Chapter

Assessment of Diversity, Growth Characteristics and Aboveground Biomass of Tree Species in Selected Urban Green Areas of Osogbo, Osun State

Omolara Aremu, Olusola O. Adetoro and Olusegun Awotoye

Abstract

This study assessed the abundance and diversity of trees, estimated the growth characteristics and determined the aboveground biomass of the trees within three selected green areas, namely Riparian Corridor was abbreviated as Riparian corridor (RC), Industrial sites (IS), and Residential sites (RS) in Osogbo, Southwestern Nigeria. Species Diversity Index, Relative Dominance, and Importance Value Index of trees were also estimated. Trees' diversity and ranking were determined using the R statistical package. A total number of 124 tree stems were enumerated and (RC), (IS), and (RS) had 49, 38, and 37 tree stems belonging to 27, 18 and 20 species respectively. *Albizia zygia* (Mimosaceae) was the most abundant species in both RC and IS, while *Milicia excelsa* (Moraceae) was the most abundant in the RS. Growth variables were recorded as 1.18 m^2, 5.01 m^2, and 11.06 m^2 (basal area), and 13.49 m^3, 64.03 m^3 and 122.39 m^3 (volume) for RC, IS, and RS, respectively. The highest mean aboveground biomass was recorded in the RS (28325.20±7639.57 Kg C ha^{-1}). There was no significant difference ($P \geq 0.01$) between the aboveground biomass of RC and IS but a significant difference ($P \geq 0.01$) existed between the aboveground biomass of RC and RS. There is a continuous transition of the urban forest.

Keywords: urban green areas, tree diversity, growth characteristics, aboveground biomass

1. Introduction

Urban green areas (green spaces) encompass all vegetation found in the urban environment, including blue spaces such as lakes or rivers and their adjacent greens and economic values [1]. The continuous changes in the natural ecosystem from disturbances, especially human activities, have been a global concern for decades. This has not only resulted in continuous reductions in its volume but has also led to a reduction in the services provided, such as water protection, flood control, air filtration and carbon

sequestration [2, 3]. Also, this has positioned urban green spaces as a better option for tree species conservation, since increasing prosperity and residential density require more green infrastructure (green areas) and trees to serve amenity functions [4]. In addition to the various critical functions that urban vegetation support in the ecosystem [5–7], the lives of urban residents depend on the availability and lushness of green areas as well as the abundance and diversity of urban trees [8]. Trees are a valuable asset to the urban community [9] which occur in many different sets of species, genera, orders and families with a variety of growth forms, shapes, vegetative and reproductive characteristics, leading to their great range of diversity [10]. Despite several documentations on the great potential for preserving high tree species diversity, several cities are still experiencing loss of green areas and trees diversity, especially in developing countries as a result of rapid economic and urban growth rate [11, 12]. This results in land cover conversion into other land-use forms which affects urban forest cover as well as the functions and services they provided. [13] noted that urban areas are responsible for more than 70% of the anthropogenic release of carbon dioxide and 76% of wood used for industrial purposes. Increasing urban green biomass contributes to an increase in atmospheric carbon sequestration in the urban's terrestrial biosphere. [14] ascertained that the largest single source of CO_2 emissions comes from fossil fuel combustion, followed by industry, residential and commercial activities. Therefore, the huge release of emissions requires urgent mitigation measures.

However, the long-term ecosystem service provision by urban trees is dependent on diversity. Urban centers can also support the great number of trees diversity [15]. The connectivity of the urban forest patches in the urban landscape may be critical for maintaining the species population and diversity [16]. Trees' population and diversity can greatly be increased through human direct or indirect activities in the urban environment. These aids increase in connectivity and tree populations by planting more than one type of species in streets, parking lots, gardens and other areas within the urban centers. Species diversity is necessary for an adaptable urban ecosystem [17] which promotes resistance and resilience to disturbance, such as pests, fire outbreaks and destructions from various human activities. Therefore, the focus should be on increasing diversity to ensure ecosystem stability with more emphasis on the conservation of native species. The introduction of exotic species in urban areas can spread to neighboring rural areas as invasive plants, compete with and threaten the existence of native species and affect the ecosystem negatively by altering its processes [18, 19]. It has been predicted that current species could be at risk of extinction in the nearest future [20]. Therefore, the first step towards ensuring sustainable management of urban biodiversity is by quantifying the green infrastructure. This is done by conducting a tree inventory which may serve as a tool for the establishment of a baseline for setting management objectives by determining the resources present and where they are [21]. However, insufficient information about the status of green infrastructure in most urban cities in Nigeria remains a serious research gap, therefore this study was designed to assess the abundance and diversity of these trees within the three urban green areas of Osogbo.

