TREE AND TRAIT DIVERSITY, COEXISTENCE AND DIVERSITY-FUNCTIONAL RELATIONS OF GREEN SPACES IN KUMASI, GHANA

Bertrand F. Nero (nerbefest@yahoo.com)
Center for Development Research (ZEF), University of Bonn

INTRODUCTION

Urban areas are rich preserves of modified regional biological diversity which can contribute to conservation and sustainable use of biological diversity, improve human wellbeing, and ameliorate urban environmental crisis. However, apart from being threatened by urbanization processes (Seto et al. 2012; McDonald et al. 2013), a challenge confronting contemporary ecology is the paucity of knowledge about biological diversity on earth (including cities) (Mora et al. 2011). In particular, data on urban biological diversity from developing countries, species and trait diversity linkages with ecosystem processes such as carbon sequestration and storage (Wright et al. 2006) and pattern and basis of urban species abundance distribution in tropical cities are lacking. 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.

The **objectives** of this study were to 1) examine the tree species diversity of green spaces, 2) explore the species abundance distribution as basis for tree species co-existence and 3) examine the links between species and/or trait diversity and green space/tree function (productivity) in a medium-sized city in Ghana.

STUDY SITE

Kumasi is located in south central Ghana (6° 41″N, 1° 37″W, Figure 1A). The climate is tropical, characterized by a bi-modal rainfall system.
Mean annual rainfall = 1250 mm
Mean annual temperature = 26.4°C
Original vegetation type = tropical high forest
Population = ~ 2.5 million, Growth rate = 4.8%, Land area = 254 km^2

