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Full Length Research Paper

Diversity and floristic composition of rural and sub-urban home garden in Wadera district of Oromia region, Ethiopia

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This study was conducted in Wadera district of Oromia region in Ethiopia, with the objective of quantifying the diversity and floristic composition of home garden agroforestry systems. A stratified random sampling design was used to select 132 sample home gardens and a detailed inspection was conducted on diversity and floristic composition of the plant species using the Shannon-Wiener diversity index and Pielou's Evenness index. A total of 65 cultivated plant species belonging to 36 families were recorded with an average of 28 plant species per individual's home garden. Rutaceae was the dominant family with 6 species followed by Lamiaceae and Solanaceae. Shannon's diversity indexes of 1.63 to 2.06 were recorded at the village level with an overall mean diversity index (H') of 1.85 and evenness index (E) of 0.58. The findings from this study may help government and other stakeholders in providing baseline information, supported with scientific evidence, which further can contribute to policy and decision making process.

Key words: Agroforestry, home garden, diversity, floristic composition, Guji zone.

INTRODUCTION

The floristic diversity and composition of home gardens differ from place to place depending mainly on different factors; e.g., farm size, family size, and access to markets (Tesfaye et al., 2010; Talemos et al., 2013). Both vertical and horizontal arrangements have resulted from a long history of farmers' knowledge based on trial and error rather than being supported by scientific and empirical evidence. Individual farmers pursue their own way of species selection and arrangements, which lead to tremendous variation in the number, size, and placement of specific components of the arrangement. As these systems differ based on their species diversity and composition, their contribution to household subsistence, economic and environmental benefits differ as well.

In most parts of sub-Saharan Africa, particularly in Ethiopia, it is becoming difficult to meet the food demand of every household in the face of the increasing population and decreasing arable land, with limited land

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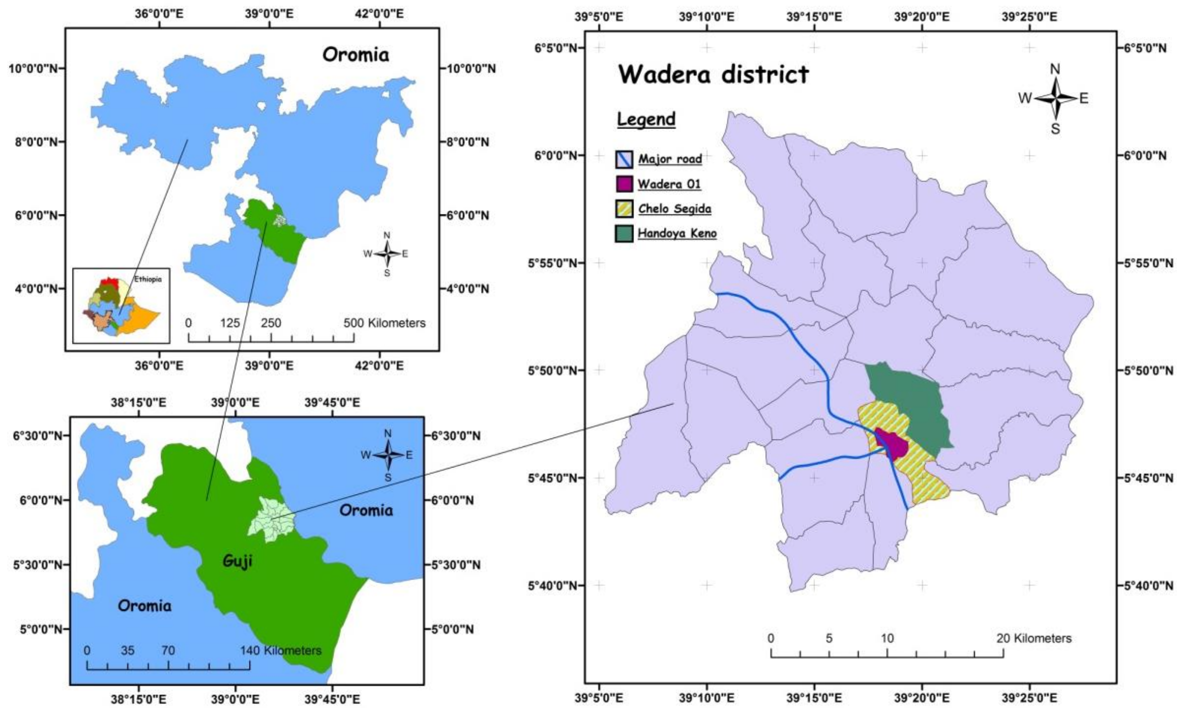

Figure 1. Map of the study area.

resources (Mersha, 2013; Sunderland et al., 2013); as a result, millions of farmers in Ethiopia are struggling to subsist. The pressure to meet the food demand of each family member saddles farmers' survival strategies toward improper landuse and shifts in the farming system, primarily to mono-cropping of cash crops (Mersha, 2013; Mellisse et al., 2017).

Agroforestry allows the diversification of products and integration of trees in farms and rangelands that sustain production for increased social, economic and environmental benefits (WAC, 2019), and thus play a significant role in solving these persistent problems. This study focused on home garden agroforestry practice, which is characterized by its multi-layered floristic composition of species that are managed in intimate association with each other in a landscape that resembles a forest ecosystem that is located close to residential houses and plays an important role in the production of subsistence and cash crops. These farm places are a source for medicine, spices, fiber, fodder for livestock, construction wood; while maintaining year-round production by stabilizing microclimate and nutrient cycling under the vegetation (Agbogidi and Adolor, 2013; Tesfaye et al., 2013). Therefore, this study was carried out to quantify the diversity and floristic composition of cultivated home garden species in *Wadera* district, and addressed the following question:

(1) What is the diversity and floristic composition of cultivated species in Wadera home gardens?'

MATERIALS AND METHODS

The study area

This study was conducted in *Wadera* district (05° 40' to 06° 03' N and 39° 05' to 39° 28' E) in the East Guji administrative zone of Oromia Regional State, Ethiopia (Figure 1). The district is located at 535 km South of the country capital city, Addis Ababa. Its altitude ranges between 1,489 and 1,914 m above sea level. Based on the CSA (2007), the district has a total population of 50,075, of which about 10% is suburban. The district has a total area of 95,169 ha. The mean annual rainfall of 1,000 to 1,400 mm occurs in a bimodal pattern, and the region enjoys a mean annual temperature of 19°C. The long rainy season starts from mid-March to May, while the short rainy season occurs from mid-September to October. Between the beginning of December and mid-March the area encounters high temperatures and strong winds. The major soil types of the district are Oxisols and Alfisols, characterized by their red brown colors. High forests, grassland, exposed sand soil, riparian woodland or bush land and cultivated land are available in the district. The land use includes: cultivated land 31,426.2 ha (33.39%), forest land 27,979 ha (29.73%), grazing land 24,012 ha (25.51%), and others 10,417.2 ha (11.07%).

Sampling

A stratified random sampling technique was employed following Alexiades (1996). Villages in the district were grouped into two dominant groups based on their farming practice: pure farmers and semi-pastoralists. A total of 7 villages were identified in the category of pure farmers' villages and further divided into 2 sub-groups (suburban and rural). Three villages, namely: *Wadera 01, Chelo Segida* and *Handoya Keno* were selected for detailed inspection, and used for the diversity and floristic composition analyses. A total of 132 households were randomly selected for detailed inventory on diversity and floristic composition of home garden species using Watson's (2001) formula.

$$n = \frac{\dfrac{P(1-P)}{\dfrac{A^2}{Z^2} + \dfrac{P(1-P)}{N}}}{R}$$

where n = sample size required, N = total number of population (2150), P = estimated variance in population, as a decimal: (0.1) for 90-10%, A = precision desired expressed as decimal: (0.05 for 5%), Z = based on confidence level: (1.96) for a 95% confidence level, R = response rate: (0.99 for 99% response).

Data collection

Both qualitative and quantitative data regarding floristic composition of home garden species were collected from primary and secondary data sources. All vegetation data were collected from 60 home gardens using a quadrat method (Oosting, 1956). At each home garden, a random quadrat of 100 m^2 (10 m × 10 m) for trees, 25 m^2 (5 m × 5 m) for shrubs and 1 m^2 (1 m × 1 m) for herbs, were laid out and data on species name, number of individuals of each species per quadrat and number of structural layers based on the plant height were collected. All recorded species were identified using Azene (2007) and flora of Ethiopia and Eritrea. Furthermore, voucher specimens were collected and taken to the national herbarium of Addis Ababa University to confirm the identification. Diameter at breast height (DBH) of trees and shrubs were measured using diameter tape and height of plants was measured using measuring poles (for small plants < 3 m) and clinometers for larger plants (height > 3 m: such as trees and shrubs).

Data analysis

The qualitative and quantitative data collected for the study were described and analyzed by calculating percentages and descriptive statistics (mean and standard deviation). Differences between group means were determined by F-test (to compare two groups) and one-way analysis of variance (ANOVA; to compare more than two groups), followed by post-hoc least significant difference (LSD) test. The relationships of diversity indices with socioeconomic factors were determined using separate linear correlation (Pearson's correlation) for each index. Data were analyzed using Statistical Package for Social Sciences (SPSS).

Important quantitative analysis like frequency of cultivated species was determined following Martin (1995). Floristic species (cultivated) richness (S), Shannon-Wiener diversity index (H') and Pielou's evenness index (E) were calculated using Magurran (1988). This method was selected because it provides an account for both abundance and evenness. It also does not disproportionately favor some species over the others as it counts all species according to their frequencies. Sorensen's index of similarity (Ss) was calculated to compare the vegetative composition of home garden of the villages taking into consideration all species found in all representative villages (Sorensen, 1948). Data were analyzed using Statistical Package for Social Sciences (SPSS Version 20.0).

$$S = \sum n$$

$$E = \frac{H'}{\ln(S)}$$

$$H' - \sum_{i=1}^{S} (pi)(\ln\ pi)$$

$$Ss = \frac{2C}{2a + 2b}$$

where S = Species richness, n = number of individuals of each species per quadrat, H'= Shannon-Wiener diversity index, i = Species, pi = proportion of individuals of the i^{th} species and ln = natural logarithm, E = Species evenness, Ss = Sorensen's similarity coefficient, a = Number of species in community a, b = Number of species in community b, C = Number of common species in both communities.

RESULTS AND DISCUSSION

Structure of Wadera home gardens

From the 132 households inspected, 95 of them (72%) arranged their gardens as a combination of side and back yards. Other management layouts such as front yards and enclosed (surrounded) yards were also observed in the study area. The average size of home garden in the study area was 0.51 ha (0.28, 0.54 and 0.71 ha for *Wadera 01*, *Chelo Segida* and *Handoya Keno* villages, respectively), with ranges between 0.25 and 1.5 ha (Table 2).

Considering the living house as a reference point, the spatial horizontal structure of a Wadera home garden is characterized into four main parts, namely: front garden (1), medicinal and spices garden (2), food and cash crops garden (3) and trees (fruit) garden (4) (Figure 2).

Based on height of the flora, three distinct strata (<3, 3-10 and > 10 m) were stratified. Fully grown tree species like *Cordia africana*, *Podocarpus falcatus* and *Croton macrostachyus* dominate in the upper stratum. In the middle, fruit trees like *Persea americana* and *Citrus medica* and cash crops like *Coffea arabica* and *Catha edulis* are dominant. In the lower layer (ground 3 m), food crops like *Zea mays*, spices and medicinal plants are planted and managed (Figure 3). This finding agrees with Fernandes and Nair (1986) and Montagnini (2006) who noted that most tropical home gardens are vertically stratified into 3 to 4 strata.

Diversity and floristic composition of the home garden

This study revealed that *Wadera* home gardens have a high floristic species diversity amounting to a total number of 65 cultivated species (28 herbs, 17 trees, 18 shrubs, and 2 lianas) comprising 36 families (Table 1). The maximum number of species per home garden was recorded from *Handoya Keno* village (47) and minimum from *Wadera 01* (13), with an overall average species number of 27.5. Rural home gardens in the study area were richer ($p < 0.05$) in floristic species as compared with sub-urban one. Shannon's diversity index of the sub-urban village (*Wadera 01*) was 1.63 while that of the rural villages, *Chelo Segida* and *Handoya Keno*, was 1.99 and 2.06, respectively (Table 2). The Shannon's diversity index at *Wadera 01* village was significantly lesser ($p < 0.01$) than both *Chelo Segida* and *Handoya Keno* villages. However, species evenness between selected villages was not significantly different. Sorensen's similarity index values for pairs of villages varied between 0.67 and 0.93. The result in overall floristic composition across 132 home gardens in the three villages proved that similarity among groups of species was high (Ss = 0.93) between *Chelo Segida* and *Handoya Keno* villages followed by *Wadera 01* and *Chelo Segida* (Ss = 0.75) and *Wadera 01* and *Handoya Keno* (Ss = 0.67) villages (Table 3).

Regarding floristic similarity of species, all villages in the study area shared a total of 33 species. The two rural villages, *Chelo Segida* and *Handoya Keno*, shared a total of 54 species; while *Wadera 01* and *Chelo Segida* shared a total of 37 species. Other than common species shared between all three villages, there were no species shared between *Wadera 01* and *Handoya Keno* villages. *Wadera 01* and *Handoya Keno* had 3 species each that are not shared with any of the villages; while *Chelo Segida* had only 1 species (Figure 4).

