Tropentag 2016, Vienna, Austria
September 18-21, 2016

Conference on International Research on Food Security, Natural Resource Management and Rural Development
organised by the University of Natural Resources and Life Sciences (BOKU Vienna), Austria

Woody species diversity of green spaces and a theoretical basis of species co-existence in Kumasi, Ghana

Bertrand F. Nero

Center for Development Research, ZEF, University of Bonn, Germany. Email nerbefest@yahoo.com

Abstract

Conserving biodiversity in cities is essential to halting global biodiversity loss. Nevertheless, there is paucity of data on the underlying mechanisms shaping species assemblages and species/trait diversity in urban landscapes. The objectives of this study were to; 1) compile native and exotic woody species diversity of urban green space (UGS) types and (2) describe the theoretical basis of species co-existence in Kumasi, Ghana. Stratified sampling and species abundance models were combined in this study.

About 176 tree species in 46 families were recorded within Kumasi. About 96 species were in a natural forest located towards the outskirts of the city. Home gardens, institutional compounds, and public parks had the highest species richness of 76, 75 and 71, respectively while urban rangelands and farmlands were the least species rich with 6 and 23, respectively. Species richness (S) in the peri-urban (mean ndvi >0.2, S=142) and core urban (mean ndvi<0.2, S=108) areas were significantly different (X^2 =15.7, p< 0.0001, n=1). Native species richness was lowest in the core urban area and highest in the neighboring natural forest. Home gardens and institutional compounds had the highest species richness. The geometric series model best fitted the tree assemblage of the city, depicting a species impoverished and environmentally hash landscape. Pioneers and anthropochory dispersed species were the most abundant suggesting that this urban landscape is shaped by both environment and social filters.

Tree species diversity and distribution depend on the type of UGS and portray a perturbed landscape in early seres of succession. The implications of these findings for improving urban biodiversity conservation and overall urban sustainability are discussed.

Introduction

A challenge confronting contemporary ecology is the paucity of knowledge about biological diversity on earth (including cities) (Mora et al. 2011). Urban areas which are rich preserves of modified regional biological diversity can contribute to sustainable use of biological resources, improve human wellbeing, and ameliorate urban environmental crisis but are often neglected in national and regional biodiversity assessments in many developing regions/countries. Earlier studies in urban ecology traditionally described the patterns and processes of biodiversity in cities at broad spatial scales ((Burton et al., 2005; McKinney, 2008; Pauchard et al., 2006). Problem-oriented research designed to provide direct answers to the need of urban practitioners and urban dwellers are however proposed as advances that could move urban ecology to better pedestal (McDonnell, 2011; McDonnell and Hahs, 2013). In line with this thesis, studies analyzing microhabitat effects on species richness and composition as well as the pattern and basis of urban species abundance distribution in tropical cities remain scanty. Aronson et al. (2014) underscored the dearth of urban biodiversity data from tropical cities and the immediate need for research in the current frontiers of urban ecology. Hence, the current study describes tree species profiles, examine the native and exotic species compositional differences among green spaces and urban zones and explores species abundance distribution as basis for species co-existence in Kumasi.

Material and Methods

Kumasi is located in south central Ghana (6° 41"N, 1° 37"W), has a population of about 2.5 million, and a land area of 254 km^2. The mean annual rainfall and temperature are respectively, 1250 mm and 26.4°C. It is sited in the moist semi-deciduous high forest zone of Ghana with Haphic Alisols and Lithic Leptosols as the major soil types at the north and southern halves, respectively.

The city was divided into two based on normalized difference vegetation index, NDVI: Core or HDUZ area with mean NDVI < 0.11 and peri-urban or LDUZ area with mean NDVI > 0.11 Supervised classification was performed on a rapidEye image (May 2014) to generate 8 UGS types; plantations, natural forest, home gardens, institutional compounds, farms, cemeteries, public parks, and grasslands. Overall accuracy and kappa coefficient were respectively 62.3 ± 5.5 % and 0.56 with producer's and user's accuracies in the range of 45 – 99 %. Detailed description of supervised classification is presented in Nero, (2016). Sample points were randomly generated on the map for each UGS type within each urban zone using a stratified random sampling technique. Each point was visited on the ground with the aid of a GPS receiver. A 10 x 10 m quadrat was established on each sampling point (except in home gardens where the entire area was considered) with the help of a compass, a distance tape measure, and ranging poles. Within each plot, the height and diameter at breast height (DBH) of all trees with DBH > 5 cm were measured and identified to the species level. In addition, 10 streets (with distances ranging between 50 to 1000 m) lined with trees were purposively selected and all trees along them enumerated and identified to species level. Tree identification was carried out with the aid of tree experts and published tree identification guides such as those by Hawthorne and Gyakari (2006) and Oteng-Amoako (2002).