2. Materials and method

2.1 Study area

The study was conducted in Osogbo, the capital city of Osun state due to its commercial importance. Osogbo covers a total area of 144 km^2 and is located

within latitudes $7^0$43′ N to $7^0$56′ N and longitudes $4^0$33′ E to $4^0$35′ E, with an elevation beyond 502 m above sea level [22]. The population size of Osogbo for 1991, 2006 and projected population for 2016 were 187,219, 288,455 and 395,500 respectively [23]. The climate of the study area is a tropical hinterland type with a mean annual rainfall of 1200 mm to 1400 mm and a mean annual temperature of about 27°C [24]. Osogbo falls within the lowland tropical rainforest vegetation characterized by multiple canopies and lianas, most of which had since given way to secondary forest and derived savannah [25] due to intensive cultivation and bush burning for several years. Tender forest trees become replaced with fire-tolerant species and vegetation changes in features within short distances.

2.2 Woody trees sampling

Purposive selection of the study sites was done based on the urban forest cover and study objectives where three green spaces were identified: Riparian vegetation (site A), Industrial site (site B) and Residential site (site C) after the reconnaissance survey inside the urban center. Ten sample plots of 25 m x 25 m each were selected at random at the three sites. Tree species (≥ DBH 10 cm, h ≥ 1.3 m) within the sampled plots were identified. The Diameter at Breast Height and height (≥ DBH 10 cm, h ≥ 1.3 m) of each tree were also measured. Saplings of woody tree species (≥1 cm < 10 cm) were also identified and recorded.

2.3 Data analysis

The tree data collected were analyzed to determine the following parameters:

2.3.1 Biodiversity assessment

Shannon-Weiner Diversity Index, Species evenness and Rényi diversity ordering technique were estimated using the R-statistical package. The Shannon -Weiner Index is well recognized for measuring wood species abundance and richness [26, 27]. It measures the average probability of where a specie will belong when randomly predicted individually [28] and this is considered in the study to assess specie abundance and richness. This was incorporated in the Rényi Diversity profile. Rényi Diversity Profile which is used to order the diversity of tree species within the different physiognomy [29, 30] was used in this study. Studies have shown that only one diversity index may not be sufficient enough to provide information on ordering sites from high to low. Rényi profile incorporated species richness, evenness, Shannon's index, Simpson's index and Berger-Parker's index in a simple index. R statistical package was employed for accurate and effective computation [31]. Species Relative Density (RD) was determined to assess species relative distributions across the different habitats.

Species relative density (RD) for each tree species was determined by:

$$RD\ (\%) = (N/ni)\ \text{x}\ 100 \tag{1}$$

ni = number of individual species; N = Total number of species in the entire community.

2.3.2 Growth characteristics and aboveground biomass of sampled urban trees

Growth characteristics are important in the determination of the health status and biomass of trees and were measured using growth parameters such as girth size, basal area and volume. Species Relative Dominance (RD_o %) was used to assess the relative space occupancy and management practice of forested lands.

- Species Relative Dominance (RD_o %) [10]

$$RD_o = \text{Total basal cover of individual species} + \text{Total basal cover of all species} \times 100 \quad (2)$$

Where Ba = ^{2} /4

Importance Value Index relates how dominant a species is or the share of each species in a tree community.

- Importance Value Index (IVI) [31, 32]

$$IVI = RD + RF + RD_o \quad (3)$$

Where RF = number of chances of a species occurrence / total number of plots x 100

Where, ni = number of individuals of species i, N = total number of all individual trees of all species in the entire community, Bai = basal area of all trees belonging to a particular species i, Ban = basal area of all trees in a habitat, RD = Relative Density, RDo = Relative Dominance, RF = Relative Frequency.

The improved pantropical biomass Equation for tropical rainforest developed by [33] was employed for the estimation of the above-ground biomass content of tree species.

$$AGB_{est}\ (Kg) = 0.0673\ x\ \left(\rho D^2 H\right)^{0.976} \quad (4)$$

AGB is aboveground biomass, ρ = wood density, D = Diameter at breast height, H = Height.

