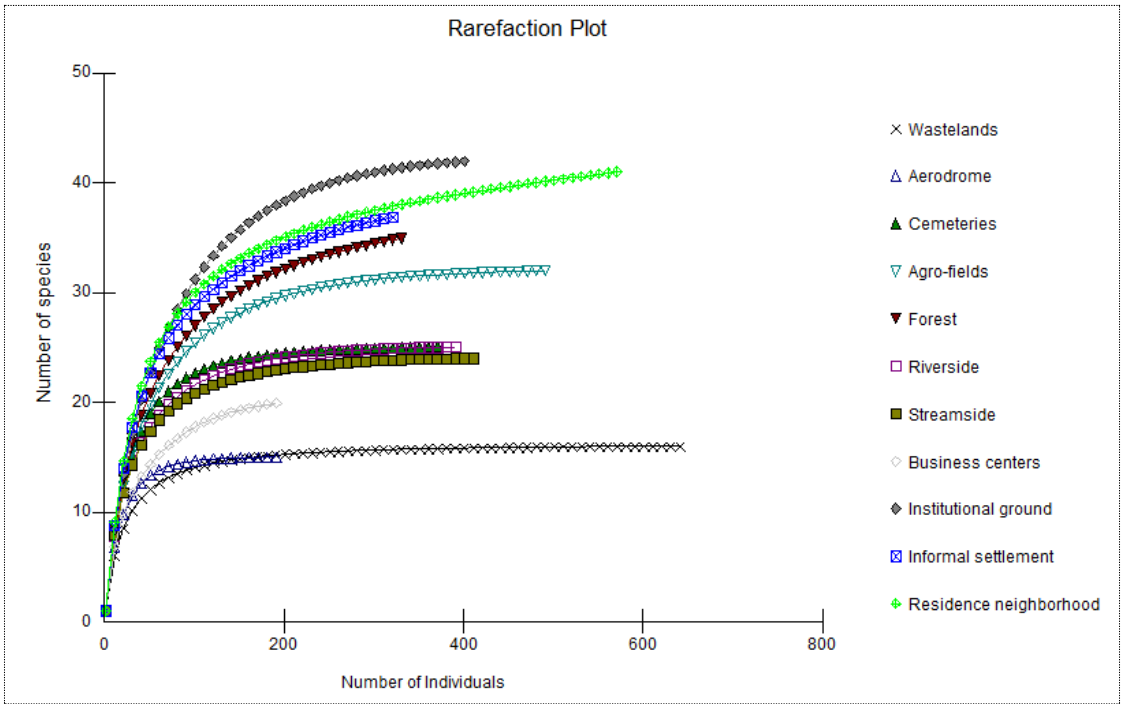


Figure 2. Bird species rarefaction curves at the site considered in this study

To determine the level of significance of the obtained results, hypothesis testing tools were used, including the test of Student (t-test). Bio-professional, MVSP, Origin and R software packages were used for these analyses.

III. RESULTS

III.1 Species Richness

A total of 94 bird species were observed in Musanze City, of which 15 species were found opportunistically outside plots. Only one Albertine Rift endemic species (Ruwenzori double-collared sunbird, *Cinnyris stuhlmanni*) and seven migrant bird species were recorded (Appendix 1).

III.1.1 Number of bird species by macro-landscape types

There was no significant difference in the number of identified bird species per visit in plots allocated to open fields and built-up areas for the number of species (*t=-0.42; p=0.67*; Fig. 3). Equally, the total number of bird species observed across all visits in both macro-landscape types were similar (N built-up = 63, N open fields = 61).

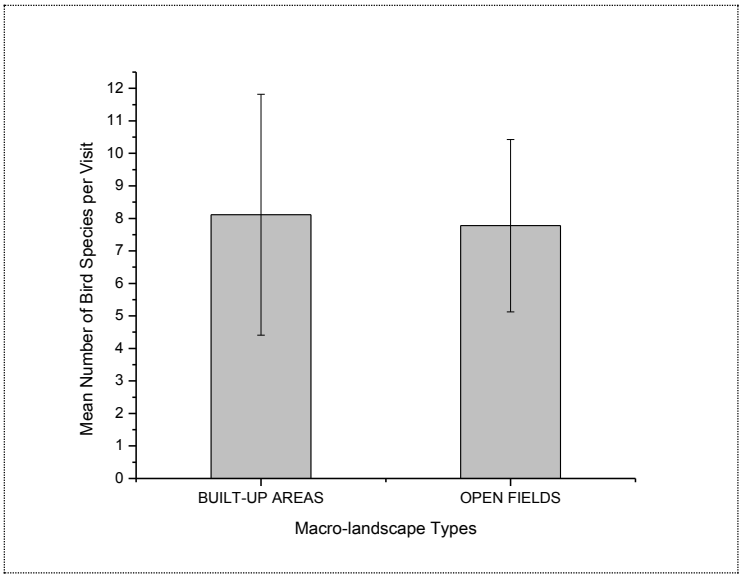


Figure 3. Mean number of species observed during plot visits in the two macro-landscape types.

III.1.2 Number of species by micro-landscape types

Among the different micro-landscape types, the highest number of species was registered in institutional grounds (N=42), followed by residential neighborhood (N=41), and informal settlements (N=37). Forest and riverside landscapes similar number of species (N=35). Wasteland and aerodrome were the micro-landscape types with the smallest number of bird species number (N=16 and N=15 respectively) (Fig. 4).

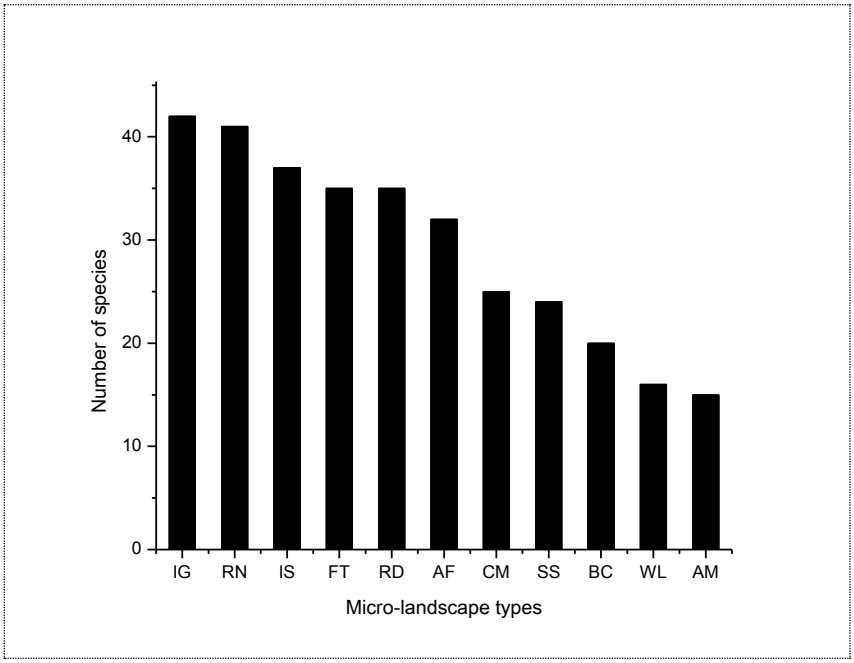


Figure 4. Total bird species in Micro-landscape types. For symbols: AM: aerodrome; AG: agro-fields; BC: business centers; CM: Cemeteries; FT: Forests; IS: Informal settlements; IG: Institutional grounds; RN: Residential neighborhoods; RS: Riversides; SS: Streamside; WL: Wasteland.

For the LMM which examined the impact of micro-landscape types on the number of bird species observed per plot visit, 'residential neighborhood' was defined as reference micro-landscape type as it showed the highest mean number of bird species per plot visit (Fig. 5). Thus, the mean number of bird species found in all other micro-landscape types was compared to the number of bird species found in residence areas. The LMM analysis revealed that the mean

number of bird species found in all micro-landscape types, except cemeteries and riversides, was significantly lower than in residential neighborhood areas in Musanze City (Tab. 2). However, the mean number of bird species observed in plots located in cemeteries tended to be lower than the mean number found in residential neighborhoods.

