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Tree and trait diversity, species coexistence, and diversity-functional relations of green spaces in Kumasi, Ghana

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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-productivity relationships in urban landscapes. The objectives of this study were to; 1) compile tree species diversity of different green space (GS) types, (2) describe the theoretical basis of species co-existence and 3) examine the links between species and life history trait diversity to GS and species productivity (carbon storage) 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 neighbouring natural forest. 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.
Plant 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.

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Keywords: Green spaces, species richness, geometric series, species traits

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1. Introduction

Urban biodiversity is instrumental in meeting the Convention on Biological Diversity (CBD) biodiversity targets [1] and the Sustainable Development Goals (SDG). However, in Africa, the achievements of these targets could be compromised due to habitat losses, degradation, and fragmentation emanating from rapid urbanization [2], potentially driving species extinction [3]. Change in biodiversity is a global change with important and sometimes irreversible ecological and social impacts [4]. Furthermore, a challenge confronting contemporary ecology is the paucity of knowledge about biological diversity on earth (including cities) [5]. This is even murkier in cities in developing countries in that urban biodiversity concerns are not merely subsidiary to more pressing issues such as unemployment, poverty alleviation [6], national biodiversity strategies and most assessments neglect urban biodiversity outright [7], [8]. Consequently, empirical and conceptual understanding of the biological diversity and the fundamental principles behind plant community assembly and function in cities remain elusive.

Historically, ecological studies in cities treated urban areas as single habitats [9]–[11] or were conducted at broad spatial scales that blurred the distinctions in microhabitat effects in cities [12]. However, urban landscapes consists of severely fragmented and heterogeneous habitats (green spaces) which may prescribe varied savage consequences on patterns of species diversity, abundance and distribution [13]–[16]. Such fine-scale heterogeneity in habitats are important forces structuring animal species assemblages within cities [16]. For plants, which are sessile and restricted in distribution by ecological and social filters, analysis of the array of heterogeneous fine-scale green space (microhabitat) types in cities may reveal new patterns underpinning urban communities and importance for global biodiversity conservation.

Species abundance distribution (SAD) is a fundamental measure of ecology and provides insight into how species subdivide the niche space to coexist [17], [18]. Niche apportionment models such as lognormal, log series, geometric and the Broken-Stick which relate species relative abundance to niche breadth constrained to species richness have characteristically depicted specific communities and predicted specific environmental or ecological scenarios. However, the emergence of the neutral theory of biodiversity and biogeography has challenged the niche as basis of species co-existence; proposing instead that processes such as speciation, dispersal, random drift in population size are major shapers of biological communities [19]. In some ecosystems, niche and neutral theories have jointly [20] or in a continuum [21] explained species coexistence. Considering the rise of human-dominated landscapes in recent history, the need for refined understanding of theoretical explanations to species coexistence in these modified ecosystems couldn't be more pressing.

Urbanization also causes shifts in plant species traits with many urban plant species being wind-pollinated, scleromophic or animal dispersed (zoochory) [22] and mostly pioneers [23], [24]. Also, due to environmental selection pressure favoring only closely related species [25], urban plant species traits or functional groups can be uniquely similar [22], [26]. Species and trait plasticity arise in the process, favoring plants with high affinity for nutrient-rich warm habitats, high irradiance, and recurrent disturbance [9], [27]–[29]. Such changes in urban species and trait composition can have important consequences on ecosystem functions and hence the amount and variety of ecosystem services they deliver.

While, urban floral diversity is critical to providing ecosystem services and improving human wellbeing [30], it remains threatened by both anthropogenic and environmental consequences resulting from urbanization [2], [31] and research on the theoretical basis of species distribution and coexistence [32], the extent and pattern this diversity in urban landscapes is lacking. Aronson et al. [33] underscored the dearth of urban biodiversity data from tropical cities and the immediate need for research in the current frontiers of urban ecology. Hence, this paper seeks to fill these knowledge voids using a case study in Kumasi, Ghana. Knowledge of species co-existence in any ecosystem is relevant to the restoration, conservation, and management of such ecosystems.

The goal of this chapter is to examine tree species and life history trait diversity and basis of species coexistence in the UGS of Kumasi. It is hypothesized that the niche space limits tree species abundance distribution in cities and that species and trait diversity and composition are influenced by the green space type and zone of urbanization.