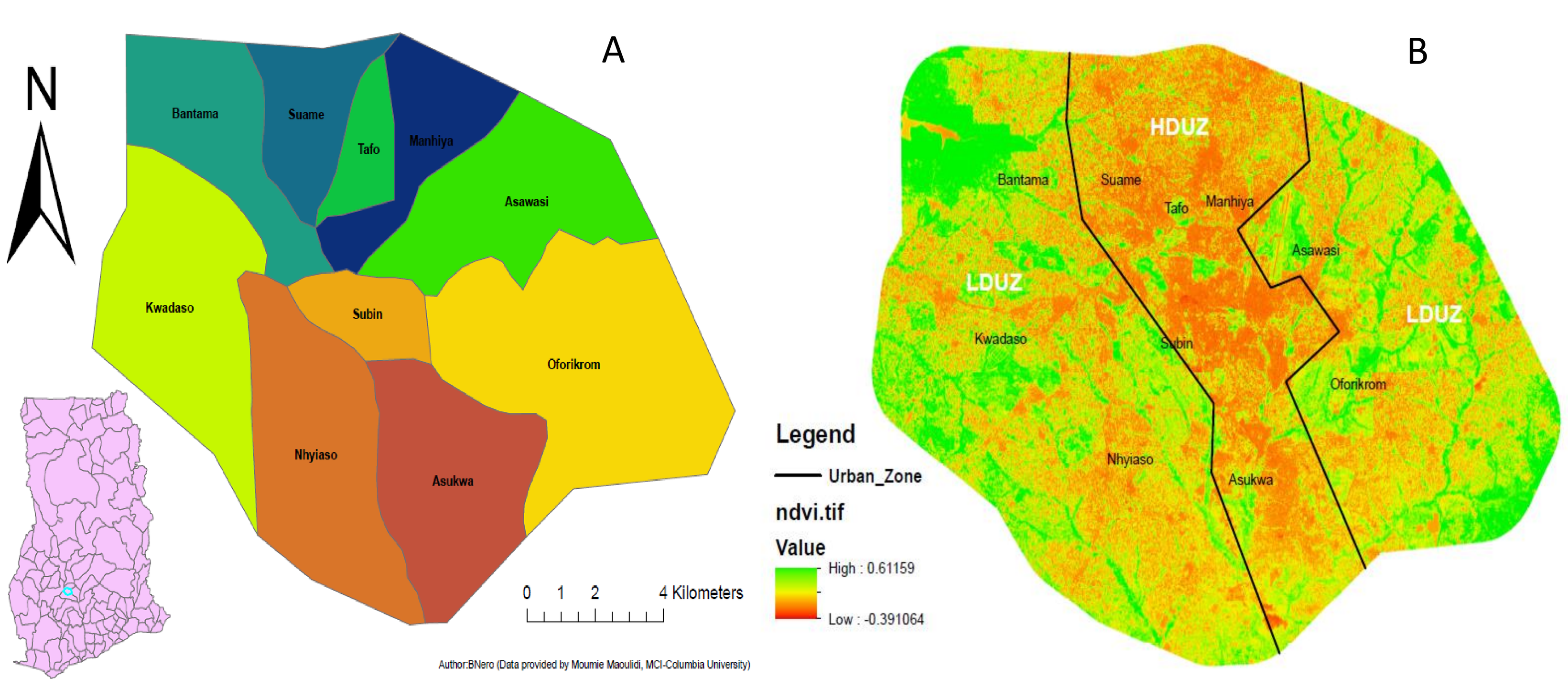

Figure 1. Political map (A) and NDVI map (B) of Kumasi metropolis showing the 10 submetropolises. Mean NDVI of HDUZ ≤0.11 and of LDUZ > 0.11

METHODS

- Stratified random sampling; 2 urban zones, 9 green space (GS) types (Figure 1B). Urban zones defined based on mean NDVI: core (HDUZ), NDVI ≤ 0.11; peri-urban (LDUZ), NDVI > 0.11.
- At least ten 100 m^2 plots were established in each GS type within each urban zone except home gardens (HG). The entire HG was adopted and the area determined using spatial techniques.
- All trees and shrub species at least 5 cm in diameter at breast height (DBH) were counted by species and identified to at least the level of genus.
- Heights and DBH of these species in each plot were measured (Figure 2) and the carbon content determined using allometric equations.
- Life history traits of all the species were determined from tree species database; TRY and Agroforestry database.
- Species richness, Chao1 richness estimates, Shannon, Simpson and Pielou evenness were estimated for each GS type and urban zone.
- Correspondence analysis was conducted to determine species composition differences of GS and urban zones.
- Three biogeographic species abundance models were fitted to the data; LogNormal, Geometric series and Broken-stick
- Chi-square test, ordinary least square and multiple linear regression were used to establish statistical differences among categorical variables and their linkages with dependent variables.