Similar to most multistory tropical home gardens, Wadera home gardens are rich and diverse in floristic species, especially in rural home gardens. This could be best attributed to the family sizes (households' food supply and food preferences of individuals in a household), lack of market access (alternative livelihood options) and home garden size conditions. Households with many family members include children, adults, and elders whose food preferences mostly differ from each other. To satisfy the need of each member (group), the Wadera home garden plays an important role in ensuring food security of the household by providing a variety of food crops so that the family members do not skip a day without eating. This is in agreement with Eyzaguirre and Watson (2001) and Krishnal et al. (2012) who noted that home gardens have an important role in achieving a sufficient food supply for the household's family. In general, this study produced similar result as that of Tesfaye (2013), who reported that family size influences diversity and dynamics of species in home gardens of *Sidama*, Southern Ethiopia. In the Wadera district, farmers in rural areas are expected to walk 15 to 20 km in a single trip to reach the central market, which is located in *Wadera 01* village. Because of the distance, rural gardeners mostly visit the central market once or twice a month. Their access to livelihood commodities is limited due to their geographic location. But they cultivate as many species as they can in their gardens to compensate for their limitations and subsist and try to minimize the frequency of market visits. This means home gardens are playing an invaluable role in saving labor and time spent that could be wasted due to frequent market visits that would be needed to survive. This result is in agreement with previous studies (Eyzaguirre and Watson, 2001; Oliver and Ban, 2004; Tesfaye et al., 2006; Talemos et al., 2013; Tesfaye, 2013), which indicated that rural societies are more dependent on their home garden products and farms due to geographic location (remoteness from markets). In contrast, suburban gardeners in the study area have direct access to a marketplace (district's only market is available in a suburban village) where they can obtain most of their livelihood requirements and hence their gardens are dominated by ornamental and medicinal plant species. Rural home gardens of Wadera district are significantly larger in size ($p < 0.001$) from sub-urban ones. It is obvious that larger home gardens require a more substantial labor force as compared to smaller ones. In the study area, family size and size of home gardens are positively correlated ($r = 0.51$, $p < 0.01$), which is the same result reported by Kehlenbeck and Mass (2004) in their studies of *Sulawesi*, Indonesia home gardens.

Floristic similarity of species was best attributed to the physical proximity of villages to each other. As the distance between villages decreased, similarity in overall floristic composition of home gardens increased. This similarity could be best described by two major reasons: similarity in agroecological conditions of the district and ease of information and experiences sharing among Wadera farmers. In the same agroecological condition, the same type of species can adapt and flourish. Zebene (2003) noted that neighboring farmers, residing in the same village, have a tendency of sharing information regarding species performance, adaptability, and economic and nutritional values. This result is in agreement with Habtamu (2008) and Tesfaye (2013) who reported that closely located villages showed a high value of overall floristic similarity of species as compared to distantly located ones. This result helps researchers and development agents (experts) in providing information on how to promote and disseminate new agroforestry technologies by taking their information sharing culture into consideration.

Conclusion

Wadera home gardens are rich and diverse in floristic composition and distribution (a total of 65 cultivated floristic species). Suburban home gardens accounted for an average of 24 species, having mean Shannon's diversity (H') and Evenness (E) indices of 1.63 and 0.56,

Table 1. Plant species recorded from the study area (excluding weeds and ornamentals).

S/N	Scientific name	Vernacular (Local) name	Family	Habit	Uses
1	*Acacia abyssinica* Hochst. ex Benth.	Ambo, Dadecha (O), Bazra-grar (A)	Fabaceae	Tree	fd, fr and sh
2	*Allium cepa* L.	Qulubi dima (O), Key-shinkurt (A)	Alliaceae	Herb	fo
3	*Allium sativum* L.	Qulubi adi (O), Nech shinkurt (A)	Alliaceae	Herb	fo and m
4	*Allium wakegi* L.	Shinkurti bala (O), Kitel shinkurt (A)	Alliaceae	Herb	fo
5	*Annona reticulata* L.	Gishta (A,O)	Annonaceae	Tree	ft
6	*Artemisia absinthium* L.	Ariti (A,O)	Asteraceae	Herb	m
7	*Beta vulgaris* L.	Hunde dima (O), Keysir (A)	Amaranthaceae	Herb	fo
8	*Brassica carinata* A. Br.	Shana (O), Kitel gomen (A)	Brassicaceae	Herb	fo
9	*Brassica oleracea* L. *var. capitata*	Rafu mara (O),Tiqil gomen (A)	Brassicaceae	Herb	fo
10	*Capsicum annuum* L.	Kariya (A), Chilly (E)	Solanaceae	Herb	fo
11	*Carica papaya* L.	Papaya (O,A,E)	Caricaceae	Tree	ft
12	*Casimiroa edulis* La Llave & Lex	Shasho (A), Kazmir (O)	Rutaceae	Tree	ft
13	*Catha edulis* (Vahl) Forssk. ex Endl.	Cati, Jima (O), Khat (E,A)	Celastraceae	Shrub	st
14	*Celtis africana* Burm. F.	Meteqamma (O)	Cannabaceae	Tree	fr and sh
15	*Citrus aurantifolia* (Christm.) Swingle	Lomi (O,A), Lime (E)	Rutaceae	Shrub	ft and m
16	*Citrus aurantium* L.	Komtatie (O, A)	Rutaceae	Shrub	ft
17	*Citrus medica* L.	Tiringo (A, O)	Rutaceae	Shrub	ft
18	*Citrus sinensis* (L.) Osb.	Burtukan (O,A)	Rutaceae	Shrub	ft
19	*Coffea arabica* L.	Buna (O,A)	Rubiaceae	Shrub	st
20	*Combretum molle* R. Br. ex G. Don	Dandamsa (O)	Combretaceae	Tree	fr, m, tm and bf
21	*Commelina* sp.	Hola gabisa (O)	Commelinaceae	Herb	m
22	*Cordia africana* Lam.	Wanza (A), Wadessa (O)	Boraginaceae	Tree	fr, ft, fd, sh and tm
23	*Coriandrum sativum* L.	Dinbilal (A)	Apiaceae	Herb	sp
24	*Croton macrostachyus* Hochst. ex Del.	Bisana (A), Mekonisaa (O)	Euphorbiaceae	Tree	sh, fd, m and fr
25	*Cucurbita pepo* L.	Duba (A)	Cucurbitaceae	Herb	fo
26	*Cupressus lusitanica* Mill.	Ye ferenj tid (A)	Cupressaceae	Tree	lf and tm
27	*Cymbopogon citratus* (Dc.) Stapf.	Tej-sar (A)	Poaceae	Herb	m
28	*Daucus carota* L.	Karota (O)	Apiaceae	Herb	fo
29	*Dovyalis abyssinica* (A. Rich) Warburg	Koshim (A), Dangugo, Hakoko (O)	Flacourtiaceae	Shrub	lf
30	*Enset ventricosum* (Welw.) Cheesman.	Wesi, Koba (O), Enset (A)	Musaceae	Herb	fo and fd
31	*Eucalyptus globulus* Labill.	Nech-bahirzaf (A)	Myrtaceae	Tree	tm and m
32	*Gossypium barbadense* L.	Titi (A)	Malvaceae	Shrub	fb and fr
33	*Grevillea robusta* R. Br.	Greviliya (O), Silky oak (E)	Proteaceae	Tree	Lf, tm and fr
34	*Ipomoea batatas* L.	Metatisha (O), Sikuwar dinich (A)	Convolvulaceae	Herb	fo
35	*Justicia schimperiana* (Hochst. ex Nees) T. Anderson	Sensel (A), Dhumuga (O)	Acanthaceae	Shrub	lf and m
36	*Lactuca sativa* L.	Selata (A)	Asteraceae	Herb	fo

Table 1. Contd.

37	*Lepidium sativum* L.	Feto (A)	Brassicaceae	Herb	m
38	*Lycopersicon esculentum* Mill.	Timatima (O), Timatim (A)	Solanaceae	Herb	fo
39	*Maesa lanceolata* Forssk.	Abeyi (O)	Myrsinaceae	Shrub	fr
40	*Mangifera indica* L.	Mango (A,O)	Anacardiaceae	Tree	ft
41	*Mentha spicata* L.	Nana (A)	Lamiaceae	Herb	sp
42	*Musa paradisiaca* L.	Muzi (O), Muz(A)	Musaceae	Tree	ft
43	*Nicotiana tabacum* L.	Tambo (O), Timbaho (A)	Solanaceae	Herb	st
44	*Ocimum basilicum* L.	Besobila (A)	Lamiaceae	Herb	sp
45	*Ocimum lamiifolium* Hochst. ex Benth.	Ye ken damakese (A)	Lamiaceae	Shrub	m
46	*Ocimum urticifolium* Roth	Ye lelit damakese (A)	Lamiaceae	Shrub	m
47	*Persea americana* Mill.	Abokado (O), Abukato (A)	Lauraceae	Tree	ft
48	*Phaseolus lunatus* L.	Adenguwarie (A)	Fabaceae	Liana	fo
49	*Phaseolus vulgaris* L.	Boloqqe (A,O)	Fabaceae	Liana	fo
50	*Podocarpus falcatus* (Thunb.) Mirb.	Zigba (A), Birbirsa (O)	Podocarpaceae	Tree	fr and tm
51	*Prunus persica* (L.) Batsch	Koki (O), Kok (A)	Rosaceae	Tree	ft
52	*Psidium guajava* L.	Zeytuna (O,A)	Myrtaceae	Tree	ft
53	*Pterolobium stellatum* (Forsk) Brenan.	Kontir (A), Harangama (O)	Caesapinioideae	Shrub	lf
54	*Rhamnus prinoides* L' Herit.	Gesho (A,O)	Rhamnaceae	Shrub	fl and fr
55	*Rhus vulgaris* Meikle	Dabobessa (O), Gamo (A)	Anacardiaceae	Shrub	fr
56	*Ricinus communis* L.	Qobbo (O), Gulo (A)	Euphorbiaceae	Shrub	sh, fr and oth
57	*Rosmarinus officinalis* L.	Siga metibasha (A)	Lamiaceae	Herb	sp
58	*Ruta chalepensis* L.	Tenadam (A)	Rutaceae	Herb	m
59	*Saccharum officinarum* L.	Shenkora (O,A)	Poaceae	Herb	fo and fr
60	*Solanum tuberosum* L.	Dinicha (O)	Solanaceae	Herb	fo
61	*Spinacia oleracea* L.	Qosta (A)	Chenopodiaceae	Herb	fo
62	*Vernonia amygdalina* Del.	Girawa (A), Ebicha (O)	Asteraceae	Shrub	m, sh and fr
63	*Vicia faba* L.	Baqiella (A)	Fabaceae	Herb	fo and bf
64	*Withania somnifera* (L.) Dunal.	Gizawa (A)	Solanaceae	Shrub	m
65	*Zea mays* L.	Boqollo (O)	Poaceae	Herb	fo and fd

(O), (A) and (E) represent vernacular names in Oromic, Amharic and English, respectively. Abbreviations in uses of species are: fo = food, fd = fodder, fr = firewood, ft = fruit tree, fb= fiber plant, fl= flavoring, m = medicinal, sh = shade, lf = Livefence, st = stimulant, sp = spice, tm = timber, bf = bee forage, Oth = other utilizations.

respectively. Rural home gardens had an average of 58 cultivated floristic species with mean Shannon's diversity (H') and Evenness (E) indices of 2.03 and 0.59, respectively. Mean results of species richness (S) showed an increment in rural home gardens. Floristic diversity of species was evenly distributed across all home gardens.

The findings in this study help the scientific community and policy makers in identifying what type of agroforestry systems are available in their district, and thus contributes its own part in promoting and disseminating agroforestry

Table 2. Mean values of home garden size and diversity indices for cultivated species in the study area.

Villages (V) (n/V = 44)	HG size (ha)			Diversity indices (N=132)								
				S		H'			E			
	min	max	mean±SD	Total	mean±SD	min	max	mean±SD	min	max	mean±SD
Handoya Keno	0.50	1.50	0.71±0.24[a]	57	27.4±5.3[a]	1.74	2.52	2.06±0.23[a]	0.47	0.66	0.60±0.06[a]
Chelo Segida	0.50	0.66	0.54±0.07[b]	59	31.0±6.1[a]	1.63	2.60	1.99±0.28[a]	0.45	0.68	0.57±0.05[a]
Wadera 01	0.25	0.50	0.28±0.07[c]	40	24.0±4.7[b]	1.02	2.25	1.63±0.35[b]	0.39	0.69	0.56±0.09[a]
Mean	-	-	0.51±0.12	-	27.5±8.6	-	-	1.85±0.28	-	-	0.58±0.06
F-test (p)	-	-	<0.001	-	<0.05	-	-	<0.01	-	-	ns

HG = Home garden, ns= not significant. Village Means in a column followed by different letters indicate significant differences at $p< 0.05$, $p< 0.01$ and $p< 0.001$.

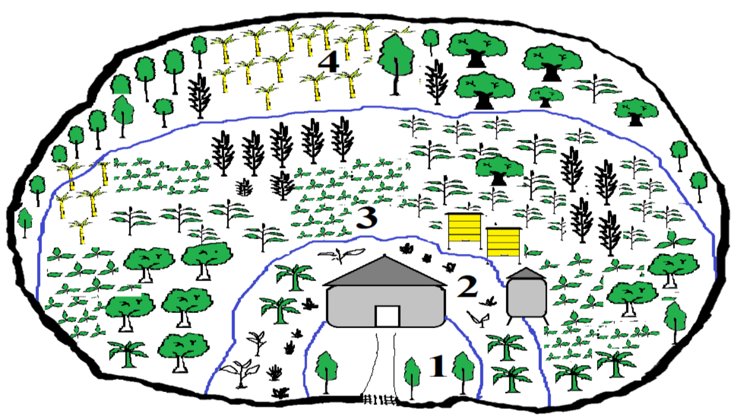

Figure 2. Horizontal structure of Wadera home garden.

Figure 3. Vertical structure of Wadera home garden.

technologies easily in Wadera communities taking into consideration their local knowledge, practice and tendency to adapt new information and technologies focusing on agroforestry. *Guji* administrative zone, where the present study was conducted, shares boundaries with *Gedeo* administrative zone, which is known by its home garden agroforestry practices. In this zone, 86% of its population is involved in the practice, and slopes as steep as 60 to 80° are under home garden utilization. As a result, both soil and water resources are reported to be well conserved (Melese and Daniel, 2015; Sileshi, 2016; Yirefu et al., 2016). This could result in knowledge and

Table 3. Sorenson's similarity index for overall floristic composition between pairs of villages.