Aboveground carbon storage of tree species [7, 34].

$$AGB_{carbon} = AGB_{est}\ X\ 0.5 \quad (5)$$

The mean aboveground biomass of the three study sites was subjected to One-Way Analysis of Variance (ANOVA) to test for their significance difference and Least Significance Difference (LSD) when ANOVA was significant. Descriptive statistics was employed for the presentation of the results.

3. Results and discussion

3.1 Tree species abundance and distribution

A total number of 124 individual trees consisting of 52 species, 43 genera and 22 families were identified in the three sites. In Site A, a total of 49 tree stems of 27 species were enumerated. Site B had 38 trees consisting of 18 species and site C had 37

trees stem of 20 species. *Albizia zygia* of Mimosaceae family was the most frequently encountered species in sites A and B, while *Milicia excelsa* of Moraceae family was most abundant in site C. The results revealed the extent of urban trees management in the selected green areas. A total of 170 tree saplings belonging to 15 families and 28 species were also encountered in the sampling sites. The higher proportion of saplings is attributed to the regeneration process occurring in the different sites which are sufficient key to maintaining forest continuity and urban greening.

Generally, the percentage of native species was 67% while 31% was exotic. Site A had a higher percentage (81%) of native species than Sites B (72%) and C (40%). while Site C had the highest percentage of exotic species (60%). Studies on urban green areas and forestry have reported variations in the proportion of trees origin where residential areas had more exotic tree species with higher percentages of native trees in cities [6, 19]. The higher percentage of native species in this study could be attributed to cultural and traditional beliefs as well as indigenous knowledge of dwellers on the usefulness of the trees and the incentives that benefited from the native tree species [35]. They also act as mitigation for poverty. This could also be true of urban areas because not all urban dwellers are financially buoyant and satisfied as life in the urban can be more expensive. [36] also signaled this in a field survey within Ibadan metropolis, Oyo State, Southwestern Nigeria. The higher percentage of the trees serve medicinal value (29%), followed by miscellaneous values (23%) such as ornament, clothing, dye-making, paper, tobacco, cosmetics and fencing. Trees used primarily as fuel and charcoal are 9% of the tree species population. Tree species used as a food source (15%) are trees that supply fruits, seeds and condiments, or spices. Their products may also be sold during fruit seasons (**Figure 1**). Trees for shade and support (10%) are used on farmlands for the protection of crops against harsh environmental conditions and as support for stem tubers. Trees used for construction and furniture trees constitute 99% of the total population. Also, primarily 5% of the tree species enumerated help in soil nutrient enhancement and protection.

Diversity indices are a more compact method of comparing the diversity (variety) of species. Shannon-Wiener diversity estimation for the three sites has values within the expected range of 1.5 - 3.5 [10, 28, 37]. This shows that the sites are rich and diverse in tree species. Site A had the highest diversity index value of 3.15, while Site B had the lowest diversity index value of 2.55. Describing species diversity as a single

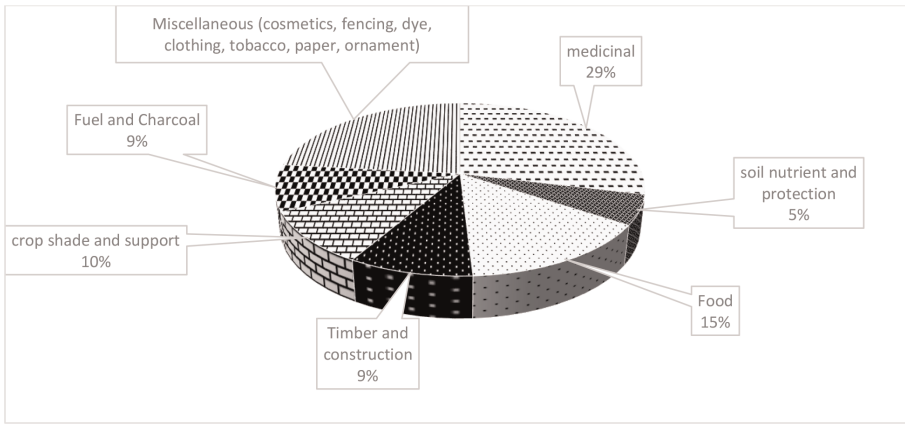


Figure 1.
Ecosystem Services of Tree Species within the study sites.