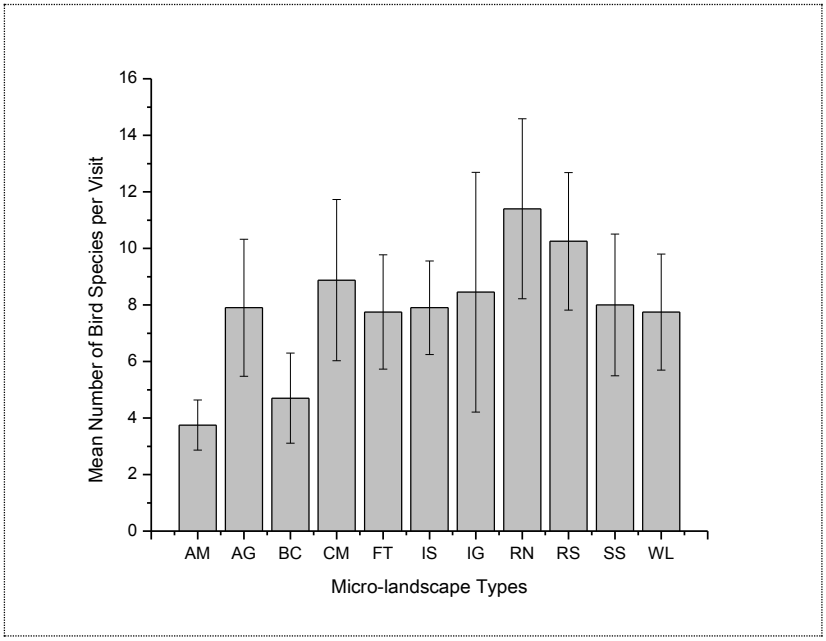


Figure 5. Mean number of bird species observed during plot visits in each micro-landscape type. AM: aerodrome; AG: agro-fields; BC: business centers; CM: Cemeteries; FT: Forests; IS: Informal settlements; IG: Institutional grounds; RN: Residential neighborhoods; RS: Riversides; SS: Streamside; WL: Wasteland.

Table 2. LMM output showing parameter estimates of micro-landscape types on the number of bird species.

Landscape Types	Std. Error	t value	p value
Intercept	0.74	15.338	<0.001
Aerodrome	1.39	-5.502	<0.001
Agro-field	1.05	-3.330	<0.01
Business centers	1.05	-6.374	<0.001
Cemeteries	1.39	-1.816	0.069
Forests	1.05	-3.473	<0.01
Institutional ground	1.05	-2.807	<0.01
Riversides	1.39	-0.827	0.408
Informal settlements	1.05	-3.330	<0.01
Streamside	1.39	-2.445	<0.05
Wastelands	1.39	-2.625	<0.01

III.2 Species Relative Abundance

III.2.1 Number of individuals by macro-landscape types

There is no significant difference between open fields and built-up areas in terms of number of bird individuals observed per visit (*t=0.35; p= 0.73*; Fig. 6).

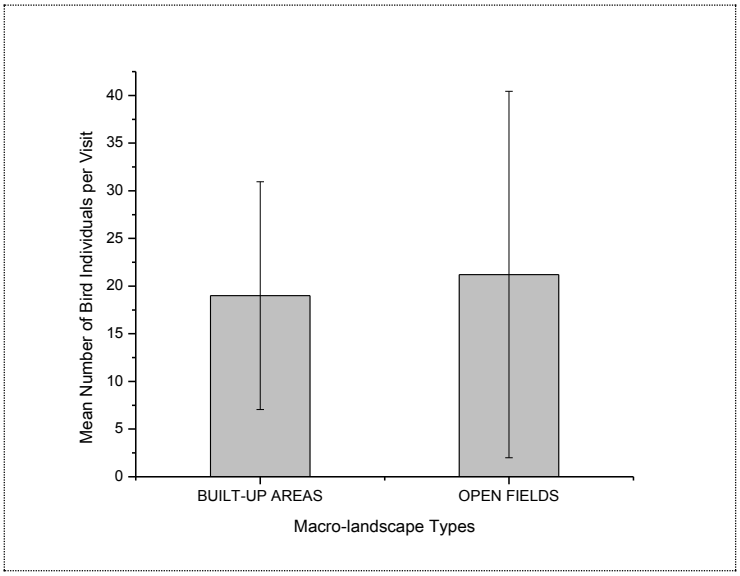


Figure 6. Mean number of bird individuals encountered per visit by macro-landscape type.

III.2.2 Number of individuals by micro-landscape types

There was a significant lower number of bird individuals in all micro-landscape types compared to the number of bird individuals encountered in plots located in residential neighborhood areas, except for cemeteries (number of bird individual tended to be lower), riversides and wastelands (Fig. 7; Tab.3).

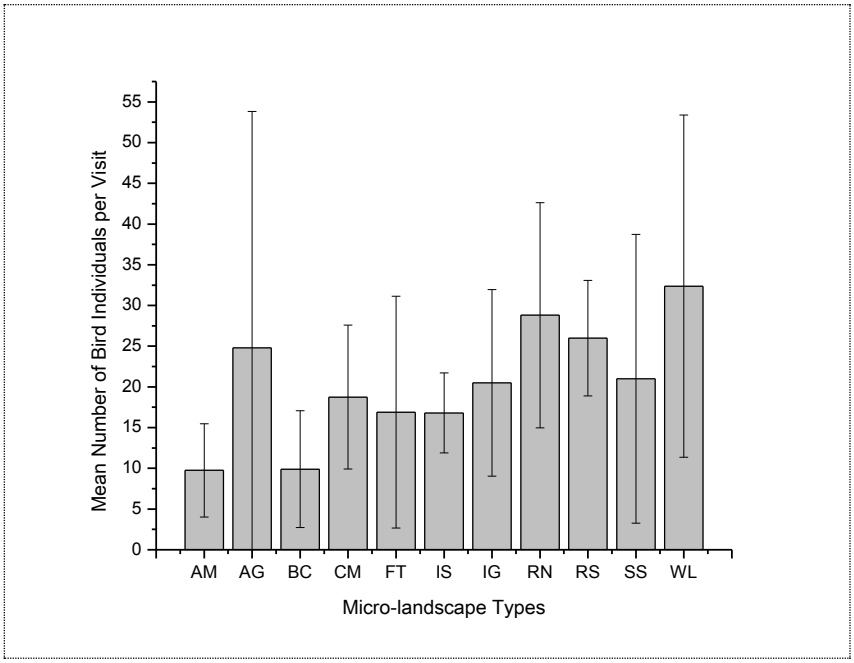


Figure 7. Mean number of bird individuals observed per plot visit by micro-landscape type. AM: aerodrome; AG: agro-fields; BC; business centers; CM; Cemeteries; FT: Forests; IS: Informal settlements; IG: Institutional grounds; RN: Residential neighborhoods; RS: Riversides; SS: Streamside; WL: Wasteland.

Table 3. LMM output showing parameter estimates of micro-landscape types on the number of bird individuals.

Landscape Types	Std. Error	t value	p value
Intercept	0.12	27.250	<0.001
Aerodrome	0.224	-4.970	<0.001
Agro-field	0.169	-2.330	<0.05
Business centers	0.169	-6.646	<0.001
Cemeteries	0.224	-1.919	0.055
Forests	0.169	-3.615	<0.001
Institutional ground	0.169	-2.229	<0.05
Riversides	0.224	-0.16	0.873
Informal settlements	0.169	-2.899	<0.01
Streamside	0.224	-2.029	<0.05
Wastelands	0.224	0.173	0.860

III.2.3 Most represented species

The Pied Crow (*Corvus albus*), the Grey-headed Sparrow (*Passer griseus*), Streaky Seedeater (*Serinus striolatus*) and the Black Kite (*Milvus migrans*) are the most ubiquitous (Fig. 8; Appendix 2).