Village	*Wadera 01*	*Chelo Segida*	*Handoya Keno*
Wadera 01	1		
Chelo Segida	0.75	1	
Handoya Keno	0.67	0.93	1

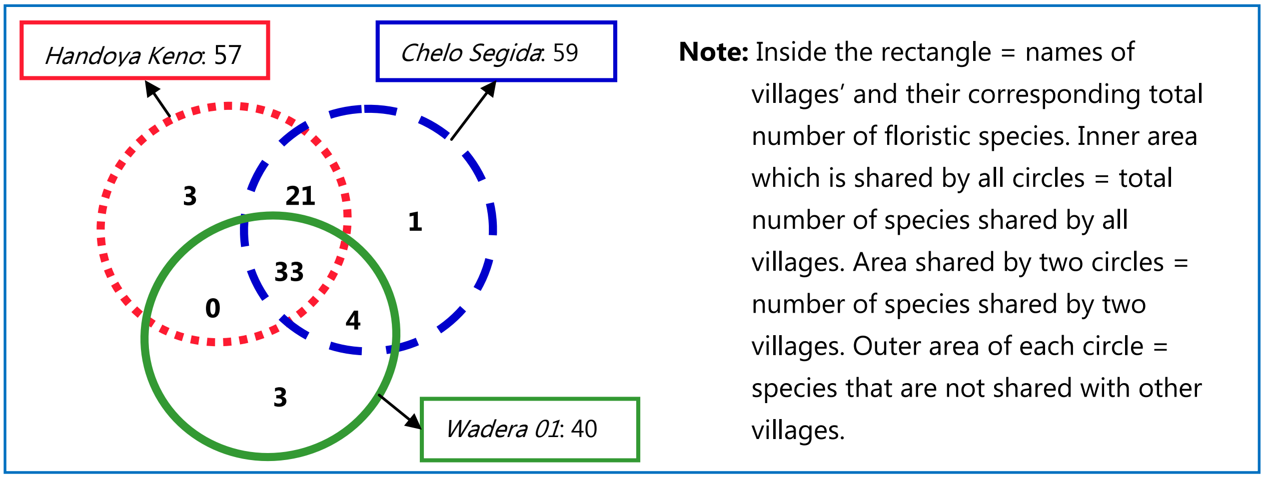

Figure 4. A Venn diagram of the number of species overlaps between 3 villages.

information transfer among farmers. The finding from this study may help government and other stakeholders in providing baseline information, supported by scientific evidence, which can further contribute to more informed policy and decision making processes. To sum up, the findings from this study inform, encourage and create fertile insights to enhance the effort that the country is making in promoting agroforestry (GTP II, 2016).

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Phytosociological survey of environmental park in Antonio Danubio municipality of Ananindeua, Para, Brazil

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This article reports the floristic and phytosociology of a solid ground forest, located in the Environmental Park Antonio Danubio Lourenço da Silva, municipality of Ananindeua, Pará, Brazil. The inventory of 1 ha considered individuals with diameter at breast height (DBH) ≥ 10 cm, allocated twenty plots in each field, all of size 20 m x 25 m (500 m^2) arranged randomly. A total of 239 plants was registered, distributed in 61 species, 51 genera and 27 families, referring to biocenose area. The families with most species, in a decreasing order, were: Leguminosae, Lecythidaceae, Sapotaceae, Urticaceae, Anacardiaceae, Annonaceae, Caryocaraceae, Vochysiaceae, Lauraceae, Arecaceae and Malvaceae. In relation to the importance value index (IVI$_i$), the highest values were presented by the species: *Oenocarpus bacaba, Nectandra cuspidata, Theobroma grandiflorum, Diplotropis purpurea, Piptadenia suavelons, Inga lauriana, Cecropia obtusifolia, Cecropia sciadophylla, Tapirira guianensis and Jacaranda copaia*. These species represent 56.06% of the individuals sampled per hectare and 58.63% of the IVI$_i$. The diversity index of Shannon-Weaver (H '= 3.53) indicates that the park has a floristic diversity less than other native forest fragments in State of Para, Brazil. This is probably due to the park being part of an anthropic area near the federal highway BR-316, where a large number of vehicles circulate daily.

Key words: Phytosociology, biodiversity, conservation, identificacion.

INTRODUCTION

Vegetation plays essential roles in urban centers, because from a physiological point of view, it improves the urban environment through the ability to produce shade, filter noise, lessen noise pollution, improve air quality, increase oxygen content and moisture, and absorb carbon dioxide, as well as moderate the

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temperature, among other contributions (Graziano, 1994). The trees exert a vital role for the welfare of urban communities, because they have the unique ability to control many of the adverse effects of the environment, and thus should contribute to a significant improvement in quality of life (Volpe-Filiket et al., 2007). Consequently, there is a growing need to manage urban green areas for the benefit of the whole society.

The Danube Environmental Park Antonio Lourenço da Silva, located in Ananindeua municipality in the State of Pará, is an Area of Relevant Ecological Interest (ARIE) (Brazil, 2000), created by the Municipal Law n^{o}. 2472, on January 5, 2011, with the following objectives: (i) maintain the natural ecosystem of regional and local importance; (ii) to ensure the preservation and protection of the existing fauna and flora; (iii) promote the use of natural components in environmental education, in order to make the community a partner in the conservation of the natural heritage of the municipality; and (iv) provide the population able to exercise cultural, educational, recreational and leisure activities in a balanced natural environment. Studies on the floristic composition and phytosociological structure of forest formations are of fundamental importance, because they offer information for understanding the structure and dynamics of these formations - essential parameters for the management, regeneration and conservation of different plant communities (Silva et al. 2002; Chaves and Del, 2013).

According to Oliveira et al., (2003), among the most important phytosociological parameters are: Frequency, indicating the occurrence of the taxon in the sample units; Density, which basically refers to the number of individuals of a given species per unit area (Mueller-Dombois and Ellenberg, 1974); Dominance, which expresses the influence or taxon contribution in the community, usually calculated in indirect values of biomass; Importance Value Index, which allows the sorting of species hierarchically according to their importance in the community (Durigan, 2003); Coverage Value Index, which is defined as the vertical projection of the crown or root área of a species on the ground (Mueller-Dombois and Ellenberg, 1974); and Shannon-Weaver Diversity Index (H'), which accounts for both abundance and evenness of the species present in the area surveyed.

Considering the socioenvironmental importance of the Antônio Danúbio Environmental Park for the municipality of Ananindeua in the State of Pará, the floristic surveys and the phytosociological studies of the area can provide useful information in the elaboration and planning of actions that aim at the conservation or even the forest recovery of the area studied (Watzlawick et al., 2005). Accordingly, this study aims to characterize the floristic composition, structure and functioning of the dynamic distribution of this vegetation in the Environmental Park Antonio Danubio, located in the city of Ananindeua, Pará, Brazil, thus seeking a theoretical basis for the elaboration of conservation projects in these kinds of urban forest fragments.

MATERIALS AND METHODS

The Environmental Park Danube Antonio Lourenço da Silva has a total area of 3,544 ha and is located along the BR 316 highway, 5 km, in the urban area of the city of Ananindeua in the State of Pará, Brazil, between the coordinates 01° 40' 62.80'' S and 48° 44' 78.76'' W (Figure 1). The vegetation data were obtained employing the methods of fixed area or multiple portions, as recommended by Mueller and Dombois (1974). The surveyed sites were allocated twenty (20) plots in each field, all of size 20 m x 25 m (500 m²) arranged randomly, totaling 10,000 m² (1 ha). The vegetation data collections were conducted in the period from January to May 2016.

In each of the 20 sample units, the circumferences of all trees were obtained using a tape measure based on the criterion of diameter at breast height (DBH), measured at 130 cm in height on the trunk, for trees with diamteters that were greater than or equal to 10 cm. Specimen identification was conducted at Pará State University Herbarium using classical taxonomy used by the standards, based on vegetative and floral morphological characters. The names of species and plant families have been updated using the database Species List Flora of Brazil (Flora do Brasil, 2020) and Missouri Botanical Garden (Tropicos, 2014). From the database file of all plots, a phytosociological analysis for the total sample was obtained, in order to characterize the tree community studied. For each sampled species, the following were calculated to characterize the Phytosociology (Mueller-Dombois and Ellenberg, 1974; Lamprecht, 1964):

Absolute Density (AD_i) = n_i / A
Relative Density (DR_i) = n_i / N
Absolute Frequency (AF_i) = j_i / k
Relative Rrequency (RF_i) = $AF_i / \Sigma AF$
Relative Dominance (RDO_i) = $BA_i / \Sigma TBA$
Coverage Value Index (CVI_i) = $DR_i + RDO_i$
Importance Value Index (IVI_i) = $FR_i + DR_i + RDO_i$

where:
n_i = Number of individuals of the species i
N = Total number of sampled individuals
j_i = Total number of times the species i occurs in parcels
k = Total number of parcels
BA_i = Basal Area of species i
TBA = Total Basal Area

The diversity of species was analyzed by Shannon diversity index (H '). The Shannon index is calculated using the following equation (Magurran, 1988):

$$H' = - \Sigma pi \ln pi$$

where pi = n_i / N; ni = abundance of the ith species; and N = total abundance of all species.

RESULTS AND DISCUSSION

In the Antônio Danúbio Environmental Park area, 239 individuals were sampled, distributed into 61 species, 51 genera and 27 families (Table 1). The families with most species were Leguminosae 13 (thirteen), Lecythidaceae, Sapotaceae and Urticaceae with 4 (four) each,

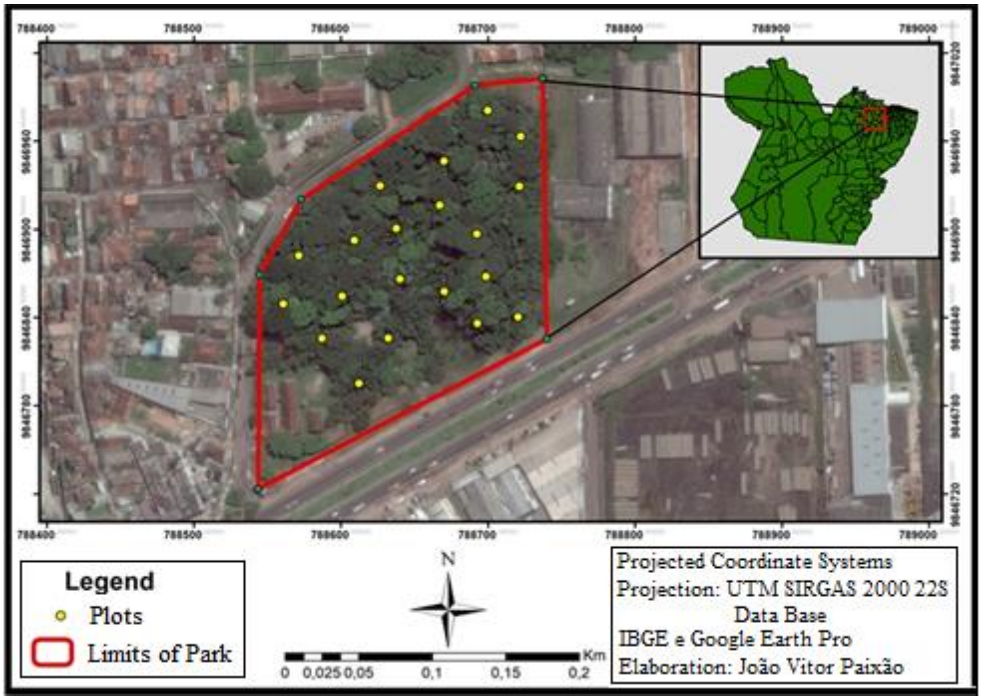

Figure 1. Map of study area: Environmental Park Danube Antonio Lourenço da Silva, city of Ananindeua in the State of Pará, Brazil.

Anacardiaceae, Annonaceae, Caryocaraceae, Vochysiaceae and Lauraceae with 3 (three) each, Arecaceae and Malvaceae with 2 (two) each (Figure 2).

The composition of the families presented in the park under consideration confirms the representativeness of fitocenose in other studies of green areas and urban conservation areas in the metropolitan region of Belém (Laus and Jardim, 2013; Trinity et al., 2007; Santos and Garden, 2006)

Particularly, Environmental Park Antonio Danubio comprised a few families that have obtained a large number of species. This can happen possibly because families are restricted in terms of species in the study area and are therefore more difficult to be located. In the study by Carim et al. (2013), on the floristic composition of a fragment of Atlantic Forest in the extreme north of Brazil, a good representation at the family level has been identified; in the community only 17% had a single species, whereas at the Park this value was 37.5%. The families with the highest number of individuals are Leguminosae (59), Lauraceae (32), Arecaceae (28), Malvaceae (24), Urticaceae (20), Lecythidaceae (10), Vochysiaceae, Anarcadiaceae, Annonaceae and Sapotaceae with 7 (seven) each and Bignoniaceae with 5 (five) each (Figure 2). Among the ten (10) sampled, Leguminosae was the family that most stands out in both species richness and number of individuals.

In Brazil, the family Leguminosae or Fabaceae appears among the main families that comprised the flora of the diverse ecosystems (Souza and Lorenzi, 2005). In floristic studies related to the family, Silva et al. (2013) cited Leguminosae with values expressive in numbers of species for the state of Pará, Brazil. A significant number of individuals (67.21%) have diameters ranging from 10.00 to 135.40 cm, whereas the latter class of diameter from 511.60 cm trees has two maxima Ducke Vochysia and Endopleura Uchi (Huber) Cuatrec (Figure 3).

The behavior shown in definition tends to distribute inverted "J" in diameter distribution of the classes, as the concentration of individuals is considerably on greater numbers in the first tracks. According to Andrade et al. (2017), the distribution of "j" inverted observed in upland forest of Rondônia (Curia Ecological Station), suggests its own natural dynamics arising from mortality and recruitment conducted in the first classes, which ultimately reflect the regeneration intensity in component tree.

In Figure 4, it is possible to observe that, among the individuals sampled, those in the corresponding class from 7.20 m to 11.40 m in height are where the highest percentage of individuals occur, about 28.99%, followed by the class in which the height is between 11.40 to 15.70 m, representing 21.01% of the inhabited individuals. Within the class range that presents the smallest number of individuals (only 0.84%), it comprises the highest individuals with a height of 36.80 to 41.00 m. In a study conducted by Laus and Jardim (2013) at APA Combu Island, the height distribution obtained the highest

Table 1. Phytosociological parameters of the Antônio Danúbio Environmental Park species, Ananindeua, Para, Brazil.