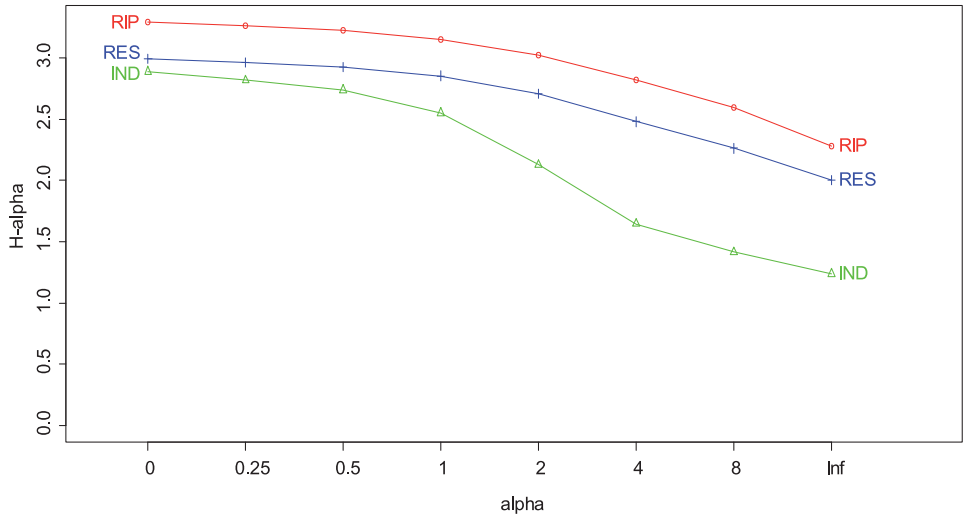


Figure 2.
Rényi diversity profile. H = Rényi diversity profile, alpha = diversity parameter, RIP = riparian vegetation, RES = residential site, IND = industrial site.

value has been reported to compromise much of the detailed structure of a community and that different measures may lead to different rankings among communities [38, 39]. Therefore, a diversity profile that portrays the simultaneous values of a large collection of diversity indices in a single diversity spectrum has been recommended. Rényi diversity profile revealed that the riparian site was the most diverse. Ordering of the sites by Rényi Profile diversity followed; Riparian > Residential > Industrial site (**Figure 2**). Comparing the slope of the three-diversity profile, it is revealed that riparian sites and residential sites have similar and higher species evenness than the industrial site. The more horizontal the shape of the side profile, the higher the species evenness [30, 31]. However, the Riparian and Industrial sites have more connectivity (**Figure 3**) to the number of tree species common to both of them, The nine [9] tree species common to both sites are *Albizia adianthifolia, A. zygia, Brachystegia eurycoma, Ceiba pentandra, Ficus exasperata, Gliricidia sepium, Holarrhena floribunda, Lecaniodiscus cupanioides* and *Margaritaria discoidea*. The agricultural practice was also common within the two sites (Riparian and Industrial sites) in the past. This could be affirmed by the presence of tree species which are usually found within regrowth vegetation previously used for agricultural practice. Species evenness, as a basic component of diversity that measures the equitability of species spread [40], was observed to be highest in site A (0.9681), followed by site C (0.9529) and site B (0.8826). More evenly distribution of trees within the riparian vegetation could be attributed to less competition for space among the tree species and high competition among the tree species within the industrial site as a result of stem proximity which could have also led to competition.

The growth characteristics of the trees in each site varied with growth parameters. Growth variables were estimated as 1.18 m^2, 5.01 m^2 and 11.06 m^2 (basal area), and 13.49 m^3, 64.03 m^3 and 122.39 m^3 (volume) for sites A, B and C respectively. Site A had the highest percentage of small-sized trees (65.31%) while large and largest-sized trees were absent. Industrial sites had 42.11% of the trees within the small-sized range and only 2.63% within the largest-sized range, while site C had 43.24% and 10.81% within the medium and largest-sized ranges respectively (**Figure 4a**). Generally, a