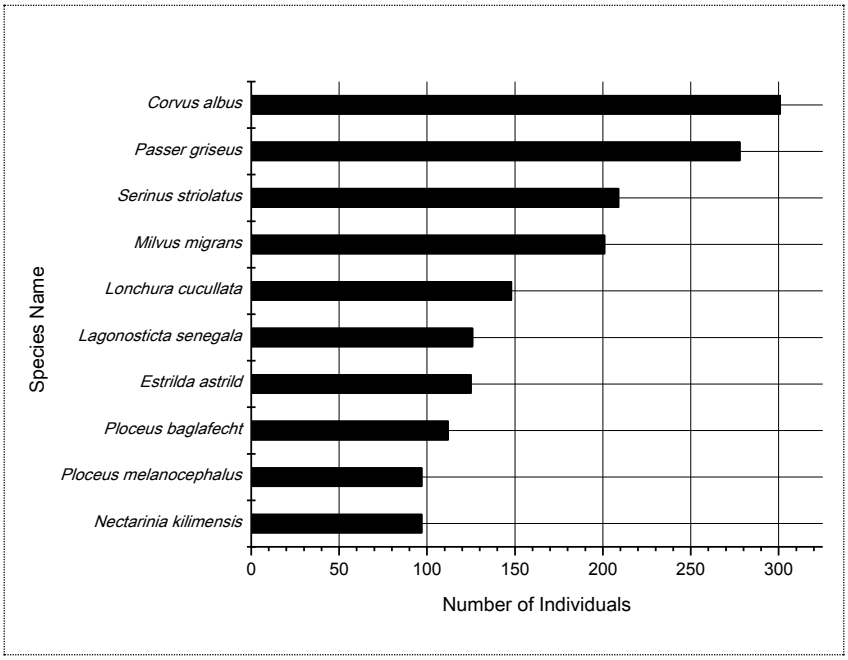


Figure 8. Top ten most represented bird species in all sites of Musanze City

3.3 Feeding guild categories

III.3.1 Feeding guild categories by macro-landscape types

Among the 11bird feeding guilds found of Musanze City, seedeaters were the most represented in both built-up areas and open fields, followed by insectivorous and scavengers (Fig. 9).

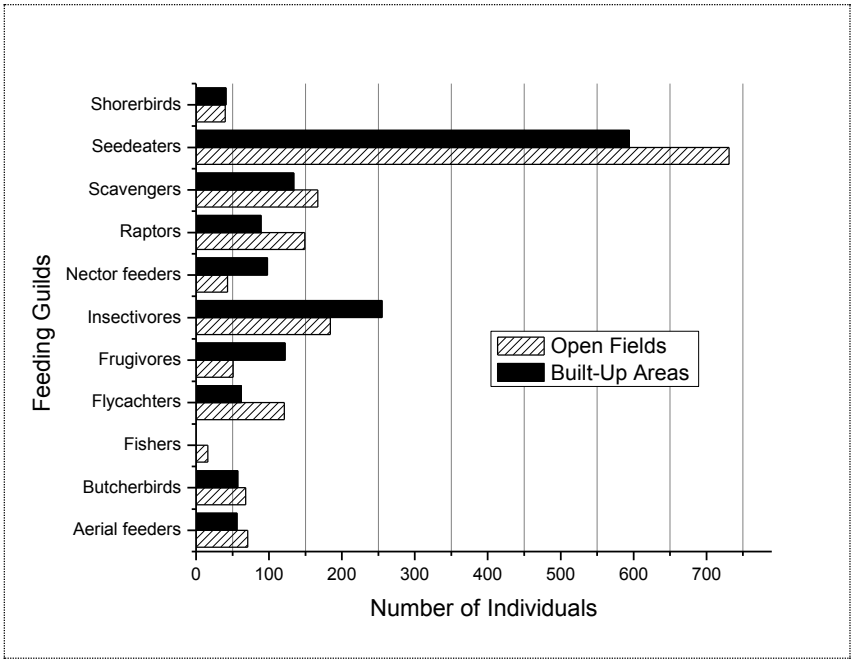


Figure 9. Feeding guild categories of bird species as classified in micro-landscapes types

III.3.2 Feeding guild categories by micro-landscapes

Seedeaters were the most present category in all micro-landscape types, except in wastelands, which, instead, were dominated by scavengers, also present in every landscape type. Insectivorous were also present in all micro-landscape types while fishers were only seen at the riverside landscape where flycatchers (also present in all landscape type) have their biggest number (Appendix 3).

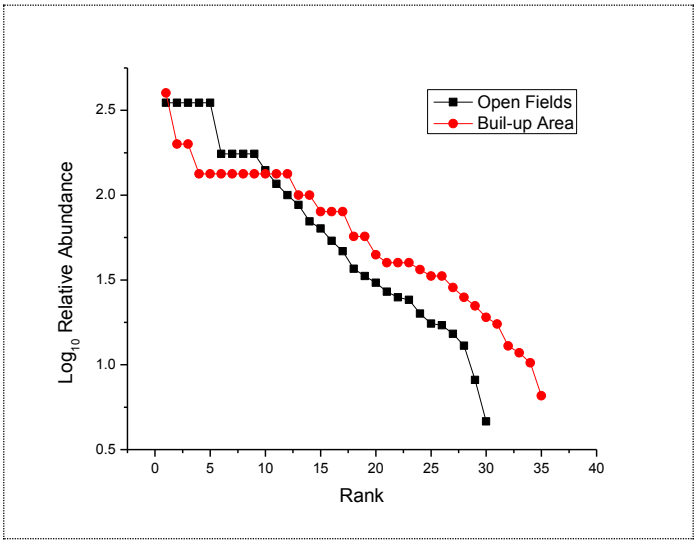
III.4 Species diversity

III.4.1 Alpha Diversity in macro- and micro-landscape types

The bird species diversity in both macro- and micro-landscapes of Musanze City are described using Whittaker curves (Fig. 10) Built-up areas are slightly higher ranked than open fields (Fig.10A). Among micro-landscapes, institutional grounds have the highest diversity rank

followed by residential neighborhoods and informal settlements while aerodrome and Westland were ranked with the lowest bird diversity (Fig. 10B).

A



B

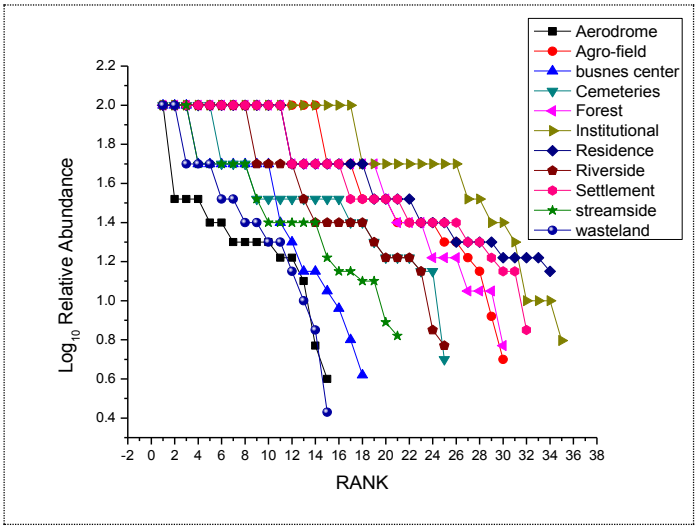


Figure 10. Species rank/abundance: (A) in macro-landscape types and (B) in micro-landscape types

The Shannon index was comparable between the two macro-landscape types, built-up areas (*H'=1.456*) and its counterpart, open fields (*H'=1.518*). At micro-landscape type level, residential neighborhood was most diverse followed by informal settlement and institutional ground, while wasteland showed the lowest bird diversity (Fig.11).