Species	Family	N_i	RD_i	RDO_i	RF_i	CVI_i	IVI_i
Amphymenium rohri (Vahl) Kunth	Leguminosae	1	0.42	0.01	0.22	0.34	0.34
Anacardium spruceanum Benth. ex Engl.	Anacardiaceae	1	0.42	0.20	0.31	0.40	0.40
Bastardiopsis densiflora (Hook. & Arn.) Hassl.	Malvaceae	2	0.84	0.09	0.46	0.70	0.70
Bowdichia Virgilioides Kunth	Leguminosae	1	0.42	0.08	0.25	0.36	0.36
Buchenavia huberi Ducke	Combretaceae	2	0.84	0.49	0.66	0.84	0.84
Buchenavia spp	Combretaceae	1	0.42	0.01	0.22	0.34	0.34
Carapa guianensis Aubl.	Meliaceae	2	0.84	0.35	0.60	0.79	0.79
Caryocar glabrum (Aubl.) Pers.	Caryocaraceae	1	0.42	0.01	0.22	0.34	0.34
Caryocar microcarpum Ducke	Caryocaraceae	2	0.84	0.20	0.52	0.74	0.74
Caryocar villosum (Aubl.) Pers.	Caryocaraceae	1	0.42	0.68	0.55	0.56	0.56
Cecropia obtusifolia Bertol.	Urticaceae	7	2.93	2.03	2.48	2.84	2.84
Cecropia angustifolia Trécul	Urticaceae	5	2.09	0.46	1.27	1.44	1.44
Cecropia sciadophylla Mart	Urticaceae	6	2.51	1.28	1.90	2.05	2.05
Cecropia hololeuca Miq.	Urticaceae	2	0.84	0.10	0.47	0.51	0.51
Cedrela fissilis Vell.	Meliaceae	2	0.84	0.16	0.50	0.73	0.73
Copaifera sp	Leguminosae	5	2.09	0.81	1.45	1.76	1.76
Couratari oblongifolia Ducke & Kunth	Lecythidaceae	3	1.26	1.92	1.59	1.65	1.65
Diplotropis purpurea (Rich.) Amshoff	Leguminosae	9	3.77	13.46	8.61	7.12	7.12
Dydimopanax morototoni (Aubi.) Decne & Planch	Araliacese	3	1.26	0.60	0.93	0.82	0.82
Endopleura uchi (Huber) Cuatrec.	Humiriaceae	2	0.84	1.48	1.16	1.17	1.17
*Enterolobium schomburgkii (*Benth.) Benth.	Leguminosae	2	0.84	0.21	0.53	0.74	0.74
Erisma uncinatum Warm.	Vochysiaceae	4	1.67	1.77	1.72	1.54	1.54
Eschweilera sp	Lecythidaceae	3	1.26	0.64	0.95	1.22	1.22
Euterpe oleracea Mart.	Arecaceae	2	0.84	0.21	0.52	0.74	0.74
Euxylophora paraensis Huber	Rutaceae	1	0.42	0.00	0.21	0.34	0.34
Geoffroea spinosa Jacq.	Leguminosae	2	0.84	0.68	0.76	0.90	0.90
Goupia glabra Aubl.	Goupiaceae	1	0.42	0.10	0.26	0.37	0.37
*Guapira graciliflora (*Mart. ex. Schmidt) Lundell.	Nyctaginaceae	1	0.42	0.09	0.25	0.37	0.37
Guapira Noxia (Netto) Lundell.	Nyctaginaceae	1	0.42	0.03	0.22	0.35	0.35
Holopyxidium jarana Huber ex Ducke	Lecythidaceae	1	0.42	0.18	0.30	0.40	0.40
Inga edulis Mart.	Leguminosae	5	2.09	0.28	1.18	1.78	1.78
Inga laurina (Sw.) Willd.	Leguminosae	15	6.28	6.40	6.34	5.41	5.41
Inga sessilis (Vell.) Mart.	Leguminosae	3	1.26	0.43	0.85	0.96	0.96
Jacaranda copaia (Aubl.) D. Don	Bignoniaceae	5	2.09	0.45	1.27	1.83	1.83
Lecythis pisonis Cambess.	Lecythidaceae	3	1.26	1.60	1.43	1.54	1.54
Manilkara bidentata (A.D.C) A. Chev.	Sapotaceae	1	0.42	0.23	0.33	0.41	0.41
Manilkara huberi (Ducke) A. Chev.	Sapotaceae	1	0.42	0.74	0.58	0.58	0.58
Maytenus rigida Mart.	Celastraceae	1	0.42	0.03	0.23	0.35	0.35
Minquartia guianensis Aubl.	Olacaceae	2	0.84	0.05	0.44	0.69	0.69
Nectandra cuspidata Nees	Lauraceae	29	12.13	11.24	11.69	9.96	9.96
Nectandra rubra (Mez) C.K. Allen.	Lauraceae	2	0.84	0.77	0.80	0.93	0.93
Ocatea cymbarum Kunth	Lauraceae	1	0.42	0.24	0.33	0.42	0.42
Oenocarpus bacaba Mart.	Arecaceae	26	10.88	17.89	14.39	12.55	12.55
Onychopetalum amazonicum R. E. Fr.	Annonaceae	4	1.67	0.68	1.18	1.38	1.38
Picrolemma pseudocoffea Ducke	Simaroubaceae	1	0.42	0.11	0.27	0.37	0.37
Piptadenia suaveolens Miq.	Leguminosae	10	4.18	10.05	7.12	6.12	6.12
Pouteria pachycarpa Pires	Sapotaceae	1	0.42	0.04	0.23	0.35	0.35
Protium heptaphyllum (Aubl.) Marchand	Burseraceae	4	1.67	0.91	1.29	1.65	1.65
Rollinia exsucca (DC.) A.DC.	Annonaceae	2	0.84	1.04	0.94	1.02	1.02
*Schefflera morototoni (*Aubl.) Maguire et al.	Araliacese	2	0.84	0.87	0.85	0.96	0.96
Sclerolobium paniculatum Vogel	Leguminosae	2	0.84	0.81	0.82	0.94	0.94

Table 1. Contd.

Sideroxylon gardnerianum A. DC.	**Sapotaceae**	**4**	**1.67**	**0.45**	**1.06**	**1.30**	**1.30**
Spondias mombin L.	Anacardiaceae	1	0.42	0.00	0.21	0.34	0.34
Stryphnodendron barbadetiman (Vell.) Mart.	Leguminosae	1	0.42	0.06	0.24	0.36	0.36
Tachigali myrmecophila (Ducke) Ducke	Leguminosae	3	1.26	1.24	1.25	1.42	1.42
Tapirira guianensis Aubl.	Anacardiaceae	5	2.09	1.02	1.56	2.02	2.02
Theobroma grandiflorum (Willd. ex Spreng.) K. Schum	Malvaceae	22	9.21	11.03	10.12	8.72	8.72
Virola surinamensis (Rol.) Warb.	Myristicaceae	3	1.26	1.10	1.18	1.38	1.38
Vochysia maxima Ducke	Vochysiaceae	1	0.42	0.99	0.71	0.67	0.67
Vochysia spp	Vochysiaceae	2	0.84	0.88	0.86	0.77	0.77
Xylopia nitida Dunal	Annonaceae	1	0.42	0.04	0.23	0.35	0.35
Total		239	100	100	100	100	100

N_i: number of individuals; RDi: relative density; RDO_i: Relative dominance; RF_i: relative frequency; CVI_i: coverage value index; and IVI_i: importance value index.

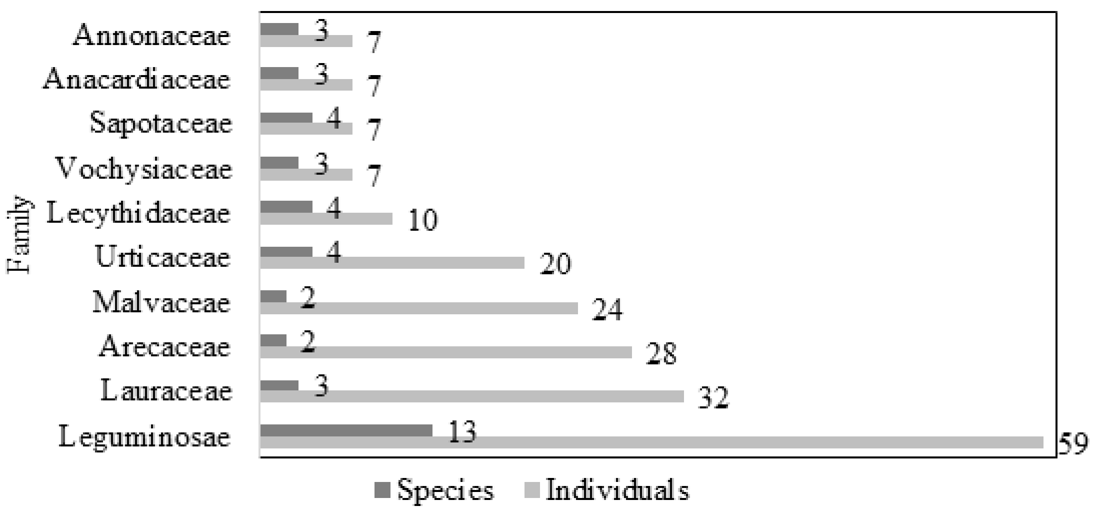

Figure 2. Distribution of the number of species and individuals by botanical families. Environmental Park Antonio Danube municipality of Ananindeua, PA, Brazil.

concentration in the first two classes which corresponds to 60% of the total of individuals, and the lowest in the last classes follows along the curve one distribution. The species that obtained the highest values of relative density (Figure 5) were: *Nectandra cuspidata*, *Oenocarpus bacaba*, *Theobroma grandiflorum*, *Inga laurina, Piptadenia suaveolens, Cecropia obtusifolia*, *Cecropia sciadophylla, Tapirira guianensis and Cecropia angustifólia*. These species represent 17.54% of the total sampled species; however, it holds 61.08% of the total number of individuals per hectare.

In relation to the species with greater relative dominance (Figure 6), the species *Oenocarpus bacaba* presented the highest basal area per hectare, followed by the species, *Diplotropis purpurea*, *Nectandra cuspidata*, *Theobroma grandiflorum*, *Piptadenia suaveolens*, *Inga laurina*, *Cecropia obtusifolia*, *Couratari oblongifolia*, *Erisma uncinatum* and *Lecythis pisonis*. These species together hold 77.38% of the basal area per hectare. The species that obtained the highest values of the relative frequency (Figure 7) are: *Oenocarpus bacaba* (arecaceae), *Nectandra cuspidata* (Lauraceae), *Theobroma grandiflorum* (Malvaceae), *Piptadenia suaveolens* (Leguminosae), *Cecropia obtusifolia* (Urticaceae), *Inga laurina* (Leguminosae), *Tapirira guianensis* (Anacardiaceae), *Jacaranda copaia* (Bignoniaceae) and Inga *edulis* (Leguminosae).

The families of the species found reveal the characteristic of an area that is in the secondary forest phase, both by the behavioral analysis of some that appear after anthropic disturbance (Urticaceae, Malvaceae and Anarcardiceae) and by the successional

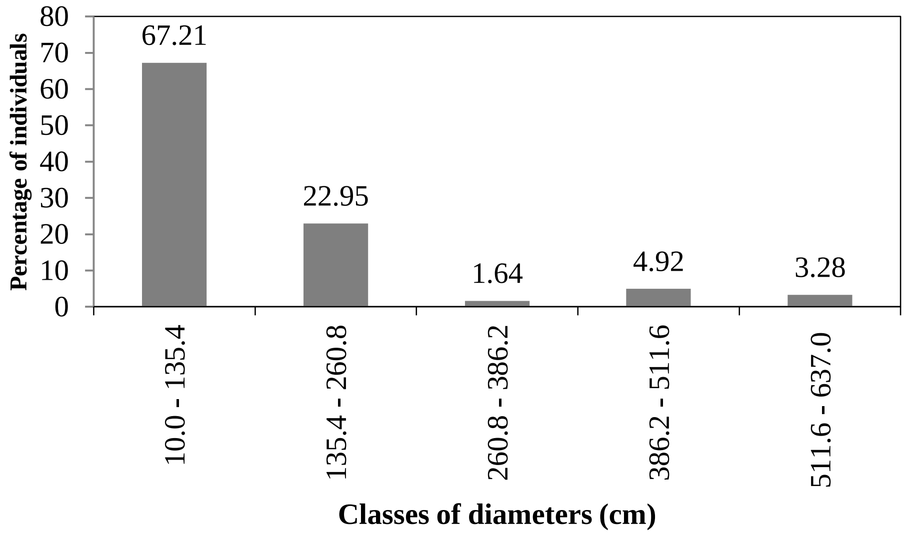

Figure 3. Distribution of individuals diameters at breast height (DBH) cm in their class interval. Antônio Danúbio Environmental Park, municipality of Ananindeua, PA, Brazil.

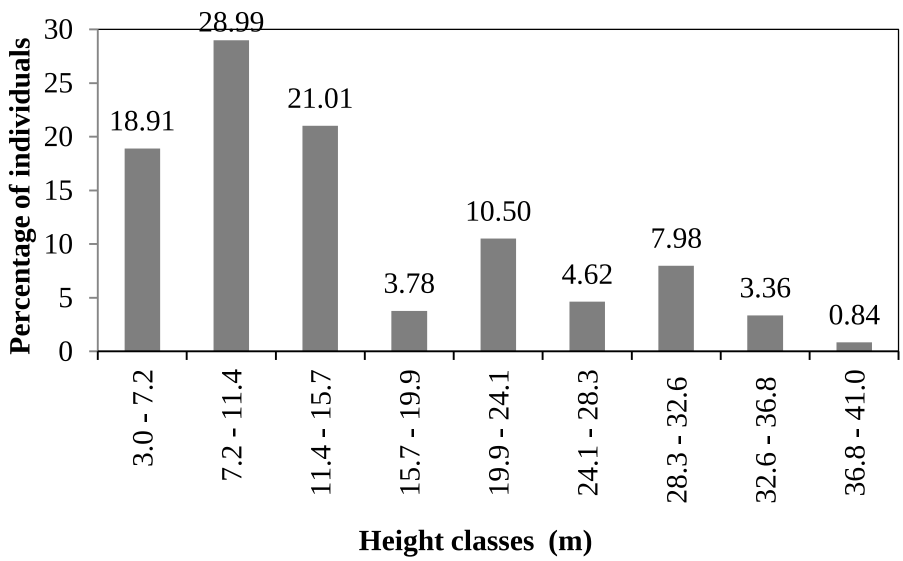

Figure 4. Distribution of the number of individuals per height class (m). Antônio Danúbio Environmental Park, municipality of Ananindeua, PA, Brazil.

analysis of families that are commonly present in the early stages (Leguminosae) of areas.