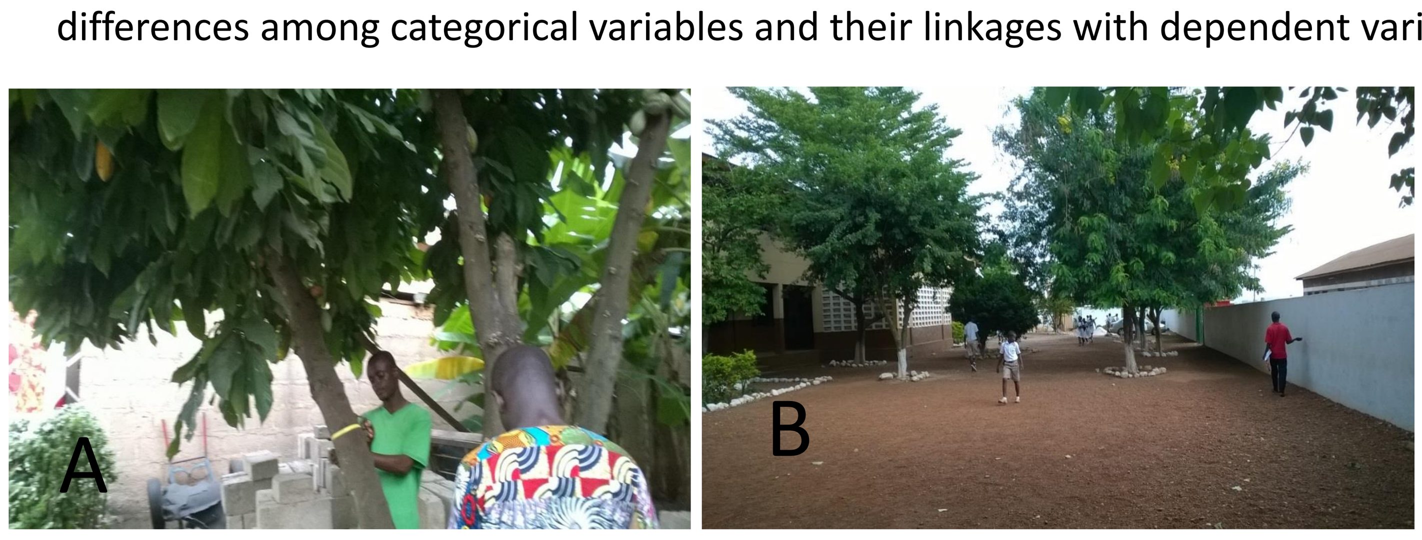

Figure 2. Measuring biomass and diversity in (A) a home garden and (B) a school compound in Kumasi

RESULTS

Table 1. Tree species abundance, richness, and diversity indices in different green space types within Kumasi. Chi-square analysis of richness indicates significant differences (p<0.0001, n=8, X^2 = 139.4).

Green space Type	# of Individuals	Observed Species Richness, S	Estimated Chao1 Sest	Shannon H	Simpson λ	Pilou J Evenness
Plantation	630	48	73.6	2.561	0.146	0.66
Natural Forest	980	96	105	3.84	0.031	0.84
Home garden	1095	80	98.6	3.158	0.081	0.72
Institutional Compound Trees	715	79	101.3	3.502	0.049	0.80
Farm	100	23	47.0	2.269	0.179	0.72
Cemetery	266	51	81.3	3.242	0.065	0.82
Streets	565	37	57.2	2.809	0.097	0.78
Public Park	334	75	127.7	3.521	0.048	0.82
Grassland	39	6	8.3	0.749	0.672	0.42
Total	3757	176	222.4	3.716	0.044	0.72

Table 2. Similarity (Jaccard index and Sørenson indeces) in species composition among urban zones in Kumasi. Values close to 1 indicate high similarity and close to zero indicate high dissimilarity. Bootstrap 95% confidence intervals are also shown

Land use	Shared species	Jaccard			Sorenson		
		Index	95% LL	95% UL	Index	95% LL	95% UL
Core – Peri-Urban	74	0.897	0.559	2.230	0.946	0.717	1.380
Peri-urban – NF	45	0.520	0.218	1.204	0.684	0.358	1.092
Core – NF	27	0.312	0.135	0.605	0.476	0.239	0.754