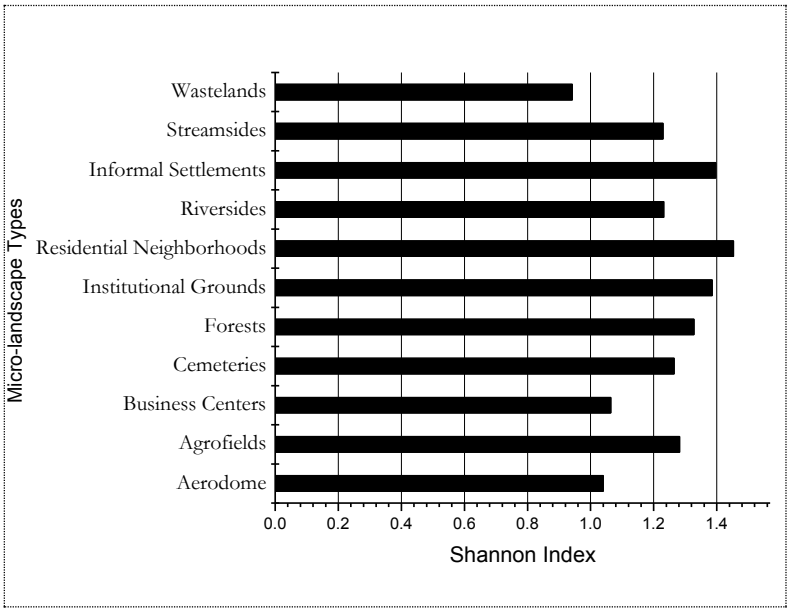


Figure 11. Shannon index for micro-landscape types of Musanze City

III.4.2 Species similarity in macro- and micro-landscape types

Of the 94 bird species recorded in Musanze City, 45 species were shared by both open fields and built-up landscapes. In terms of species composition found in each micro-landscape type, the riverside landscape was most different from the remaining micro-landscape types. Residential neighborhoods and informal settlements were most similar. The gradient of difference between the landscape types, illustrated by the increasing the distance from the chart root to the point where a given branch stems, the following order appears: Riverside < Aerodrome < Streamside < Wasteland <Agro-fields< Cemeteries < Forest < Institutional and business center < Informal settlements and Residences (Fig. 12).

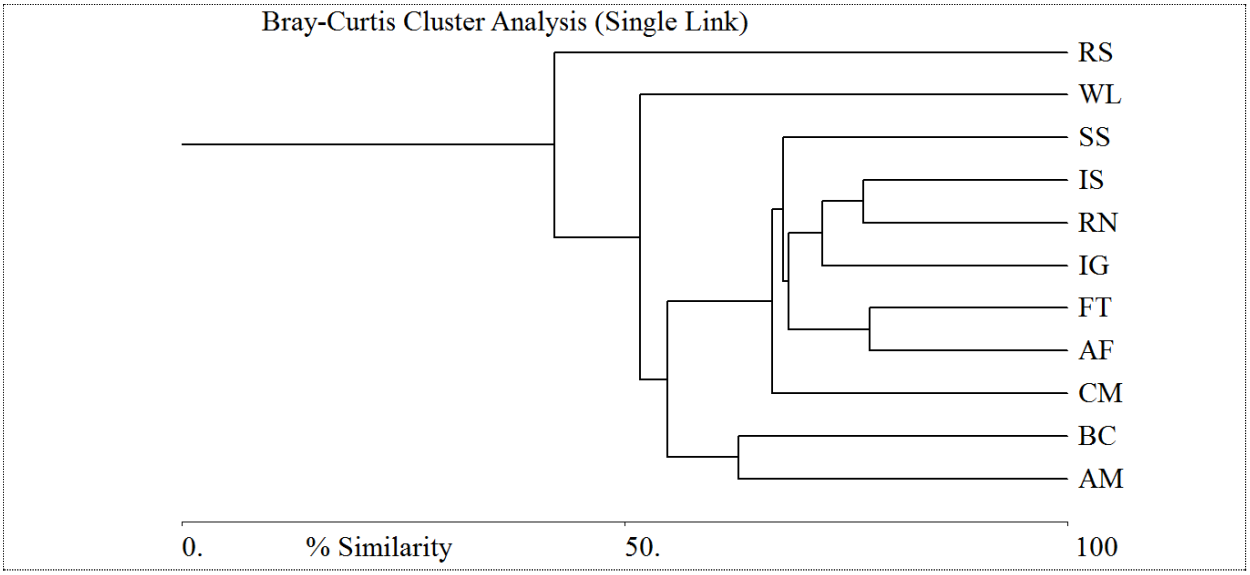


Figure 12. Species composition-based micro-landscape clusters. AM: aerodrome; AG: agro-fields; BC; business centers; CM; Cemeteries; FT: Forests; IS: Informal settlements; IG: Institutional grounds; RN: Residential neighborhoods; RS: Riversides; SS: Streamside; WL: Wasteland.

III.5 Bird diversity in Musanze City and nearby protected areas

In addition to the above internal comparison, the level of similarity between Musanze City and its nearby protected areas (Parc National des Volcans and Buhanga-Eco-Park) is shown by Fig. 13.The total number of bird species in Musanze City was 94 opposed to 105 and 81 VNP and Buhanga Eco-Park, respectively. Among the 94 bird species recorded in Musanze City, 32 are also present in Buhanga Eco-Park, 51 in the VNP and 21 in both Buhanga and in VNP. Moreover, we found one endemic bird species, Ruwenzori double-collared sunbird (*Cinnyris stuhlmanni*), in Musanze City compared to three endemic bird species present in Buhanga Eco-Park and 15 in the VNP. This Arbertine Rift endemic species, is absent in Buhanga Eco-Park while its presence is also confirmed in VNP.

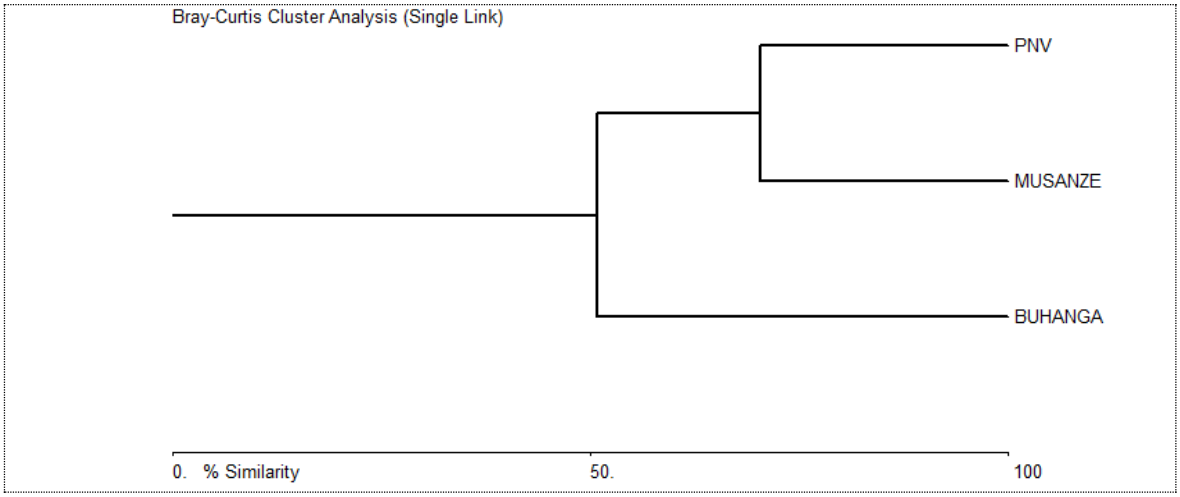


Figure 13. Musanze City, VNP and Buhanga Eco-Park bird species composition

When comparing bird species found in the three sites, Musanze City stands out in the number of migratory bird species with seven species recorded in Musanze City, two in the VNP, and none in the Buhanga Eco-Park (Tab.5). Musanze City micro-landscapes that were visited by migratory birds include riversides of Mukungwa River, informal settlements, forests, business centers, and residential neighborhoods.