In particular, the species *Oenocarpus bacaba* and *Cecropia obtusifolia* are typical of the Amazon region, where they can grow in the shade, but prefer more open areas. The first one is fire resistant, being found in capoeiras and pastures (Cymerys, 2005). The second is found either in open forest areas (recent clearings or more advanced clearings), near the slopes of water courses, less crowded places, or in depleted soils (Berg, 1978). The species with the highest coverage value index were: *Oenocarpus bacaba*, *Nectandra cuspidata*, *Theobroma grandiflorum*, *Diplotropis purpurea*, *Piptadenia suaveolens*, *Inga laurina*, *Cecropia obtusifolia*, *Cecropia sciadophylla*, *Erisma uncinatum* and *Couratari oblongifolia* as shown in Figure 8. These species represent 56.06% of the total individuals per ha and 65.94% of the cover value index (CVI%).

Oenocarpus bacaba, *Nectandra cuspidata*, *Theobroma grandiflorum*, *Diplotropis purpurea*, *Piptadenia suavelons*, *Inga Lauriana*, *Cecropia obtusifolia*, *Cecropia sciadophylla*, *Tapirira guianensis* and *Jacaranda copaia* are the species with the highest value index of importance (Figure 9). These species represent 56.06%

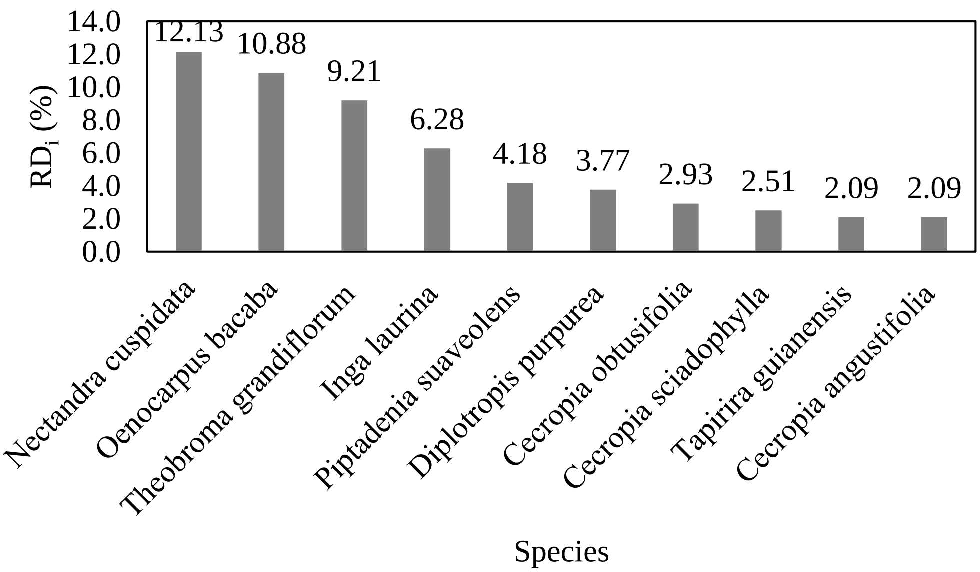

Figure 5. Relative Density (RD_i) of the most representative species of the arboreal stratum of the Antônio Danúbio Environmental Park in the municipality of Ananindeua, PA, Brazil.

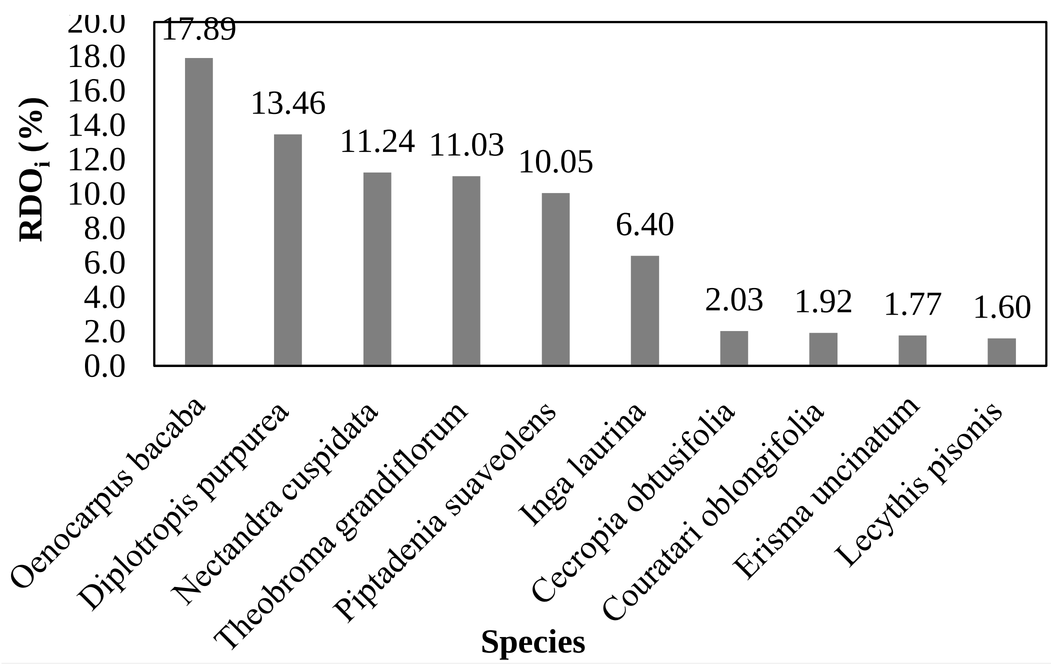

Figure 6. Relative Dominance (RDO_i%) of the most representative species of the arboreal stratum of the Antônio Danúbio Environmental Park in the city of Ananindeua, PA, Brazil.

of the individuals sampled per ha and 58.63% of the importance value index (IVI_i). The species with the highest values of importance consequently are those that obtained the highest values of frequency, density and absolute dominance, since the value of importance is the sum of these results, and attributes to these species are greater ecological importance within this plant community (Table 1).

Carim et al. (2013) assumed that by the characteristic rate associated with the three parameters, phytosociological confers actual weight in each species' ecological importance that is present within the community. In ascending order, among the species with the highest levels of importance, *Oenocarpus bacaba*

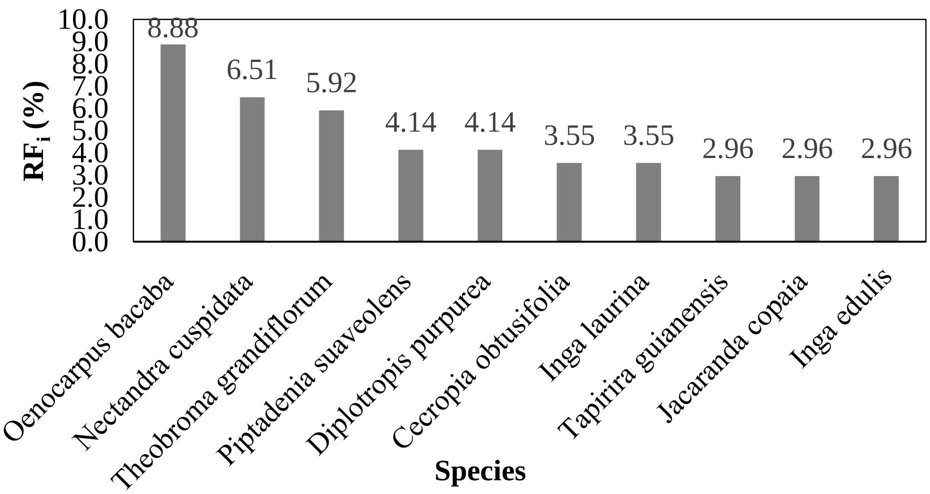

Figure 7. Relative frequency (FR$_i$) of the most representative species of the arboreal stratum of the Antônio Danúbio Environmental Park in the municipality of Ananindeua, PA, Brazil.

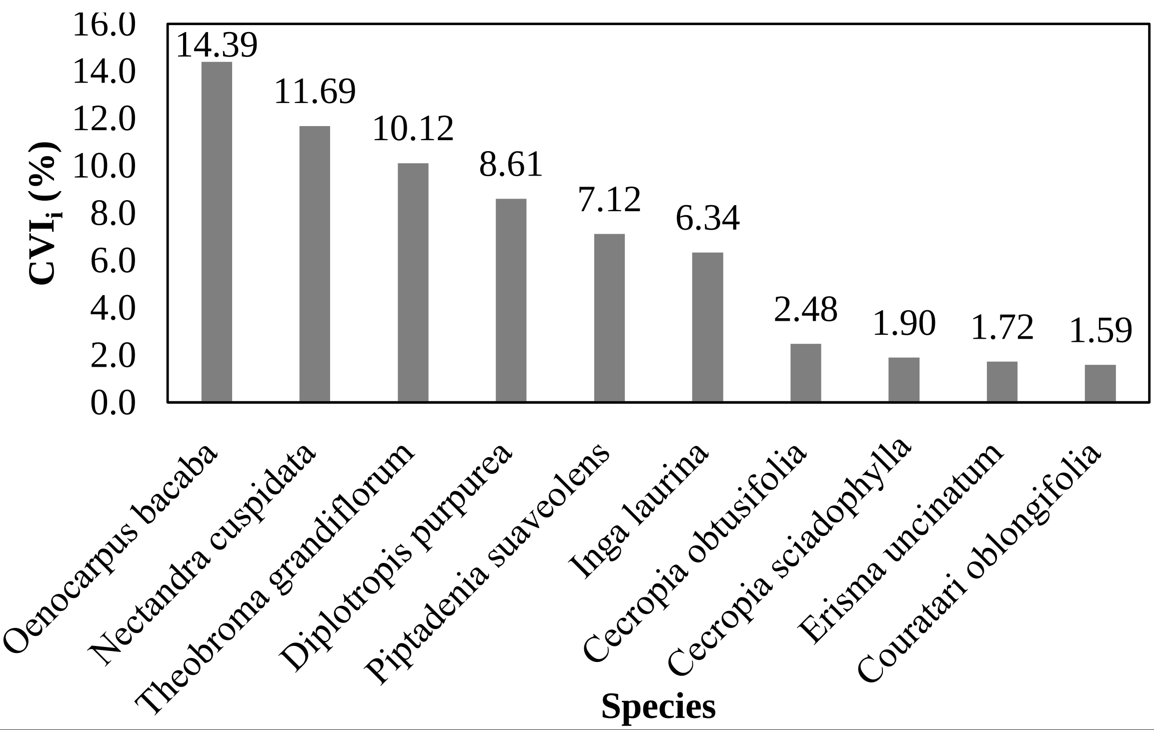

Figure 8. Coverage Value Index (CVI$_i$%) of the most representative species of the arboreal stratum of the Antônio Danúbio Environmental Park in the municipality of Ananindeua, PA, Brazil.

value stood out by presenting IVI of 23.21; thus, leaving the front *Nectandra* species cuspidata which has the greatest number of individuals in the community (29) to obtain a lower level (20.82).

The result cited is related to the weight that the dominance and relative frequency of individuals earned in relation to species Arecaceae family. The species that showed higher importance local conditions are theoretically the most suitable (Estigarribia et al., 2017). The diversity of trees found in the study area was 3.53 nats/ind. by Shannon-Wiener index (Table 2). Compared to other arboreal strata of the metropolitan area, the Environmental Park Antonio Danube has a flora diversity below the others. Only the front of Combu Island,

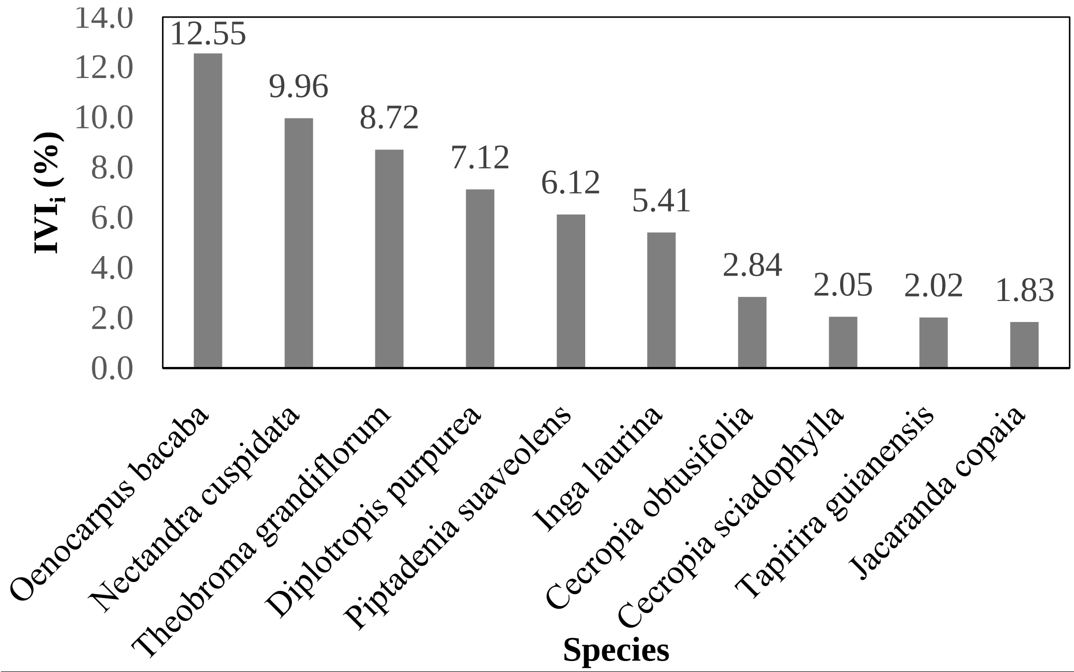

Figure 9. Importance Value Index (IVI$_i$) of the most representative species of the Antônio Danúbio Environmental Park in the municipality of Ananindeua, PA.

Table 2. Comparison of the diversity index (H') of Antônio Danúbio Park with other remaining fragments of primary forests located in the State of Pará, Brazil.