UL = Upper limit, LL = Lower limit, NF = Natural forest

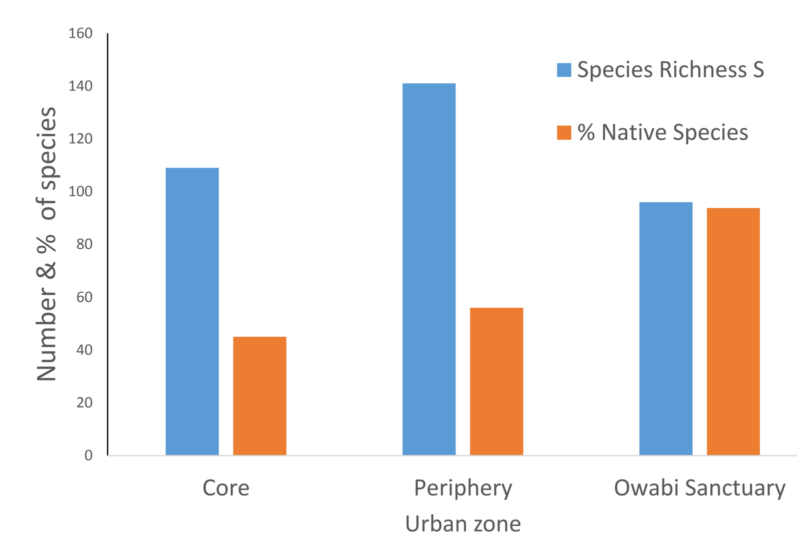

Figure 3. Species richness and % native species in three zones along an urban-rural gradient. Owabi sanctuary is natural forest intersecting periurban and rural areas

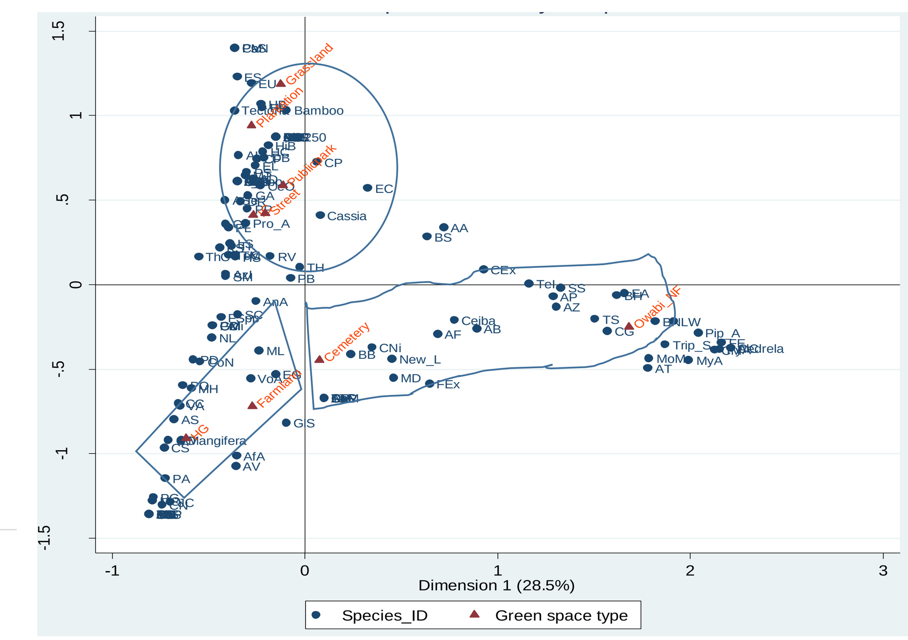

Figure 4. Species composition differences among green spaces in Kumasi

Table 3. Comparison of Broken Stick (BS) and Geometric series (GS) models by regression. Best fit model in all communities is the Geometric series model; indicated by higher R^2, lower CV and RMSE.

	BS: $A = b_0+b_1 LogRank$				GS: $LogA = b_0+b_1 Rank$				
Community	equation	RMSE	CV	R^2	Equation	RMSE	CV	R^2	p-value
Whole Kumasi	y=255.16 - 133.96x	32.1	109	0.76	y=1.926 - 0.016x	0.214	24.0	0.90	<0.0001
Peri-Urban (LDUZ[1])	y=123.9 - 66.3x	16.1	109	0.74	y = 1.628 - 0.016x	0.197	28.5	0.89	<0.0001
Core-Urban (HDUZ[1])	y=168.01 - 93.7x	19.0	93.2	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