Table 4. Migratory birds in Musanze City, VNP and Buhanga Eco-Park

Common Name	Scientific Name	Musanze City	Protected Areas	
			VNP	Buhanga Eco-Park
Common Sandpiper	*Actitis hypoleucos*	X		
European Bee-eater	*Merops apiaster*	X	X	
Garden Warbler	*Sylvia borin*	X		
Lesser-spotted Eagle	*Aquila pomarina*	X		
Red-chested Cuckoo	*Cuculus solitarius*	X	X	
Spotted Flycatcher	*Muscicapa striata*	X		
Willow Warbler	*Phyloscopus strochulus*	X		

IV. DISCUSSION

The number of bird species recorded during the data collection in Musanze City was interesting given that urban areas do not match well with wildlife conservation. The bird species richness is more diverse than Buhanga Eco-park and similar to Volcanoes National Parks, the two surrounding natural habitats found in the same district. Even the species with ecological concern like endemic and migratory species were also seen in the City landscapes.

IV.1 Species Richness

The unique endemic species found in Musanze City is the Ruwenzori Double-collared Sunbird (*Cinnyris stuhlmanni)* which has also been previously found in the Parc National des Volcans. The species is known to live in the high altitude habitats of the Albertine Rift (Tuyisingize and Fawcett, 2011). It is, therefore, not surprising that it was found in urban landscapes of Musanze City, knowing that it is located at high altitude (1850 m) and not far from the VNP (Miroslav et al., 2010). However, in contrast to Stevenson and Fanshawe (2002) who suggest that its most preferred habitats are flowering bushes of forest edges, it is unusual that, it was recorded foraging on *Markhamia lutea* trees within open fields of Musanze City. This means that the species distribution is not restricted to the natural and protected habitats in high altitudes of the Arbrtine Rift but can also exist in its urban landscapes as it was confirmed by the field observations. This indicates that the species can adapt to human-dominated landscapes and suggests that it may forage on other garden trees. The species adapted its feeding preferences to the city conditions and available plants despite the threat posed by the loss of its natural habitat, as a result of park amputations (Murererehe, 2000).

The seven migrant bird species found in the study site were regular September-April visitors from Palearctic regions. Two of them, the Red-chested Cuckoo (*Cuculus solitarius*) and the European Bee-eater (*Merops apiaster*) had been previously sighted in the gallery forests of the Rwandan's Eastern Province (Nsengimana et al., 2009) and in the VNP (Tuyisingize and Fawcett, 2011). Common Sandpiper, Spotted Flycatcher and Willow Warbler have also been reported to visit Rwanda (www.rwandabirding.org, 02.09.2012) and were recorded in Musanze

City, but had never been sighted in the Lava Plain or in the Volcano Range of Rwanda. The remaining two migrants, the Garden Warbler (*Sylvia borin*) and the Lesser Spotted Eagle (*Aquila pomarina*) have been reported for the first time within the framework of this study to occur in Rwanda. As a whole, the seven migrant species had never been reported to occur in urban environments of Rwanda and only two had been reported to visit its highlands (Tuyisingizeand Fawcett, 2011). However, the African Pitta (*Pitta angolensis*), which is an intra-African breeding migrant bird sighted in the Buhanga Eco-Park in 2006 and 2008 (Nsabagasani, 2008), was not recorded in this study. The above findings encourage efforts to develop bird watching activities in Musanze City which can especially interest oversea tourists.

IV.1.1 Number of species by macro-landscape types

It was hypothesized that open fields inhabit more bird species than built-up areas, which was not supported by this study. This may be explained by the fact that some built-up areas, including institutional grounds, residential neighborhoods and informal settlements are designed with plant communities that attract birds (Jokimäki and Kaisanlahti-Jokimäki, 2011). Those communities include a number of trees with a considerable canopy and ornamental plants which make bushes. On the other hand, some micro-landscapes within open fields had a small number of species such as the Musanze aerodrome which is a grassland habitat, regularly cut to facilitate landing and thus offering little food and unsuitable habitat for birds and exposing small-sized birds to predators (Bergin et al., 2000).

IV.1.2 Number of species by micro-landscape types

In line with Koellner et al. (2004), the different landscape types in Musanze showed differences in bird species richness. The institutional grounds are a good example of a landscape type with relatively high species richness, perhaps due to the presence of more varieties in its plant assemblages. The high number of bird species found in residential neighborhoods and informal settlements can be explained by the diversity of plant resources in these areas, including nectar-producing flowers such as banana plants which attract sunbirds, fruit-bearing trees and shrubs

like guava plants on which frugivorous can feed. In addition, the high concentration of domestic wastes (residues, food disposable and waste-water) in the home-stead environment offers a unique opportunity not only to predator and insectivorous birds that feed on small mammals (e.g. mice, frogs) and insects (e.g. flies, mosquitoes) which live in this kind of micro-habitats. Domestic waste, also attract scavengers that use them as food sources. In particular, informal settlements are surrounded by a mosaicked vegetation type that offers many opportunities for bird forage and nesting (Jokimäki and Kaisanlahti-Jokimäki, 2011).

IV.2 Species relative abundance

IV.2.1 Number of individuals by macro-landscape types

That no significant difference was found between macro-landscape types and the number of bird individuals may be connected to the fact that they had no significant influence on bird species richness. In addition, and probably more meaningful here, due to the historical non-formal character of urban design in Musanze, both types of landscapes appeared to have similar kinds and levels of bird-exploitable resources including plant coverage and places where birds can put their nests. (Faeth et al., 2005).

IV.2.2 Number of individuals by micro-landscape types

Cemeteries, riverside and wastelands did not differ in number of individuals compared to residential neighborhood (Tab. 3). This fact can be attributed to the fact that these landscapes appeared to be intrinsically heterogeneous, which gives room to think about possible existence of confounding factors that may have overshadowed their effect on bird relative abundance. Wastelands attract many scavengers and raptors, cemeteries have plant coverage and riversides over water access and plant coverage along the bed (Hitchmough and Dunnet, 2004).

IV.2.3 Most represented species in Musanze City

The Pied Crow (*Colvus albus*) was the dominant species in the city and seemed to be the most adapted to human-dominated landscapes (Fig. 8). For instance, in contrast to many birds of the area, with a high number registered close to human agency such food market, slaughterhouses, wastelands, domestic yards and cropland, where its sources of food, including insects and other small invertebrates, small reptiles, small mammals, grain, peanuts, carrion, scraps of human food and fruits are most occurred (Stevenson and Fanshawe, 2002). To a lesser extent, this kind of habitat appeared to favor the Grey-headed Sparrow (*Passer griseus*), whose occurrence was found to be associated with open woodlands and human settlements, where it easily finds its resources. The third most represented species is the streaky seedeater (*Serinus striolatus*) which is a common bird of the highlands, found above 1300m in gardens and cultivated areas, woodland edges, heath and scrub. Similarly, the Black Kites (*Milvus migrans*) proved to be adapted to the human-built environment, especially in densely populated areas where they can easily find their pray, including small birds, bats and rodents. During data collection, this species was seen in exceptionally large numbers flying around the slaughterhouse and scavenging in wastelands.

IV.3 Feeding guild categories

IV.3.1 Feeding guild categories by macro-landscape types

Seedeater guild was most represented category of birds in Musanze (Fig. 9). This can be partly explained by the fact that data collection was done during a period when people were harvesting maize and the neighborhood fields were covered by grass with a lot of seeds ready to be collected by birds, which may have selectively attracted species of this category(Fuller and Wilson, 1995). In addition, during the period of data collection, seedeaters were seen feeding on seeds from different fruits and doing so, according to Holland and DeAngelis (2002), they contribute in plant reproduction through pollination. The insectivore guild was also important in

the city. In line with the findings of Austin and Smith (1972), they appeared to be abundant in insect-rich landscapes, including streamside, forests and informal settlements.

IV.3.2 Feeding guild categories by micro-landscapes

That seedeaters, especially Grey-headed Sparrow (*Passer griseus*), dominated in almost all micro-landscapes, for the same reasons as discussed in the previous section, should not overshadow the fact that in wastelands, scavengers were exceptionally the most abundant (Fig.14).

Figure 14. Abundance of pied crows in a landfill within Musanze City (Photo © Author, 2012)

This finding confirms that birds of Musanze City, as other birds, contribute to biomass recycling (Whelan et al., 2008). Although this category of birds comprises few species in the city, it was interesting to realize that the abundance of a single species was high enough to compensate for their low number of species and make their impact noticeable to almost all city dwellers. This was, in particular, true for the Pied Crow (*Corvusalbus*) whose count amounted to more than sevenfold the average number of individuals per species or, in other words, almost 10 % of the total number of individuals.