Area	No. of species	Diversity index (H ')	References
Antonio Danubio Park	57	3.53	Authors (2016)
Amafrutas	325	4.62	Goeldi Museum (2009)
Trambioca	250	4.56	Goeldi Museum (2009)
Bosque Rodrigues Alves	258	4.45	Goeldi Museum (2009)
Island Combu	70	2.58	Goeldi Museum (2009)
Gunma Ecological Park	379	4.72	Goeldi Museum (2009)
Mocambo	234	4.24	Goeldi Museum (2009)

one of the factors that lead to this reduced number has low number of species found.

Silva et al. (2014) obtained a diversity index of 4.27 for primary upland forest. Already, Andrade et al. (2017) in Cuniã Ecological Station (RO) found a range of 3.76. In the latter, the authors considered that the low biodiversity in relation to other regions of the Amazon did not void the importance of the area, since the recognition becomes a contribution to the protection of the floristic composition. One explanation for the diversity found in the park may be linked mainly to the condition of being located in an urban area, where the characteristics of size, lack of connectivity with other green areas, isolation time and its disturbing history are variables that interfere with abiotic components of the medium and thus perpetuating the species.

Conclusion

The results show the existence of common floristic and structural variations of vegetation located in urban areas. The Shannon diversity index was inferior compared to other forest fragments located in the state of Pará, probably due to the Antônio Danúbio environmental park being part of an anthropic area near the federal highway BR-316, where a large number of vehicles circulate daily. In this sense, although the number of individuals was small, the study is of great relevance, since it represents the physiognomy of this fragment of forest that still remains in the municipality of Ananindeua, located in the state of Pará, Brazil.

Considering the low number of species observed, it is suggested that the municipal public authority, manager of the Antônio Danúbio Park, develop a plan to recover the area, introducing species endemic to the Amazon. In addition to implementing other actions related to the protection and management of forest resources in the area, both the awareness of the local population and the importance of maintenance, as well as the permanent studies of the forest fragment is recommended. It is observed from the results that continuous efforts are needed to achieve a more balanced environment of fauna, flora, water, air and other elements.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Schoolchildren as informants about bushmeat consumption in Western Serengeti, Tanzania

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Bushmeat contributes to household food security in Western Serengeti, particularly for low-income families who are unable to afford more expensive meat sources. However, as the human population grows, bushmeat demand is increasingly unsustainable. Formulating effective policies to reduce illegal bushmeat hunting in Serengeti National Park (SNP), requires information about the contribution of bushmeat to household meat protein consumption as it varies along a gradient of distance from protected areas and between seasons, which can be difficult to obtain from adults due to the illegal nature of hunting. Data on bushmeat consumption frequencies were collected from 127 class four pupils and compared to that of 150 adults. Data were obtained through interviews conducted in both the dry and wet seasons in October 2017 and April 2018, respectively, in three villages selected based on distance from the boundary of SNP (near, intermediate and far away). Mean reported bushmeat consumption frequencies by both schoolchildren and adults differed significantly between villages declining with distance from SNP. Bushmeat consumption frequencies reported by both groups were significantly higher during the dry season (66%) compared to the wet season (34%). Adults on average reported significantly lower bushmeat consumption frequencies than schoolchildren in both seasons. The results suggest that children are less constrained by the illegal nature of bushmeat hunting and therefore may provide more accurate information about the importance of bushmeat in household consumption than adults. Results also reveal that bushmeat contributes considerably to household meat consumption in villages close to the SNP but not further away. This study provides valuable insights for targeting policies to reduce illegal bushmeat hunting, including through promoting substitute protein sources.

Key words: Consumption frequency, spatial and temporal variations, meat types.

INTRODUCTION

Bushmeat is an important component of household food security in many locations across Sub-Saharan Africa (Lindsey et al., 2013; Nielsen et al., 2017). Bushmeat is particularly important to poor rural households providing protein and essential micronutrients that may otherwise be inaccessible with potentially severe health implications (Fa et al., 2015; Golden et al., 2011). Bushmeat, also called game or wild meat, is defined as meat from nondomesticated or wild animals hunted, processed and consumed by humans. Bushmeat hunting is considered a significant threat to conservation objectives and depletion of wildlife populations has been tied to high hunting pressure in many locations (Clements et al., 2014; Ripple et al., 2016).

In Tanzania, bushmeat hunting is practised illegally by communities adjacent to protected areas and other wildlife areas since the process of obtaining a hunting licence is economically and practically unfeasible for most local people (Ceppi and Nielsen, 2014; Mfunda and Røskaft, 2010). In Western Serengeti, illegal hunting is an important source of income for primarily young men trading a third of their catch while the rest is consumed in the household (Loibooki et al., 2002). Estimates of the number of households engaged in bushmeat hunting in western Serengeti vary between 8 and 57% of all households (Nuno et al., 2013). About 75% of arrested poachers come from nearby villages, between 0 and 16 km from protected area boundaries, but some live as far away as 45 km (Holmern et al., 2007; Kideghesho, 2010; Loibooki et al., 2002).

Bushmeat is generally much cheaper than domestic animal meat sold at prices between 0.85 and 1.0 US$ per kg (Rentsch and Damon, 2013) while beef, for instance, is sold at prices ranging from 2.7 to 4.7 US$ per kg. With such price difference combined with culturally determined preferences for bushmeat, the reliance of income-poor households on bushmeat for protein seems inevitable (Ndibalema and Songorwa, 2007). However, the sustainability of extraction levels in the Greater Serengeti Ecosystem (GSE) is questionable, and hunting intensity is expected to increase further because of the rising human population in districts adjacent to the protected areas (Holmern et al., 2007; Rogan et al., 2017, Setsaas et al., 2007). Rentsch and Packer (2015), for instance, estimate an annual offtake of 97,796 - 140,615 individual wildebeest and poaching has been identified as the driver of population decline in several species populations (Metzger et al. 2010, Strauss et al. 2015). Depletion of wildlife populations will negatively affect not only rural households directly through their reliance on bushmeat for food and income but also indirectly by reducing tourism income generation, which is an essential source of revenue for Tanzanian’s national economy, with trickle-down effects on local communities through various benefit-sharing arrangements and extension services.

A considerable number of studies have attempted to quantify the importance of bushmeat to communities in Western Serengeti (Fischer et al., 2014; Mfunda and Røskaft, 2010). Information about the importance of bushmeat is essential to develop appropriate conservation and development strategies. However, obtaining accurate, reliable data is complicated by the illegal nature of bushmeat hunting, which means that respondents are reluctant to share information for fear of reprisals (Knapp et al., 2010; Nuno et al., 2013). Recent studies have attempted to overcome the reluctance of adults to share information by interviewing children instead (Haule et al., 2002, van Vliet et al. 2015). If following appropriate ethical guidelines aiming to protect respondents, children may be a rich source of information about various questions concerned with household food and nutritional security (Baranowski et al., 2012; McPherson et al., 2000).

Interviewing children may furthermore overcome the challenge of strategic behaviour by respondents about their bushmeat consumption. We, therefore, interviewed standard-four pupils in primary schools as well as adult respondents through interview-based questionnaire surveys to collect information about the frequency of bushmeat consumption at the household level in villages along a gradient of distance from protected areas in Western Serengeti. The multiple objectives include comparing bushmeat consumption frequency in villages along a gradient of distance from protected area boundaries and between seasons. We also compare information reported by schoolchildren to that of adult respondents to assess the accuracy of information provided by the schoolchildren assuming that lower mean bushmeat consumption frequencies reported by adults reflect reluctance to report accurate information. Finally, we evaluate the determinants of bushmeat consumption frequency.

The study had four hypotheses. Hypothesis one postulated that bushmeat consumption frequency is higher during the dry season than the wet season, hypothesis two that bushmeat consumption frequency decrease with increasing distance from protected area boundary, hypothesis three that children report higher bushmeat consumption frequency than adults and hypothesis four that bushmeat consumption frequency is associated with socioeconomic characteristics including household size, age of respondent (adult or child), whether or not the household head held a formal occupation as an indicator of wealth, and the frequency of consumption of other meat types.

Approval to conduct the study was obtained following an ethical evaluation by the National Health Research Ethics Committee under the National Institute for Medical Research (NIMR). An informed consent form was developed, and children, as well as adults, were all verbally explained the objectives of the study and that they could withdraw their participation at any time during the study obtaining children's agreement to participate in the presence of their legal guardian.

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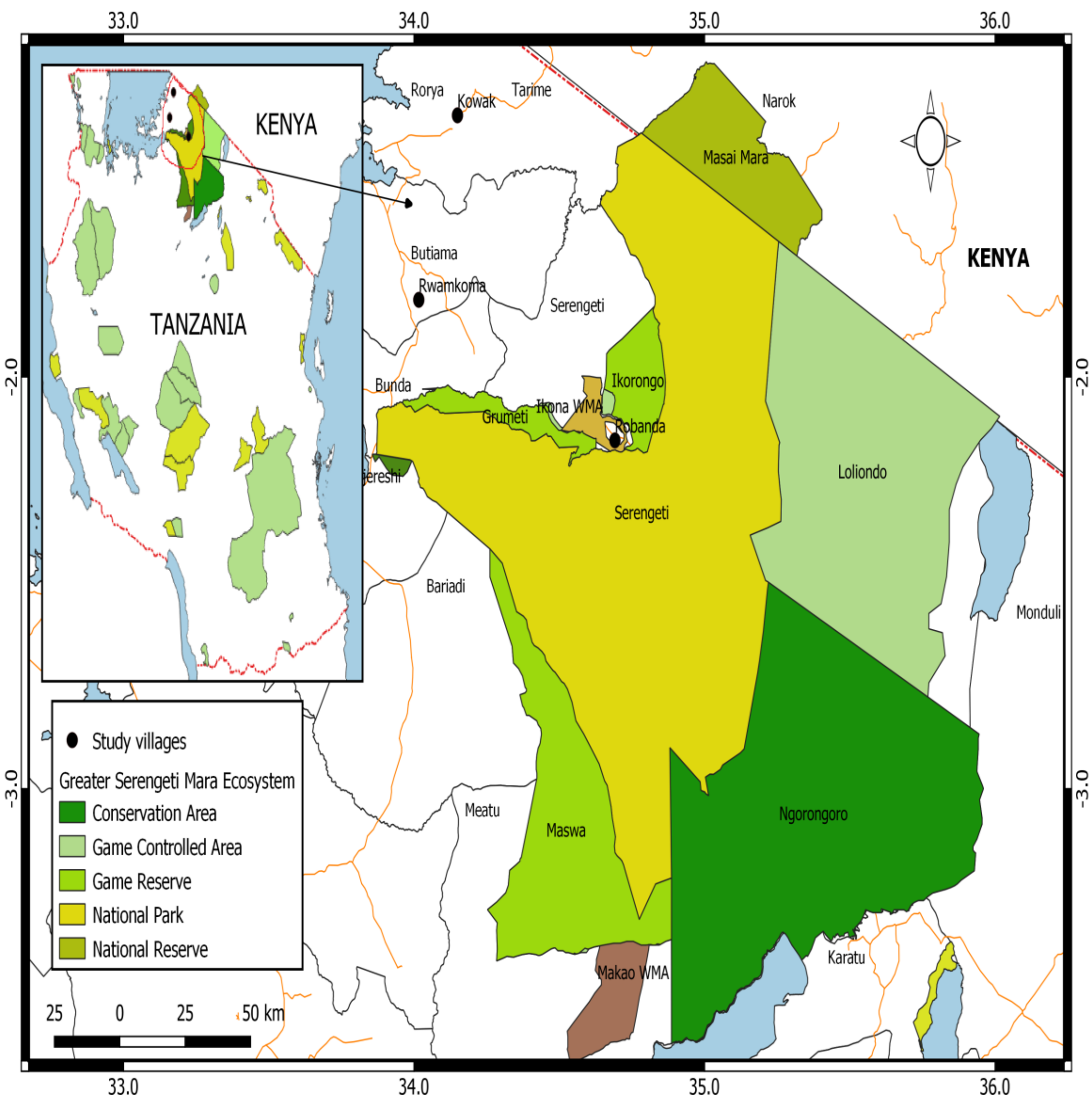

Figure 1. Map of the study area and its location in Tanzania marked with a red circle (in the top left corner). The study villages Robanda, Rwamkoma and Kowak are indicated with black circles and text.

METHODS

Study area

Serengeti National Park (SNP) (14,763 km^2) is a component of the GSE located between 1°28' to 3°17'S and 33°50' to 35°20'E in Tanzania. In addition to the SNP the GSE also includes, on the western side Ikona wildlife management area (600 km^2), Ikorongo game reserve (563 km^2), Grumeti game reserve (416 km^2), Kijereshi and Maswa game reserves (2,200 km^2) on the southern side, and Ngorongoro conservation area (8,292 km^2) and Loliondo game controlled area (4,000 km^2) on the eastern side. The GSE is a highland savannah region with plains and woodlands at an altitude of 1000 to 1800 m above sea level. The GSE is World Heritage listed and a famous tourist attraction due in part to hosting the last remaining great wildlife migration consisting of wildbeast (*Connochaetes taurus)* and other herbivores. Community land in Western Serengeti acts as a corridor for the migration on its route to the Maasai Mara reserve in Kenya (Loibooki et al., 2002). The migration influences the availability of bushmeat in adjacent communities through illegal hunting (Mwakatobe et al., 2012; Nyahongo et al., 2009).

The study was conducted in three villages (Robanda, Rwamkoma and Kowak) located in Western Serengeti (Figure 1). These villages were purposely selected based on distance from the boundary of SNP. Distances from the centre of the villages to the nearest park boundary are Robanda 3 km, Rwamkoma 27 km and Kowak 58 km. We refer to these villages as close, intermediate and far from the park. The ethnic composition in the villages is diverse including Ikoma, Kurya, Ikizu, Zanaki, Jita and Luo tribes. The human population in the villages close to the park is increasing rapidly at a rate of 3.5% annually (Estes et al., 2012; URT, 2013) and a large proportion of the population subsists on less than 1 US$ per day facing deteriorating well-being due to environmental degradation and lack of economic options (Kideghesho, 2010; Loibooki et al., 2002). The main economic activities are subsistence farming (maize, cassava, millet and sorghum), pastoralism (cattle, goat and sheep), poultry, hunting, fishing, charcoal making and making local brews (Kideghesho, 2010; Loibooki et al., 2002).