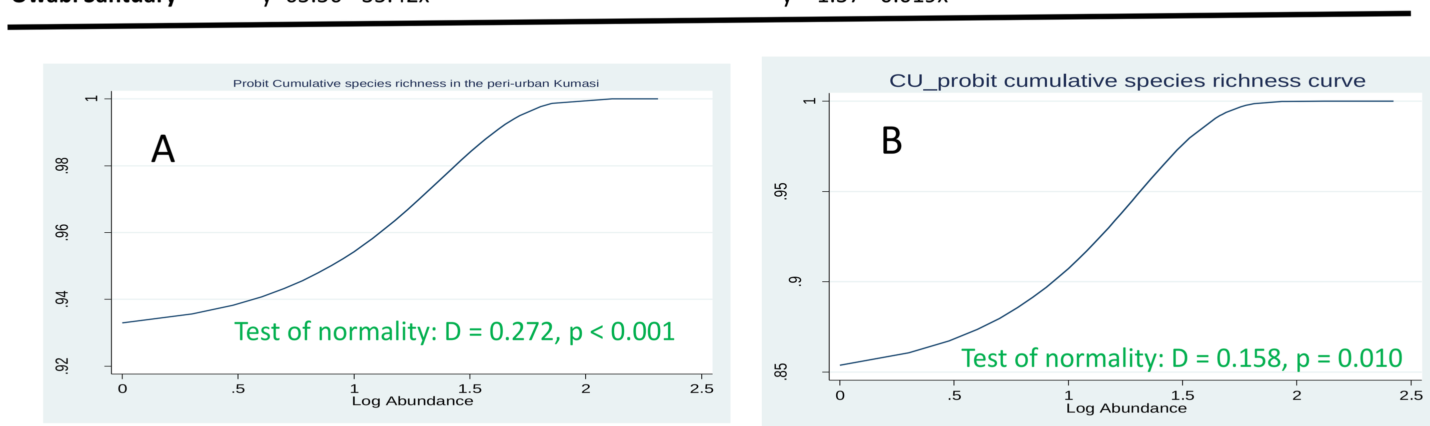

Figure 5. Test for normality in species abundance of Kumasi: Cumulative plot of species richness on a probit scale vs Log abundance in (A) peri-urban, PU and (B) core urban, CU areas.

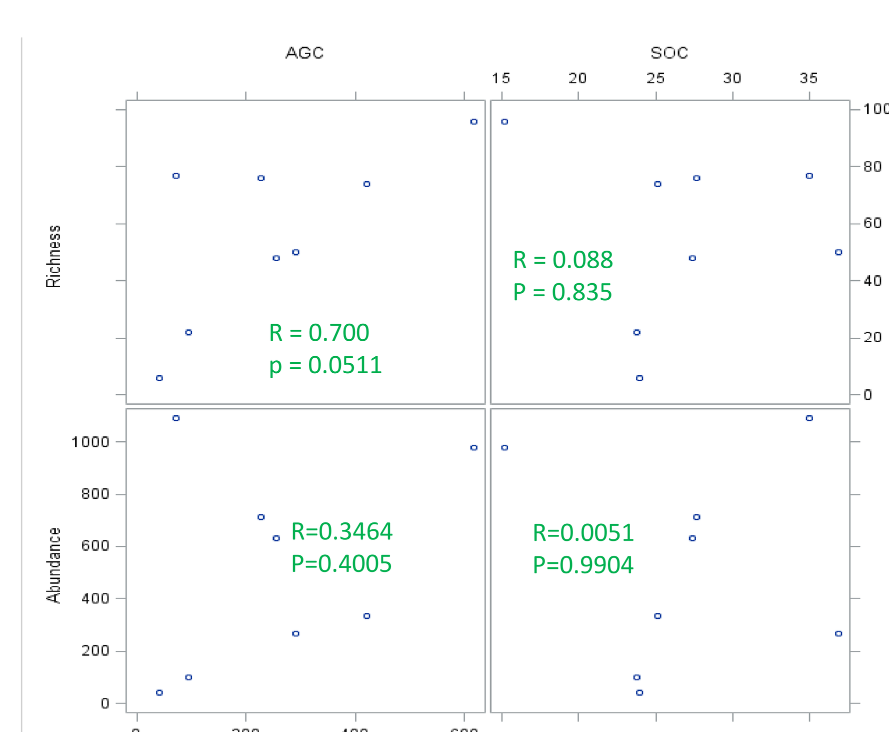

Figure 6. Aboveground carbon (AGC, t/ha) and soil organic carbon (SOC, t/ha) versus species richness and abundance of green space types in Kumasi Ghana. Coefficients of correlation and p-values are shown.