IV.4 Species diversity

IV.4.1 Alpha Diversity

The bird diversity found in built up areas is comparableto the bird diversity in urban open fields in Musanze City (Fig. 10A). This confirms the increasingly supported idea that built-up areas can have as high bird diversity as natural environment (Gilbert, 1989; Millard, 2008). It was suggested that may be due to relatively high number of alien species present in cities and the heterogeneity of urban habitats (Kowarik, 1995).In support to this finding, Luck (2007) suggests a significant positive correlation between human population density and bird species richness. In this study, species like pied crow (*Corvus albus*) were found to be exceptionally adapted to the human built-environment. Even the Albertin Rift endemic (the Ruwenzori double-collared sunbird, *Cinnyris stuhlmanni*) was sighted foraging on garden plants.

Overall, residential neighborhood, institutional grounds and informal settlements can be identified as bird hotspots in Musanze City (Fig. 10B). The common denominator between these three landscape types is the presence of a great floristic diversity, insuring many stimuli to bird life (fruits, seeds, nectar, domestic residues, insects, small mammals, reptiles and amphibians) (Jokimäki and Kaisanlahti-Jokimäki, 2011).Contrary to rural areas and natural forests that undergo seasonal shortages of resources (Bolwig et al., 2006), cities are areas where food does not show strong seasonal variation due to continuous supply from remote areas.

IV.4.2 Species similarity

The macro-landscapes types appeared to have similar bird species composition. This may have been due to landscape heterogeneity (Kowarik, 1995). It may be linked to the historical lack of professional landscape planning and design, resulting in a mosaicked and heterogeneous landscape structure in both built-up and open fields, instead of landscape specialization enhancement. The results show that residential and informal settlements were the most similar in terms of species composition. Both kinds of landscapes have the ultimate function of hosting the

family life. The main difference between them resides in their socio-economic status, which is reflected in the landscape structure, but keeps more similarities than it creates differences. On the other hand, the fact that cemeteries have a close similarity with both forests and some of the built-up micro-landscapes can be attributed to the fact that these areas are surrounded by trees. Also, cemeteries are characterized by low human disturbance. They also harbor a great variety of flowers, mainly planted by the bereaved ones. Moreover, the vegetation in the graveyards shows different stages of regeneration, resulting in a wide range of habitats, from the vegetation-free spots within the freshly dug grounds to the reconstructed thickets around the old graves (VGDSE, 2009). Expectedly, riverside emerged as a special landscape type, with many distinctive species. Almost all species counts in riverside sites are specialists of wetland and were not found elsewhere. As a result, it was the most dissimilar to the rest of micro-landscape types.

The high similarity of bird diversity between Musanze City and its nearby protected areas further supported that protected areas are not the only ones to be inhabited by wildlife (Gilbert, 1989; Dowd, 1992; Faeth et al., 2005). Although both natural ecosystems are at 8 km from Musanze City, more than half of the species found in the city were also found in the Volcano National Park. The lower similarity between the city and Buhanga Eco-Park may have something to do with the relative geographic location, with Musanze City being at almost half way between the two natural ecosystems. It may also be attributed to the microhabitat diversity within each of the three ecosystems, which apparently is lower in Buhanga Eco-park (Weber, 1987), referring its relative far smaller size.

V. CONCLUSIONS

This study contributed to the knowledge of bird diversity in urban landscapes showing the current status of bird diversity in Musanze City. It confirmed that bird diversity in cities can be as much as in surrounding natural forests. The total number of bird species in Musanze City was comparable to that of the nearest protected forests, Volcanoes National Park and Buhanga Eco-Park. Endemic and migratory birds were also found in Musanze City. One Albertine Rift endemic bird species, the Ruwenzori double-collared sunbird, *Cinnyris stuhlmanni*, was sighted in Musanze. Three migratory birds were found in Musanze region for the first time: the Common Sandpiper (*Actitis hypoleucos*), the Spotted Flycatcher (*Muscicapa striata*) and the Willow Warbler (*Phylloscopus trochilus*). Two bird species may have not been previously reported in Rwanda: the Garden Warbler (*Sylvia borin*) and the Lesser Spotted Eagle (*Aquila pomarina*). The effect of landscape types on bird richness and relative abundance were also illustrated. Residential neighborhood, institutional grounds and informal settlements were found to have highest species diversity indices and rank/abundance compared to the rest of micro-landscapes. Riverside emerged as the landscape type with a specialized bird fauna, restricted to wetland environment and water bodies. This study confirmed that scavengers in Musanze City contribute more to biomass recycling than any other bird category. This should help urban decision makers to take into account the existence of a great diversity of wild fauna when developing and implementing land use plans, especially when villages and cities are in proximity of protected areas or natural reserves. Botanical gardens and public parks should be included in the master plan of the City and their design requires studies of biodiversity including avian populations.

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APPENDICES

Appendix 1. List of Musanze City birds and their distribution

Species	Status	Aerodrome	Cemeteries	wasteland	Agro-field	Forest	Riverside	streamside	business center	Institutional	Residence	Settlement
Accipiter melanoleucus	Common	0	0	0	0	0	0	0	0	0	1	1
Actitis hypoleucos	Migrant	0	0	0	0	0	1	0	0	0	0	0
Alcedo cristata	Common	0	0	0	0	0	1	0	0	0	0	0
Amaurornis flavirostris	Common	0	0	0	0	0	1	0	0	0	0	0
Anas undulata	Common	0	0	0	0	0	1	0	0	0	0	0
Anthus cinnamomeus	Common	0	0	1	0	0	0	0	0	1	0	0
Apus affinis	Common	0	0	0	0	0	1	0	0	0	0	1
Apu sbarbatus	Common	0	0	0	0	0	0	0	0	1	0	0
Apus caffer	Common	0	0	0	0	1	0	0	0	1	1	0
Aquila pomarina	Migrant	0	0	0	0	0	0	0	1	0	0	0
Ardea melanocephala	Common	1	0	0	0	1	0	1	0	1	1	1
Batis molitor	Common	0	0	0	0	1	0	0	0	0	1	0
Bostrychia hagedash	Common	0	1	1	1	1	1	0	0	1	1	1
Buteo augur	Common	1	0	0	1	0	0	1	1	0	0	0
Camaroptera brachyura	Common	0	0	0	1	0	0	0	0	0	0	0
Ceryle rudis	Common	0	0	0	0	0	1	0	0	0	0	0
Chalcomitra senegalensis	Common	0	0	0	0	0	0	0	0	0	0	1
Chlorocichla flavicollis	Common	0	0	0	0	0	0	1	0	0	0	0
Chloropeta natalensis	Common	0	0	0	0	0	1	0	0	0	0	0
Cinnyris stuhlmanni	Endemic	0	0	0	0	0	0	0	0	0	1	0
Cinnyris venusta	Common	0	0	0	0	0	1	1	1	0	1	1
Cisticola chubbi	Common	0	1	0	1	1	0	1	0	0	1	0
Cisticola natalensis	Common	0	0	0	0	1	0	0	0	0	0	0
Colius striatus	Common	0	1	0	1	0	1	1	0	1	1	1
Corvu salbus	Common	1	1	1	1	1	1	1	1	1	1	1
Cossypha heuglini	Common	0	1	0	1	1	1	1	1	1	1	1
Cosypha cyanocampter	Common	0	0	0	0	0	0	0	0	0	0	1
Cuculus solitarius	Migrant	0	0	0	0	0	0	0	0	0	0	1
Cyanomitra verticalis	Common	0	0	0	0	0	0	0	0	1	1	0
Dendropicos fuscescens	Common	0	0	0	0	0	0	0	0	0	1	0
Dendropicos	Common	0	0	0	0	0	0	0	0	0	1	0