Sample rarefaction curves were constructed for the different green space types. Species abundance, species richness, and Shannon index for exotics and natives were estimated for each green space type. Shannon index increases as richness increases for a given pattern of evenness. Beta diversity among the core, peri-urban and rural areas were estimated with the reformulated Sørenson and Jaccard indices proposed by Chao et al. (2005) instead of the binary techniques previously employed. Species abundance data were fitted to three biogeographic models; Lognormal, Broken-stick (BS), and geometric series (GS). Both GS and BS models were fitted using regression techniques involving species abundance and the rank in abundance of the species (Fattorini, 2005). In the GS model, species abundance is log transformed (eq. 1) whereas in the BS model, the rank in abundance is log transformed (eq. 2).

$$\log A = b_0 + b_1 R \quad (1)$$

$$\log R = b_0 + b_1 A \quad (2)$$

Where A = abundance of species, b_0 and b_1 represent regression coefficients and R = rank in abundance.

The lognormal distribution is a plot of the number of species as the ordinate and the logarithm of the abundance as the abscissa. A bell-shaped curve reveals a normal distribution in the data. This approach was cross-checked by plotting cumulative species richness on the probit scale against logarithm of species abundance. A diagonal straight line of the plot indicates that the data is normally distributed.

Results and Discussion

Overall 3,757 individual trees and shrubs made of 176 species from 42 families were sampled across the different UGS types in Kumasi. Chao1 estimated species richness was 222, implying that about 46 species could not be observed during the field sampling. Home gardens, institutional compounds, and public parks has the most species richness whereas grasslands and farmlands had the least (Figure 1). The species accumulation curves indicate that sampling was thoroughly done for all green space types.

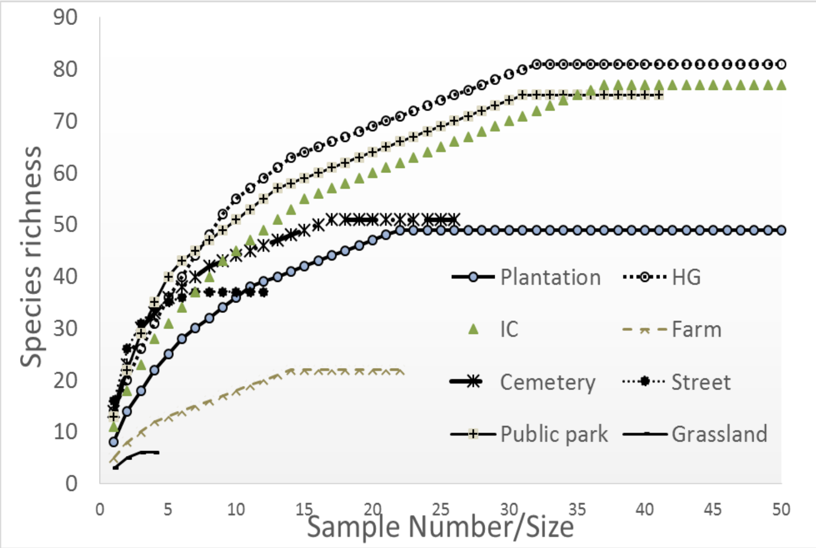

Figure 1. Sample rarefaction curves of green spaces in Kumasi, Ghana. HG = Home garden, IC = Institutional compound.

At least 60 % of the species in the natural forest, cemetery, and public parks were native in origin whereas in the home gardens and institutional compounds about 57 % of the species were exotics (Table 1). Streets, farmlands, and plantations were almost even in species richness between native and exotics. Species composition analysis among green spaces and urban zones were significantly different. With 74 common species the core (HDUZ) and peri-urban (LDUZ) were highly similar in species composition, Jaccard's index = 0.897 while the core and peri-urban were most dissimilar with 27 common species and Jaccard's index = 0.312. The proportion of exotic species declined from the core to the neighbouring natural forest in the rural area.

Table 1. Richness and abundance of exotic and native species among green space types in Kumasi, Ghana.

UGS type	Exotics			Natives		
	Abundance	Richness	Shannon, H	Abundance	Richness	Shannon, H
Plantation	527	21	2.03	100	24	2.44
Natural Forest	134	6	1.04	571	90	3.2
Home Garden	771	43	2.9	312	33	1.64
Institutional compound	517	44	3.03	196	33	2.61
Farmland	27	10	1.87	73	13	1.64
Cemetery	108	18	2.49	157	32	2.57
Street	460	19	2.37	105	18	2.15
Public Parks	192	27	2.64	135	43	3
Grasslands	38	5	0.65	1	1	0
Total	2644	72	3.24	1087	88	2.79

The lognormal model did not fit the species abundance distribution data in either zones of Kumasi (D = 0.158, p = 0.010). The GS model always proofed to be a superior model over the null BS model, displaying lower R^2, coefficients of variation (CV) and smaller root mean squares errors (RMSE) (Table 2). The tree diversity of Kumasi is constrained by resource availability and dominated by few (most common) species which exploit these limited resources at the expense of other species in the landscape. The GS model has been shown to describe many faunal and plant assemblages (Fattorini 2005; Caruso and Migliorini 2006; Do et al. 2014), often depicting early stages of succession or a species-poor environment (Whittaker 1965) or disturbed environments (Caruso and Migliorini 2006). More than 85% of the species and trees observed in Kumasi were light demanders (pioneers and non-pioneers) while more than 60 % could be propagated by humans. Hence, it is deduced that light is the predominant ecological factor shaping the tree species assemblage of Kumasi. Social/human preferences are equally essential drivers of the species assemblage in the city. The findings have implications for biodiversity conservation. Adequate measures should be pursued to improve on the diversity of tree species beyond light demanders and anthropochoric propagated species.