Data collection from schoolchildren

Data were collected through interviews during the dry season in October 2017 and the wet season in April 2018. Collecting information in both the wet and the dry seasons was done in consideration of the high influence of season and the wildlife migration on the availability of bushmeat in the study area (Nyahongo et al., 2009). Interviews were conducted with schoolchildren from primary schools in the study villages. Forty schoolchildren were selected randomly from the standard four classes in each school. This age group represent children between 9 and 12 years, which means that they are old enough to recall and explain what they have consumed (Diep et al., 2015) but too young to have participated in hunting, which may increase awareness about the illegality and possible sanctions for hunting illegally.

On the first day of the data collection in each school, the research team discussed general issues like health, nutrition and biology with the pupils to establish a good rapport with the children. Subsequently, the team implemented a questionnaire enquiring about pupils' household socio-demographic characteristics with the help of the teachers. The questions were explained in plenum and pupils were given time to complete the questionnaire with help from the teacher and researchers. The questionnaire obtained information about the children and their families (age and gender of all household members, and household head occupation), and the composition of meals consumed the day before the interview (breakfast, lunch and dinner). The second day of the study, pupils were asked specifically about types of meat consumed in meals in their household the past 24 hrs. This questionnaire was repeated each day the subsequent four consecutive weeks (information about Saturday and Sundays were recorded on the following Monday) in each season (wet and dry season). The final combined sample contains information about 21,336 meals from a total of 127 pupils from the three villages after attrition.

Data collection from adults

Information about bushmeat consumption frequencies from adults was collected through household questionnaire surveys conducted in the same three villages in the same period as the data collection from schoolchildren, that is, October 2017 and April 2018. Households were selected randomly from the village register through the aid of the Village Executive Officer. The head of the household was interviewed using a questionnaire containing questions about age, gender, education and occupation. In the absence of the household head, the wife (if the household was male headed) or the oldest household member above 18 years of age was interviewed instead. The questionnaire also inquired about the frequency of meat containing meals consumed the week before the interview. A total of 150 respondents in the three study villages were interviewed in both seasons.

Data analysis

The average frequency of consumption (that is, times per week) in each village was calculated for each meat type in each season by dividing the average number of meat meals of each type by the number of days in the recording period. Other meat types were grouped into two main categories; "domestic" for all livestock meat types and "fish" for all species and types of fish including sardines (small dried fish). Comparisons of means were conducted after testing the normality assumption using the Shapiro-Wilkes test. The variation in bushmeat consumption between villages and seasons was analysed using Kruskal-Wallis tests, and the significance of differences was tested using Dunn's post hock test. Wilcoxon tests were used to compare stated bushmeat consumption frequencies between schoolchildren and adults in the same village. As stated bushmeat consumption frequencies for adults was obtained using recall during the first week of the survey in each village we selected the first week of data collected from the children for comparison. This approach was selected in order to minimise bias induced by temporal variations in bushmeat consumption. However, the variation in children's bushmeat consumption frequency between weeks were tested in each season and found no significant difference between the four weeks was found (Kruskal-Wallis test: dry season; $H = 3.18$; $P = 0.364$, and wet season; $H = 1.32$; $P = 0.725$).

Finally, the determinants of the frequency of bushmeat consumption were evaluated through a Generalised Linear Model (GLM) with logarithmic transformation and standard specification of quasi-Poisson family and a canonical link function. Selection of variables was based on general economic theory and relevant empirical findings (Fischer et al., 2014; Knapp et al., 2010; Nyahongo, 2009). The model tested the influence of distance to protected area boundary (in kilometres), season (wet or dry season), age of respondent (child or adult), household size (number of household members) and occupation of household head (peasant and pastoralist vs employed or managing a small scale business) (Table 1). Evaluation of the model was done using the dispersion parameter and Variance Inflation Factor (VIF). The VIF was calculated to detect and evaluate the presence of multicollinearity. All statistical tests were done in R-Studio (version 1.1.456).

RESULTS

Characteristics of the sample

A total number of 127 class 4 pupils and 150 adults were interviewed in the three villages. The characteristics of villages and the sample in each village are presented in Table 2.

Frequency of bushmeat consumption

Altogether 572 meals contained bushmeat out of 3,623 meat meals recorded in the overall sample from both adults and schoolchildren. In total, bushmeat constituted 15.8% of meat containing meals. The meat of domestic animals constituted 18% while fish was by far the most common source of animal protein at 66.2% of meals containing meat. However, bushmeat consumption differed between villages (Kruskal-Wallis test: $H=454.2$; $P<0.001$) and was consumed very frequently in Robanda the closest villages to SNP at 96.3% of meals, while very little bushmeat was consumed in villages further away (Rwamkoma 1.4% and Kowak 2.3%). More bushmeat was consumed in meals for dinner (57%) than in meals for lunch (43%) and no bushmeat was consumed during breakfast. Bushmeat meals were more frequently consumed during the dry season (66%) than during the wet season (34%). Finally, more fish meals were consumed in Rwamkoma, and Kowak than in Robanda (Figure 3) and

Table 1. Explanatory variables and expected sign of coefficient for variables selected as indicators for testing hypotheses about the determinants of bushmeat consumption frequency in the GSE.

Covariate	Unit	Sign	Hypothesis
Distance	Km	-	Bushmeat consumption frequency is inversely related to distance to the protected area boundary as an indicator of availability and price of bushmeat
Dry season	Dummy variable (Dry season coded as 1 and wet season coded as 0)	+	Bushmeat consumption is higher during the dry season than in the wet season due to the presence of the wildebeest migration in the dry season
Children	Dummy variable (Children coded as 1 and adults coded as 0)	+	Children state higher bushmeat consumption frequency than adults due to lack of concern about reprisal as a consequence of the illegality of bushmeat hunting.
Household size	Number of people	+	Larger households are more efficient in wealth generation and therefore can afford to purchase more bushmeat and allocate household members to hunting
Household head occupation	Dummy variable (Employed or managing small business coded as 1 and peasants and pastoralists coded as 0)	+	Bushmeat consumption frequency is positively associated with formal occupation or running a small scale business as an indicator of wealth
Domestic meat consumption	Frequency	-	Bushmeat consumption frequency is inversely related to domestic meat consumption frequency as an indicator of wealth and fulfilment of protein needs from other ources.
Fish consumption	Frequency	-	Bushmeat consumption frequency is inversely related to fish consumption frequency as an indicator of wealth and fulfilment of protein needs from other sources.

Table 2. Baseline information of the respondents.

Variable		Robanda	Rwamkoma	Kowak
Village characteristics	Total village population	4,735	4,821	4,382
	Number of households	471	802	695
	Distance to PA boundary (Euclidean distance) (km)	3	27	58
Children sample	Children interviewed	46	49	32
	Girls (%)	52.2	57.1	46.9
	Boys (%)	47.8	42.9	53.1
	Age group 9 -12 years (%)	91.3	83.7	90.6
	Age group 13 -14 years (%)	8.7	16.3	9.4
	Household heads occupation	-	-	-
	Peasants (%)	26.1	87.8	87.5
	Agro-pastoralists (%)	32.6	0	0
	Employment and Small scale business (%)	41.3	12.2	12.5
Adult sample	Adults interviewed	**50**	**50**	**50**
	Males (%)	58	46	42
	Females (%)	42	54	58
	Household heads occupation	-	-	-
	Peasants (%)	46	86	64
	Agro-pastoralists (%)	34	14	28
	Employment and Small-scale business (%)	20	0	8

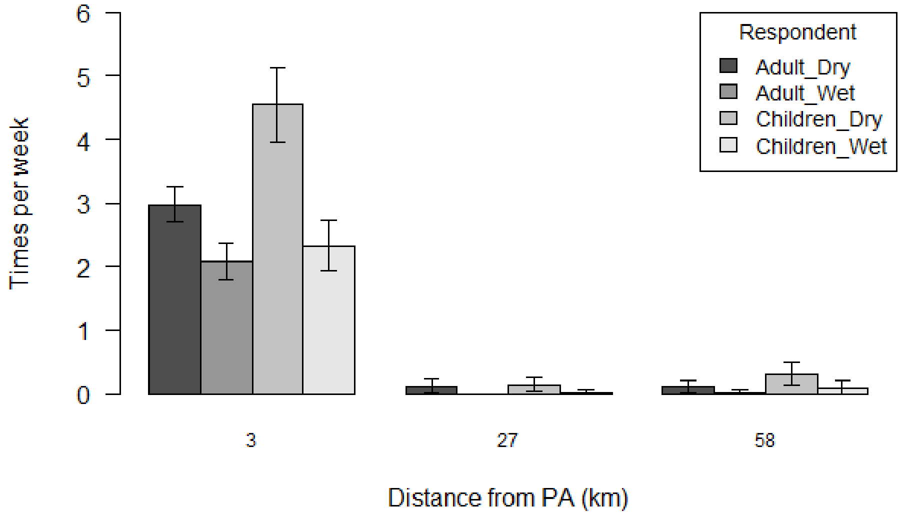

Figure 2. Average number of bushmeat meals consumed per week reported by adults and schoolchildren in the wet and the dry season in Robanda, Rwamkoma and Kowak at increasing distance from the PA boundary.

bushmeat consumption was negatively correlated with fish consumption (Spearman rank correlation test; r=-0.58; P<0.001).

Temporal variation in bushmeat consumption

A combined analysis of data from both adults and schoolchildren shows that, the average number of bushmeat meals per week was significantly higher in the dry season (1.35 ± 0.12) than in the wet season (0.71 ± 0.07), (Figure 2; Wilcoxon test; W=42.50; P=0.018). Furthermore, during the dry season schoolchildren reported a significant higher bushmeat consumption (1.78 ± 0.22) than adult respondents (0.99 ± 0.13); (Wilcoxon test; W=7820.50; P = 0.002). However, during the wet season, the consumption frequencies of adults (0.57 ± 0.08) and schoolchildren (0.87±0.12) were not significantly different (Wilcoxon test; W=8880; P=0.21). In the closest village (Robanda) where bushmeat was most frequently consumed (96.3% of meat containing meals), the consumption frequency was also significantly higher during the dry season than in the wet season (Figure 2) (Wilcoxon test; W=7137.50; P<0.01). Schoolchildren in Robanda (4.54±0.3 and 2.33±0.2, dry and wet season, respectively) reported significantly higher bushmeat consumption than adults (2.98±0.2 and 1.72±0.12, dry and wet season, respectively) in both seasons (Figure 2) (Wilcoxon test; W=3155; P<0.0001).

Spatial variation in bushmeat consumption

Bushmeat consumption was significantly higher in the closest village (Robanda) than in the more distant villages (Rwamkoma and Kowak) (Figure 2) in both seasons (Kruskal-Wallis tests; H=219.88; P<0.001 and H=240.57; P<0.001, in the wet and dry season, respectively). Furthermore, a post hoc Dunn's test shows a significantly higher consumption in Robanda than in Kowak (Z=12.28; P<0.001 and Z=12.89; P<0.001 in the dry and wet season, respectively), as well as in Rwamkoma (Z=13.23; P<0.001 Z=13.79; P<0.001, in the dry and wet season, respectively). However, the bushmeat consumption frequency did not differ significantly between Rwamkoma and Kowak in either season (Z=0.37; P=0.714 and Z=0.28; P=0.78, in the dry and wet season, respectively). In the distant villages, only few respondents both adults and schoolchildren reported bushmeat consumption in their households (Figure 2). Even in the closest village where both adults and students reported bushmeat consumption, schoolchildren reported higher consumption (57.35%) than adults (42.65%).

Spatial variations in the consumption of other meat types

In the dry season, the consumption of other meat types differed significantly between villages (Kruskal-Wallis tests; Domestic meat: H=17.23; P<0.0001 and fish: H=79.041; P<0.001). The average consumption frequency for both domestic meat and fish reported by children were significantly higher than that of adults (Figures 3 and 4) (Domestic meat: W=6302; P<0.001. Fish: W=5395.5; P<0.001) during the dry season.

Moreover, fish consumption also differed significantly

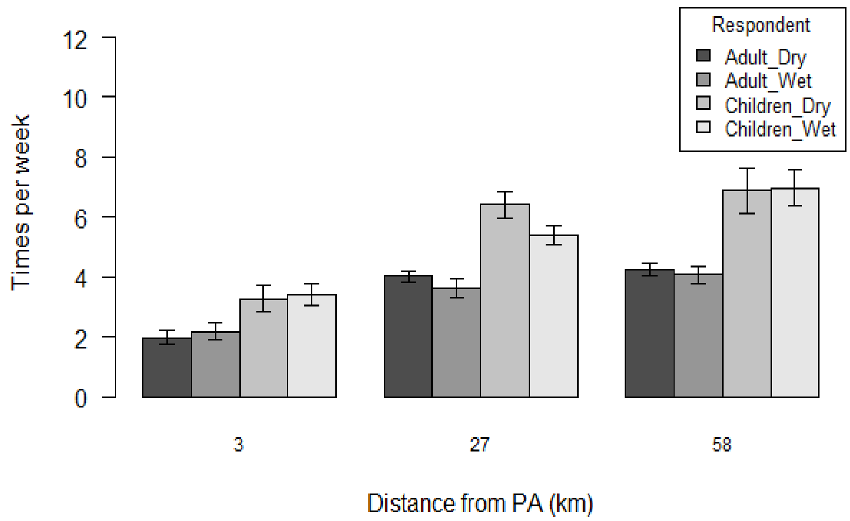

Figure 3. Average number of fish meals consumed per week reported by adults and schoolchildren in the wet and dry season in Robanda, Rwamkoma and Kowak at increasing distance from the PA boundary.