griseocephalus												
Elminia albicauda	Common	0	1	1	1	1	1	0	0	1	1	1
Eminia lepida	Common	0	0	0	1	1	0	0	0	0	1	1
Estrilda astrild	Common	0	0	0	1	0	1	1	0	0	0	0
Estrilda nonula	Common	0	0	0	1	0	0	0	0	1	1	1
Estrilda quartinia	Common	0	0	0	0	0	0	1	0	0	0	0
Euplectes axillaris	Common	0	0	0	0	0	1	0	0	0	0	1
Euplectes capensis	Common	0	0	1	1	1	1	1	0	1	0	0
Falco biarmicus	Common	0	0	0	0	0	0	0	1	1	0	0
Ficedula albicollis	Common	0	1	0	0	0	0	0	0	0	0	0
Hedydipna collaris	Common	0	0	0	0	0	0	1	0	0	0	0
Hirundo angolensis	Common	0	0	0	0	0	0	0	0	1	0	0
Hirundo daurica	Common	1	1	1	0	0	1	0	1	1	0	0
Hirundo fuligula	Common	0	0	1	1	0	1	0	0	1	0	0
Lagonosticta rubricata	Common	0	0	0	0	1	0	0	0	0	0	0
Lagonosticta senegala	Common	1	0	1	1	1	0	1	1	1	1	1
Laniarius aethiopicus	Common	0	0	0	0	0	0	0	0	1	1	0
Lanius collaris	Common	0	0	0	0	0	0	0	0	1	0	0
Lanius mackinnoni	Common	0	1	0	1	1	0	0	0	1	0	0
Lonchura bicolor	Common	0	0	0	1	1	0	0	0	0	0	0
Lonchura cucullata	Common	0	1	0	1	1	0	1	1	1	1	1
Lophaetus occipitalis	Common	0	0	0	0	0	0	0	0	1	0	0
Melaenornis fischeri	Common	0	0	1	1	1	1	0	1	1	1	1
Merops apiaster	Migrant	0	0	0	0	1	0	0	0	0	0	0
Merops oreobates	Common	0	0	0	0	1	0	0	0	0	0	0
Milvus migrans	Common	1	0	1	1	1	0	1	1	1	1	0
Motacilla aguimp	Common	0	0	1	0	0	0	0	1	1	1	1
Motacilla capensis	Common	0	0	1	1	1	0	0	1	1	1	1
Muscicapa adusta	Common	0	0	0	0	1	0	0	0	1	1	1
Muscicapa aquatica	Common	0	0	0	0	0	1	0	0	0	0	0
Muscicapa striata	Migrant	0	0	0	0	0	0	0	0	0	0	1
Necrosyrtes monachus	Common	0	0	0	0	1	1	0	0	1	0	0
Nectarinia kilimensis	Common	1	1	0	1	1	0	1	1	1	1	1
Passer griseus	Common	1	1	1	1	1	0	1	1	1	1	1
Phylloscopus trochilus	Common	0	0	0	0	0	0	0	0	1	0	0
Platysteira cyanea	Common	0	0	0	1	0	0	0	0	0	0	0
Ploceus baglafecht	Common	1	1	0	1	1	0	0	1	1	1	1
Ploceus cucullatus	Common	0	1	0	1	0	0	0	0	0	1	1
Ploceus melanocephalus	Common	1	1	0	1	1	1	0	0	1	1	1
Ploceus ocularis	Common	0	0	0	0	0	0	1	0	0	0	1
Ploceus xanthops	Common	0	1	1	0	0	0	0	0	0	0	0

Polyboroides typus	Common	1	0	0	0	0	0	0	0	0	0	0
Prinia subflava	Common	0	1	0	0	1	0	0	0	0	0	0
Psalidoprocne albiceps	Common	0	0	0	0	0	1	0	0	0	0	0
Psalidoprocne holomelas	Common	1	1	0	0	0	0	0	1	1	0	0
Pycnonotus barbatus	Common	0	1	0	1	1	0	1	1	1	1	1
Saxicola torquata	Common	1	1	1	1	1	1	1	1	1	0	1
Scopus umbretta	Common	0	0	0	0	0	1	0	0	0	0	0
Serinus canicollis	Common	0	0	0	0	0	0	0	0	0	1	1
Serinus citrinelloides	Common	0	1	0	1	1	0	1	0	0	1	1
Serinus mozambicus	Common	1	1	1	1	1	0	0	0	1	1	1
Serinus striolatus	Common	1	1	0	1	1	1	1	1	1	1	1
Serinus sulphuratus	Common	0	0	0	0	1	0	0	0	0	0	0
Streptopelia semitorquata	Common	0	0	0	1	1	0	1	0	1	1	1
Sylvia borin	Migrant	0	0	0	0	0	0	0	0	0	1	0
Tchagra australis	Common	0	0	0	0	1	0	0	0	0	0	0
Tchagra senegala	Common	0	0	0	0	1	0	0	0	0	0	0
Terpsiphone viridis	Common	0	1	0	1	1	0	1	0	1	1	0
Threskiornis aethiopicus	Common	0	0	0	0	0	1	0	0	0	0	0
Tricola emalacrymosa	Common	0	0	0	0	0	0	0	0	1	1	1
Turdus olivaceus	Common	0	0	0	1	1	0	1	0	1	1	1
Turtur tympanistria	Common	0	0	0	0	0	0	0	0	0	1	0
Vidua macroura	Common	0	0	0	0	0	1	0	0	1	1	0
Zosterops senegalensis	Common	0	1	0	0	0	0	0	0	1	1	1

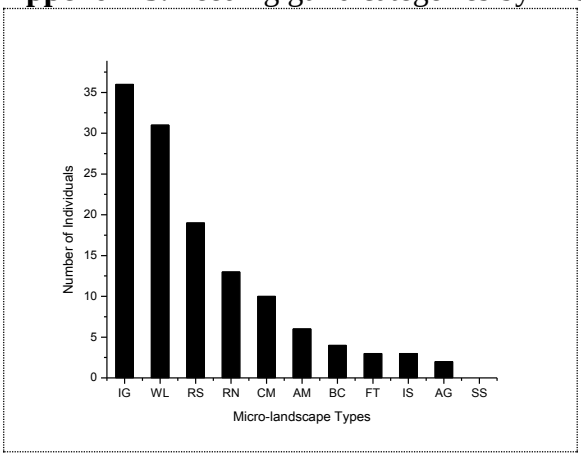
The number 1 indicates the presence; the number 0 indicates the absence.

Appendix 2. Some of the most common birds of Musanze City

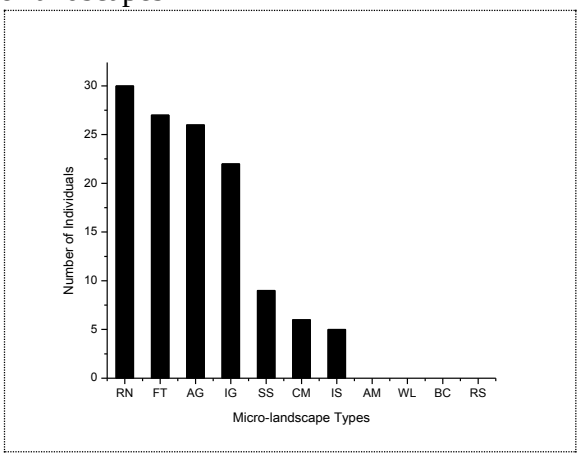
Fig 2.1a Most common Birds of Musanze City [from left to right: (1) *Milvus migrans*, photo © Mori 2012; (2) *Passer griseus*, and (3) *Corvus albus*, photos © Seburanga 2012]

Fig 2.1b Most common Birds of Musanze City [from left to right: (1) *Lagonosticta senegala*, photo © Faida 2012; (2) *Serinus striolatus* photo © Mori 2012, and (3) *Lonchura cucullata*, photos © Seburanga 2012]