Table 2. Comparison of Broken-Stick (BS) and geometric series (GS) models using regression. Best fit model in all communities is the GS model; indicated by higher R^2, lower CV and RMSE.

	BS: $A = b_0+b_1$LogRank				GS: Log$A = b_0+b_1$Rank				
Community	Equation	RMSE	CV	R^2	Equation	RMSE	CV	R^2	p-value
Whole Kumasi	y=255.16 - 133.96x	32.11	108.50	**0.76**	y=1.926 - 0.016x	0.214	24.0	**0.90**	<0.0001
Peri-Urban (LDUZ[1])	y=123.9 - 66.3x	16.11	108.55	**0.74**	y = 1.628 - 0.016x	0.197	28.5	**0.89**	<0.0001
Core-Urban (HDUZ[1])	y=168.01 - 93.7x	18.96	93.17	**0.80**	y= 1.89 - 0.023x	0.172	23.1	**0.94**	<0.0001
Owabi Santuary	y=65.56 - 35.42x	4.43	43.42	**0.91**	y = 1.57 - 0.019x	0.116	17.5	**0.95**	<0.0001

Statistics: R^2 goodness of fit statistic, RMSE = root mean square error, CV (%) = coefficient of variation, b_0 and b_1 regression coefficients of the intercept and slope respectively, A = species abundance and rank = rank in species abundance. [1]HDUZ - High density urban zone; LDUZ - low density urban zone.

Conclusions and Outlook

The study explored species diversity patterns among green spaces and urban zones as well as examined the theoretical basis of species coexistence in Kumasi. The city supports a wealth of tree diversity synonymous to some national parks within the region. Native species richness predominates in the outskirts of the city than in the core. Natural forest, home gardens, institutional compounds, and public parks should be protected and better managed to enhance the native species diversity of the city. Since light and social filters dictate the species composition of the city, the current species composition is severely simplified. Therefore, it is imperative to device appropriate conservation strategies to expand the species composition beyond light demanders. Using pioneers as nurse crops to regenerate shade-bearers could be a way forward. Patch size effects on species and trait diversity as well as diversity-functional relations of cities should be explored further.

References

Burton, M.L., Samuelson, L.J., Pan, S., 2005. Riparian woody plant diversity and forest structure along an urban-rural gradient. Urban Ecosyst. 8, 93–106. doi:10.1007/s11252-005-1421-6

Caruso, T., Migliorini, M., 2006. A new formulation of the geometric series with applications to oribatid (Acari, Oribatida) species assemblages from human-disturbed Mediterranean areas. Ecol. Modell. 195, 402–406. doi:10.1016/j.ecolmodel.2005.11.042

Chao, A., Chazdon, R.L., Shen, T.J., 2005. A new statistical approach for assessing similarity of species composition with incidence and abundance data. Ecol. Lett. 8, 148–159.

doi:10.1111/j.1461-0248.2004.00707.x
Do, Y., Lineman, M., Joo, G.J., 2014. Carabid beetles in green infrastructures: the importance of management practices for improving the biodiversity in a metropolitan city. Urban Ecosyst. 1–13. doi:10.1007/s11252-014-0348-1
Fattorini, S., 2005. A simple method to fit geometric series and broken stick models in community ecology and island biogeography. Acta Oecologica 28, 199–205. doi:10.1016/j.actao.2005.04.003
Hawthorne, W., Gyakari, N., 2006. Photoguide for the forest trees of Ghana; trees spotters's field guide for identifying the largest trees. Oxford Forestry Institute, Oxford, UK.
McDonnell, M.J., 2011. The History of Urban Ecology An Ecologist's Perspective. Urban Ecol. Patterns, Process. Appl. 5–13.
McDonnell, M.J., Hahs, A.K., 2013. The future of urban biodiversity research: Moving beyond the "low-hanging fruit." Urban Ecosyst. 16, 397–409. doi:10.1007/s11252-013-0315-2
McKinney, M.L., 2008. Effect of urbanization on species richness: a review of plants and animals. Urban Ecosyst. 11, 161–176.
Nero, B.F., 2016. Urban green space dynamics and distributional equity in Kumasi, Ghana., in: ESA Special Publications.
Oteng-Amoako, A.A., 2002. 100 Tropical african timber trees from Ghana: tree description and wood identification with notes on distribution, ecology, silviculture, ethnobotany, and wood uses. Forest Research Institute of Ghana, Kumasi.
Pauchard, A., Aguayo, M., Peña, E., Urrutia, R., 2006. Multiple effects of urbanization on the biodiversity of developing countries: The case of a fast-growing metropolitan area (Concepción, Chile). Biol. Conserv. 127, 272–281. doi:10.1016/j.biocon.2005.05.015
Whittaker, R.H., 1965. Dominance and diversity in land plant communities. Science (80-.). 147, 250–260. doi:10.1126/science.147.3655.250