Table 4. Multiple regression of factor scores of life history trait effects on tree species carbon storage (Kg).

Component	Tree carbon	p-value	R^2
Intercept	965.3	**9.32E-06**	**0.30**
Component 1	-497.5	**0.0209**	
Component 2	-475.4	**0.0250**	
Component 3	294.47	0.1719	
Component 4	279.59	0.1693	

Component 1; Native, Pioneer, Anthropochory, Zoochory, and Evergreen. Component 2; Deciduousness and Anemochory

DISCUSSION AND CONCLUSION

1. Tree species richness differ among green spaces: natural forest, HG, institutional compounds, and public parks are much richer than all other GS types (Table 1).
2. Number of native species is higher in the urban fringes (LDUZ) than in the core (HDUZ) urban areas (Figure 3). The city and its environs host more/equivalent species than some designated protected areas and biosphere reserves.
3. Similarity in species composition is much stronger between core and peri-urban and weaker between core urban and the natural forest (Table 2). Several GS are similar in species composition (Figure 4)
4. The geometric series model best account for tree species distribution in Kumasi (Table 3). This reflects a stressed landscape with limited environmental factors (high illumination) and social factors shaping the species assemblage.
5. Both species richness and life history trait diversity have a strong influence on urban green space productivity at different scales (Figure 6 and Table 4).
6. Tree species diversity and distribution depend on the type of green space and portrays a perturbed landscape in early seres of succession with the overall ecosystem function sustained by both species and life history trait diversities.

Literature Cited

1. Aronson, M. F. J., Sorte, F. a La, Nilon, C. H., Katti, M., Goddard, M. a, Lepczyk, C. a, … Pys, P. (2014). A global analysis of the impacts of urbanization on bird and plant diversity reveals key anthropogenic drivers A global analysis of the impacts of urbanization on bird and plant diversity reveals key anthropogenic drivers. *Proceedings of the Royal Society B: Biological Sciences*, *281*, 20133330. doi:10.1098/rspb.2013.3330
2. Griffin, J. N., & Silliman, B. R. (2012). Resource Partitioning and Why It Matters. *Nature Education Knowledge*, *3*(10), 49.
3. Mcdonald, R. I., Marcotullio, P. J., & Güneralp, B. (2013). Urbanization and global trends in Biodiversity and ecosystem services. In T. Elmqvist, M. Fragkias, J. Goodness, B. Güneralp, P. J. Marcotullio, R. I. McDonald, … C. Wilkinson (Eds.), *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities: A global Assessment* (pp. 31 – 52). Dordrecht: Springer Netherlands. doi:10.1007/978-94-007-7088-1
4. Mora, C., Tittensor, D. P., Adl, S., Simpson, A. G. B., & Worm, B. (2011). How many species are there on earth and in the ocean? *PLoS Biology*, *9*(8), 1–8. doi:10.1371/journal.pbio.1001127
5. Seto, K. C., Güneralp, B., & Hutyra, L. R. (2012). Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proceedings of the National Academy of Sciences of the United States of America*, *109*(40), 16083–8. doi:10.1073/pnas.1211658109
6. Wright, J., Bunker, D., Dalling, J., Davies, S., Díaz, S., Engelbrecht, B., … Zanne, a. (2006). Towards a functional trait based research program within the Center for Tropical Forest Science. . *Unpublished Report Synthesizing the Recommendations of a CTFS Workshop on the Priorities of a Functional Trait Research Program*, 15.