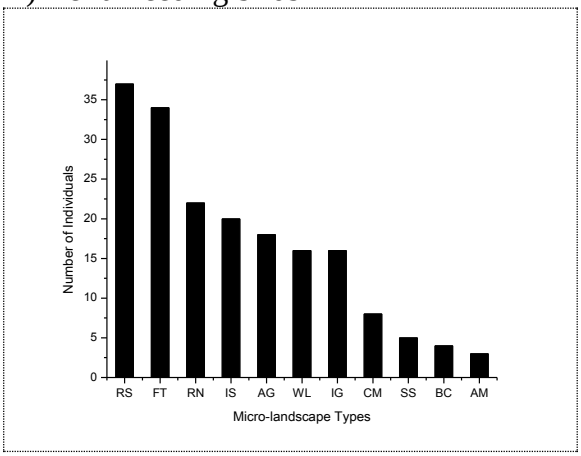
Appendix 3. Feeding guild categories by micro-landscapes



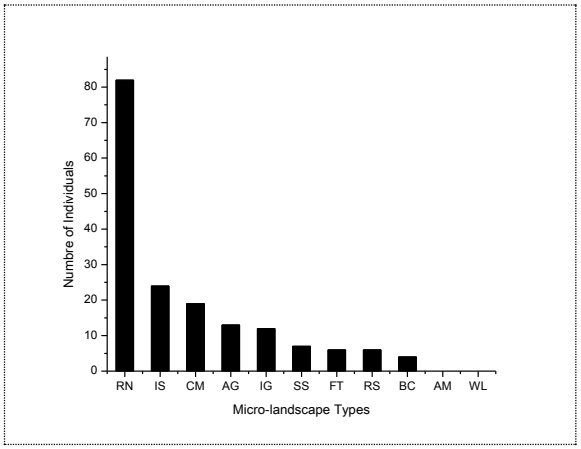
A) Aerial feeding birds



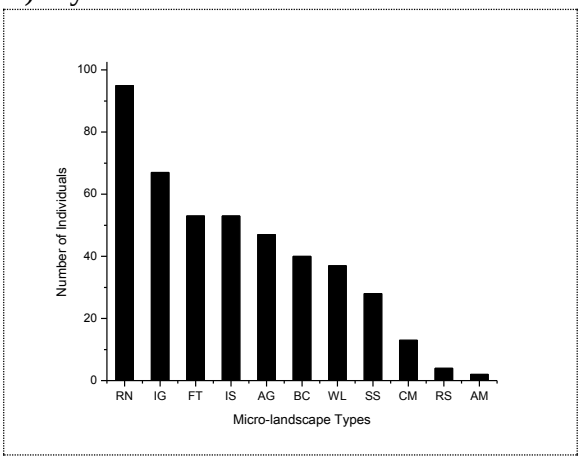
B) Butcherbirds



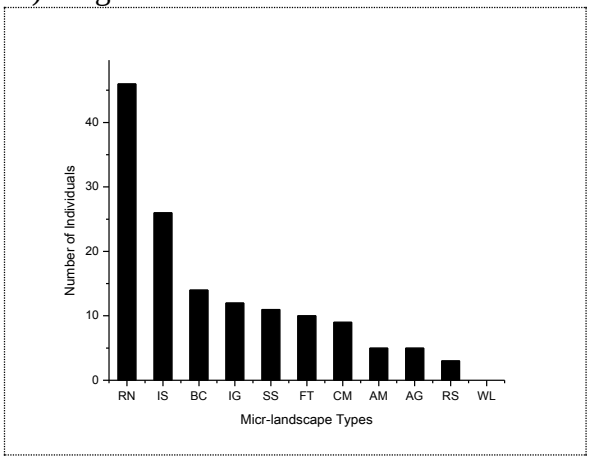
C) Flycatchers



D) Frugivorous

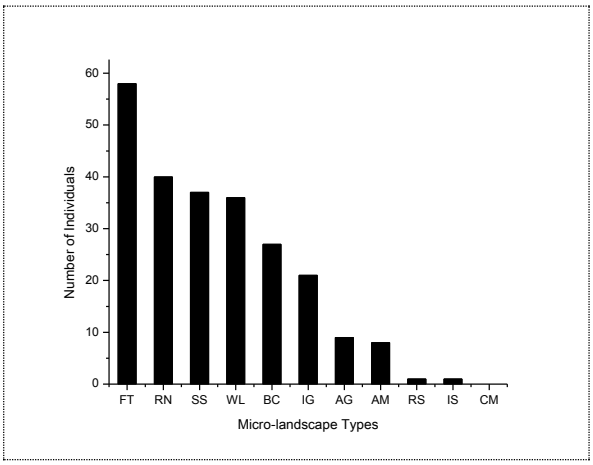


E) Insectivorous

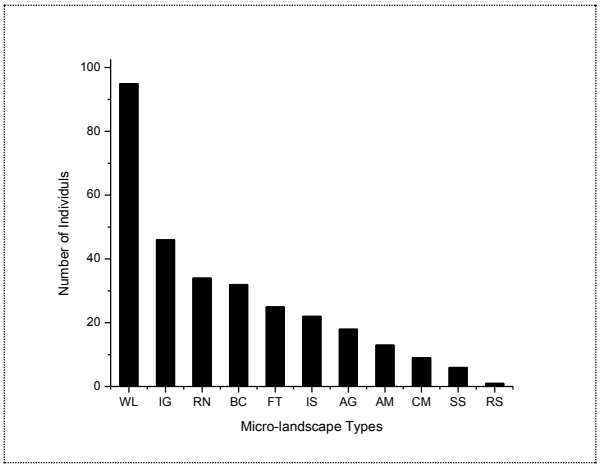


F) Nectar Feeders

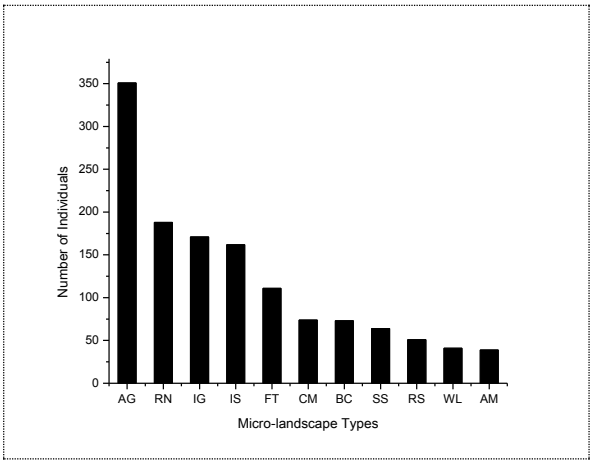
Appendix 3. Bird feeding guild categories as classified into micro-landscape types. AM: aerodrome; AG: agro-fields; BC; business centers; CM; Cemeteries; FT: Forests; IS: Informal settlements; IG: Institutional grounds; RN: Residential neighborhoods; RS: Riversides; SS: Streamside; WL: Wasteland.



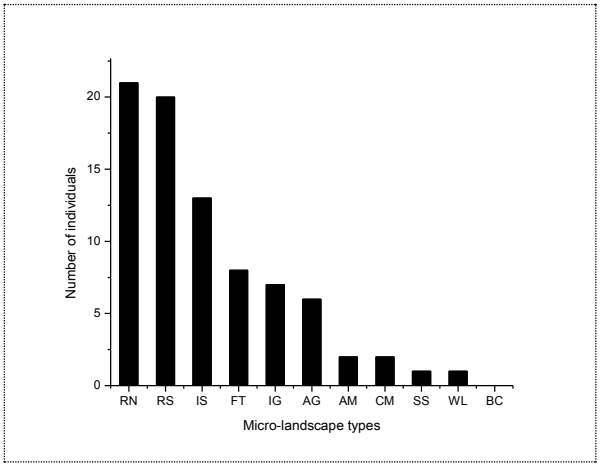
G) Raptors



H) Scavengers



I) Seedeaters



J) Shorebirds

Appendix 3 Continued. Bird feeding guild categories as classified into micro-landscape types. AM: aerodrome; AG: agro-fields; BC; business centers; CM; Cemeteries; FT: Forests; IS: Informal settlements; IG: Institutional grounds; RN: Residential neighborhoods; RS: Riversides; SS: Streamside; WL: Wasteland.