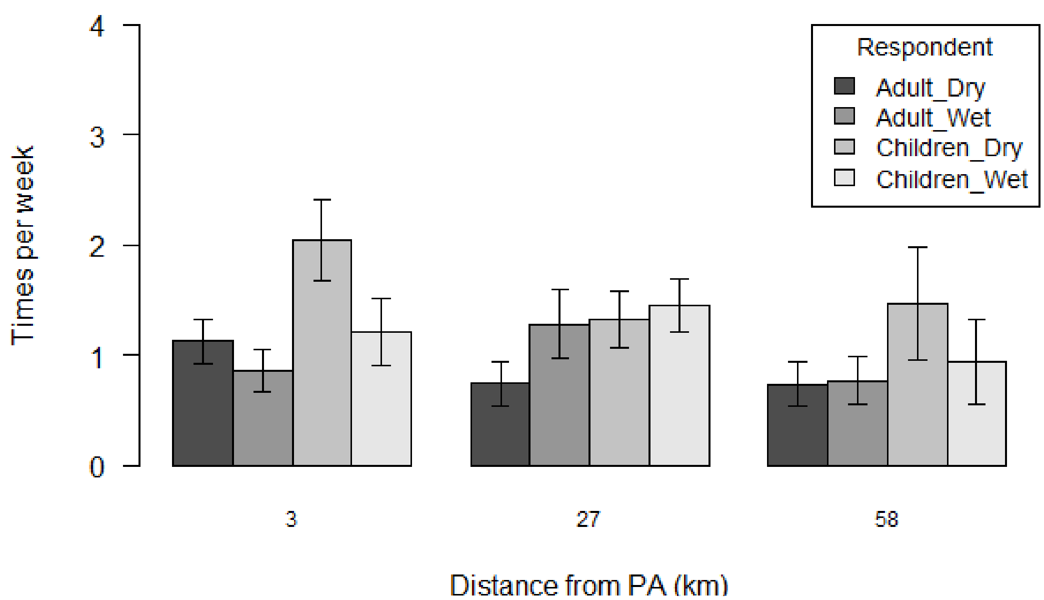

Figure 4. Average number of domestic meat meals consumption per week reported by adults and schoolchildren in the wet and dry season in Robanda, Rwamkoma and Kowak at increasing distance from the PA boundary.

between villages (Figure 3) for adults (Kruskal-Wallis tests; H=32.72; P<0.0001) and schoolchildren (H=60.98; P<0.001) separately. A post hoc Dunn's test shows that both adults and schoolchildren in the closest village Robanda consumed less fish than in Rwamkoma (Adults: Z=4.2; P<0.001. Schoolchildren: Z=6.73; P<0.001) and in Kowak (Adults: Z=5.47; P<0.001. Schoolchildren: Z=6.61; P<0.001). However, fish consumption frequencies in the two more distant villages (that is, Rwamkoma and Kowak) did not differ significantly for either adults (Dunn's tests; Z=1.25; P=0.21) or schoolchildren (Z=0.62; P=0.54).

Furthermore, the consumption of domestic meat differed significantly between villages only for school children

Table 3. Regression coefficients of the quasi-Poisson Generalised Linear Model predicting logarithmic transformed bushmeat consumption frequency from socioeconomic variables, consumption of other meat types, distance to protected area boundary, season and respondent group.

Variable	Estimate	SE	T	P
Intercept	1.58589	0.14036	11.299	<0.001
Respondent (Children = 1 and adults = 0)	0.65730	0.07050	9.323	<0.001
Household heads occupation (employment/business income = 1 and peasants/pastoralists = 0)	0.06196	0.07680	-0.807	0.420
Household size (smaller families < 7 people and large families ≥ 7 people)	0.02402	0.01629	1.475	0.141
Domestic meat consumption frequency (times/week)	-0.20436	0.02974	-6.871	<0.001
Fish consumption frequency (times/week)	-0.14485	0.02462	-5.884	<0.001
Season (dry season = 1 and wet season = 0)	0.76243	0.07215	10.567	<0.001
Distance (27 km)	-4.06938	0.28980	-14.042	<0.001
Distance (58 km)	-3.29956	0.23122	-14.270	<0.001

Model properties: Observations, 554; Respondents, 277; Dispersion parameter, 0.63.

(Kruskal-Wallis tests; H=10.45; P=0.005) but not adults (H=5.65; P=0.056). Schoolchildren in Robanda reported higher domestic meat consumption than schoolchildren in Rwamkoma (Dunn's tests; Z=2.87; P=0.012) and Kowak (Z=2.64; P=0.017) while the difference between Rwamkoma and in Kowak were not significant (Z=0.081; P=0.94).

The consumption frequency of other meat types reported by both children and adults also varied significantly between villages during the wet season (Figures 3 and 4). The consumption frequency of fish was significantly higher in the more distant villages for both adults (Kruskal-Wallis tests; H=42.18; P<0.0001) and schoolchildren (H=68.47; P<0.001) during the wet season. Furthermore, a post hoc Dunn's test shows that fish consumption reported by schoolchildren differed significantly between the three villages (Robanda vs Rwamkoma: Z=5.58; P<0.001. Robanda vs Kowak: Z=7.99; P<0.001. Rwamkoma vs Kowak: Z=3.06; P<0.002). However, fish consumption reported by adults was lower in Robanda than in Rwamkoma (Dunn's tests; Z=4.46; P<0.001) and Kowak (Z=6.32; P<0.001), while consumption frequencies in Rwamkoma and Kowak did not differ statistically (Z=1.85; P=0.06).

The variation in the consumption of domestic meat were statistically different between villages only for schoolchildren (Kruskal-Wallis tests; H=8.86, P=0.012) and H=5.26, P=0.072 for schoolchildren and adults respectively). The differences were significant only between Rwamkoma and Kowak (Dunn's tests; Z=2.97; P=0.009) but not between Robanda and Rwamkoma (Z=1.49; P=0.135) or Robanda and Kowak (Z=1.60; P=0.22).

Predictors of bushmeat consumption frequency

The GLM reveal that reported bushmeat consumption frequency is associated with the respondent category being positive and significantly associated with children as informers. The frequency of bushmeat consumption is also significantly associated with the frequency of consumption of other meat types decreasing when the consumption frequency of domestic meat and fish increases. Other significant factors include a positive association with dry season and a negative association with distance from the PA boundary. Hence, bushmeat is more frequently consumed in the dry season but less frequently consumed as distance to the PA boundary increases. Other socioeconomic factors such as household size and occupation were not significantly associated with bushmeat consumption frequency (Table 3). The average VIF was 1.11 indicating that multicollinearity is negligible and the dispersion parameter was 0.63 indicating that the model has no sign of overdispersion which can leads to type I error.

DISCUSSION

Hypothesis 1: Bushmeat consumption frequency is higher during the dry season than the wet season

The first hypothesis was supported by the study findings. The assumption was that bushmeat is consumed more frequently during the dry season than the wet season. Both schoolchildren and adult respondents stated consuming bushmeat more frequently during the dry season than the wet season. The explanation for this differnece likely includes the migration of wildebeests and other herbivores which increase their range searching for food and water during the dry season (Holmern et al., 2006; Holmern et al., 2007). Variation in resources availability influenced by seasonal changes is the main reason for the animal migration (Sinclair et al., 2015) and they often move outside protected areas during this migration. During the dry season, the animals experience food and water shortage and therefore expand their range searching for drinking water and green pasture. This provides the opportunity for hunters to access the animals and therefore increases the availability of bushmeat for household consumption in adjacent villages (Rentsch and Packer, 2015).

Previous studies have also found that illegal hunting is mostly practised during the dry season with high peaks from August to November, following the migration routes of wildebeest and zebra (Loibooki et al., 2002). The high rate of illegal hunting is also facilitated by the increased openness and right weather conditions during the dry season as well as lack of farming activities which occurs mostly in the wet season. The large harvest of wildebeest is associated with their abundance (Holmern et al., 2006) and migration behaviour, both of which make them more available compared to other herbivores (Sinclair et al., 2015). The consumption of bushmeat was low during the wet season which is mainly due to the low availability of migratory herbivores. During this time, the resident herbivores are the primary source of bushmeat (Rentsch et al., 2015). Also, people were busy with farming activities and therefore had less surplus labour to invest in bushmeat hunting (personal communication, April 26, 2018). This also explains why both children and adults consume domestic meat more frequently during the wet season in Robanda. However, the consumption of other meat types particularly fish was also low in the wet season which may be attributed to poor infrastructure and roads being inaccessible during heavy rain hindering the transportation of fish, including sardines (Nyahongo et al., 2009). Furthermore, during the wet season households experience low income since it is not yet harvest time which is the main source of cash income for most people in the area (personal communication, April 30, 2018).

Hypothesis 2: Bushmeat consumption frequency decrease with increasing distance from protected area boundary

Bushmeat was consumed more frequently by both adults and children in the closest village compared to the intermediate and the distant villages. In Western Serengeti, bushmeat is consumed regularly by 45 to 60% of households according to a recent study (Rentsch and Packer, 2015). In the closest village, Robanda households consumed bushmeat on average five times per week in the dry season and two times per week in the wet season (Figure 2). Previous studies conducted in villages adjacent to the western part of the Serengeti ecosystem have also found that closer villages consume more bushmeat than distant villages (Fischer et al., 2014; Nyahongo et al., 2009). This indicates that adjacent communities relies more on bushmeat as a source of meat protein which may offset some of the disadvantages of limited land for expansion and high rates of crop damage and livestock depredation experienced by people living adjacent to wildlife areas (Bitanyi et al., 2012; Galvin et al., 2008).

Furthermore, the closest villages consume more bushmeat than distant villages because it is easy for illegal hunters to access the animals (Holmern et al., 2002). Consuming bushmeat is a part of the culture of most ethnic groups especially those who live close to wildlife areas in Western Serengeti (Knapp et al., 2017). Since bushmeat consumption is a tradition and has cultural values (Kideghesho, 2008), these people tend to use any means to obtain bushmeat for their households especially the Ikoma (Mfunda and Røskaft, 2010). Even during the wet season where the availability of migratory herbivores is low, they hunt resident herbivores (Rentsch et al., 2015) despite the difficulties associated with hunting in the wet season. The distant villages were obtaining bushmeat from hunters through the bushmeat trade (Mwakatobe et al., 2012). However, the recent increased focus on law enforcement has increased the likelihood of being fined for trading bushmeat and also increased the penalty. Perhaps, as a result, the frequency of bushmeat consumption in the distant villages Kowak and Rwamkoma was found to below. Hence, the results support Hypothesis 2.

Hypothesis 3: Children report higher bushmeat consumption frequency than adults

Contrary to schoolchildren, adults reported very low consumption frequency in the intermediate and distant village. In the closest village Robanda, both schoolchildren and adult respondents reported higher bushmeat consumption than in distant villages. Despite similar trends in consumption frequencies, schoolchildren reported significantly higher bushmeat consumption than adult respondents in both seasons (Figure 2). Similar differences were observed for other meat types suggesting that children generally report higher consumption frequencies than adults. Depending on responsibilities household heads may fail to recall the details of the meals consumed in the household. Most households were headed by men who typically are less involved in food preparation compared to women and children and therefore may be less inclined to recall the particular meat type although they eat the same.

Another explanation may stem from the difference between the surveys. Adults were asked to recall their meat consumption over the duration of a week introducing recall bias. Schoolchildren, on the other hand, were asked to recall their meat consumption within only the past 24 hours (except for the weekend) and may have been more engaged in the exercise being unaccustomed to this level of attention. Previous studies of illegal bushmeat hunting in the Serengeti have also noticed that adult respondents provide less information through questionnaire surveys compared to other methods(Rentsch et al., 2015). It is commonly observed that adult respondents behave strategically and may provide less or incorrect information about their activities and income for fear of reprisal or to escape taxation (van Vliet et al., 2015). Some people may also exaggerate their need for assistance to be considered for assistance from the government or NGOs. However, there appears to be no logical reason why schoolchildren should exaggerate the frequency of bushmeat consumption and consumption of other meat types in their household. Hence, the results support Hypothesis 3 and suggest that children may provide more accurate information about household bushmeat consumption than adults.

Hypothesis 4: Bushmeat consumption frequency is associated with socioeconomic and other characteristics

As expected, the model revealed that bushmeat consumption frequency was significantly associated with respondent group, season and distance to the protected area boundary. Also, the consumption of domestic animal meat and fish significantly influenced the frequency of bushmeat consumption. However, contrary to expectations household size had no significant influence on bushmeat consumption suggesting that large and small households are equally reliant on bushmeat. Similarly, the occupation of the household head, whether or not he or she held employment or managed a small-scale business as an indicator of wealth had no significant influence on bushmeat consumption frequency. The majority of people in Western Serengeti depends on small-scale agriculture and has been characterised as poor (Loibooki et al., 2002). This implies that bushmeat is more important for poor households whose economy depends on small scale agriculture than the relatively fewer people who depend on employment and small-scale business.

Fish typically sardines (small sun-dried fish) were consumed more frequently than the other meat protein types in both seasons. Although sardines were consumed in the village closest to the protected area boundary where the availability of bushmeat is high, its consumption increased with distance to the boundary. Sardines were consumed frequently in villages far from the PAs, where bushmeat is less available and expensive. However, the more distant villages are also located relatively closer to Lake Victoria which is the main source of fish in the region. Sardines were the most affordable meat protein source in the area where many people are poor, and alternatives such as domestic meat and other fish are relatively expensive (Kiffner et al., 2015, Ndibalema and Songorwa, 2007). The consumption of domestic meat did not vary significantly with distance from the protected area boundary for either school children or adults. Domestic animal meat is the most expensive of the types of meat accessed. Furthermore, there were no sign of butchers selling beef but only rather few groceries selling roasted goat meat with beer, which usually is considered a luxury good.

Conclusion

The results reveal that bushmeat is an important source of meat protein and hence food securities particularly to households in villages close to protected areas and in the dry season. Enhancing the production and increasing the availability of cheap alternative sources of meat protein is recommended in order to reduce dependence on bushmeat. An increase in fish production can help to reduce the dependence on bushmeat (Brashares et al., 2004). Sardines may be the most appropriate alternative meat type because it can be obtained from nearby Lake Victoria. The results hence suggest subsidising an increase in the availability of sardines in villages located close to wildlife areas although concerns has been raised about the impact on fish stocks (Rentsch and Damon, 2013). Alternatively, the feasibility of fish farms should be tested with the help from the local government in order to increase the supply of fish near villages like Robanda that are far from Lake Victoria. The study also suggests that the use of schoolchildren at the age of 9 to 12 as informers can generate information on bushmeat consumption that may be more reliable than information obtained from adults. This may be the result of this age group not yet being cognisant about the illegality of bushmeat hunting and therefore less likely to respond strategically than adults.

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CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests regarding the publication of this paper.

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