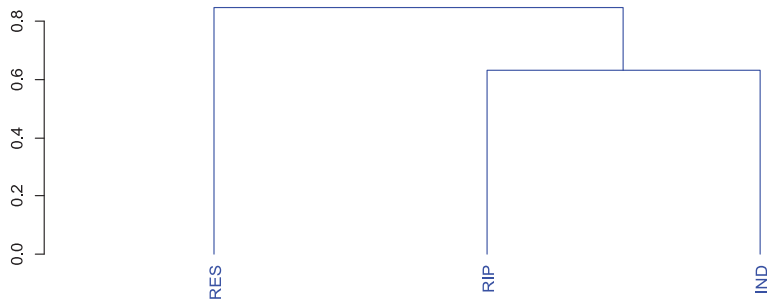
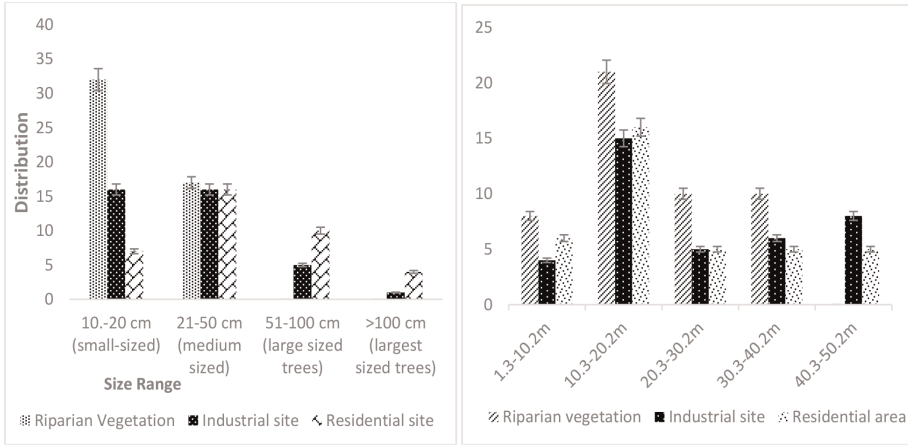


Figure 3.
Clustering analysis of trees diversity within the three sites.



a. **b.**

Figure 4.
(a) Size-class distribution (mean ± sd) and (b) height-class distribution (mean ± sd) of trees enumerated.

higher percentage of the trees (41%) were within the class of 10.3-20.2 m. Site A had no record for trees heights within class 40.3-50.2 m (**Figure 4b**). Site B had only 10.5% of trees within class 1.3-10.2 m. The variation in the DBH and heights contributed to the differences in estimated AGB (**Table 1**). The first four species that contributed to the highest growth characteristics in the three sites are presented in **Table 2**. *C. pentandra* in site A; *Chrysophyllum albidum* in site B and *Brachystegia eurycoma* in site C contributed to the highest basal area, volume and RDo. However, the highest RDe, RF and IVI were contributed to by *A. zygia* in sites A and B, and *M. excelsa* in sites C. The variations explain the management practices for trees preservation and exploitation in the different sites. From the field survey, it was observed that the riparian vegetation is an open area for public use (agriculture, logging and settlement). The residential site is a restricted area to loggers and forest exploiters. The industrial site is also restricted to exploiters but faced with the challenge of encroachment by secret exploiters. Forest resources exploitation for services such as medicine, food and cosmetics may have contributed to reduced trees growth. The depletion of these economically important species populations as habitat degradation and over-exploitation are the two main causative agents [41, 42]. The multipurpose utility of species could also indicate high pressure on them. Moreover, native species with the least abundance could be considered vulnerable in their different habitats. This agrees with a study carried out by [10]

	Species	AGB (Kg C ha^{-1})	Mean DBH (cm)	Height Class (m)
Top ten species				
	Chrysophyllum albidum	190929.20	131.0	47.0
	Milicia excelsa	94237.25	88.6	28.2
	Peltophorum pterocarpum	64652.00	89.0	32.6
	Delonix regia	60275.43	99.2	28.2
	Brachystegia eurycoma	41711.32	26.8	31.2
	Holarrhena floribunda	19068.44	44.9	27.0
	Sterculia tragacantha	17681.00	43.7	24.7
	Terminalia catappa	11606.86	27.0	7.4
	Albizia zygia	11421.60	34.1	29.4
	Persea americana	10981.86	57.8	14.9
Least ten species				
	Spondias mombin	158.92	10.0	8.2
	Croton zambesicus	237.63	10.5	9.3
	Anacardium occidentale	421.03	17.6	6.9
	Baphia nitida	482.94	16.4	14.8
	Ficus sp	573.16	15.0	14.4
	Dictyandra arborescens	592.82	17.0	7.3
	Voacanga africana	607.84	13.1	17.0
	Blighia sapida	639.35	10.7	16.2
	Albizia ferruginea	673.24	12.6	19.0
	Citrus sineensis	779.18	19.6	7.6

Table 1.
Aboveground biomass, size and height of top ten and least ten tree species in the study location.

that species with low relative density and relative dominance are at the top list of vulnerable species under threat of extinction.

The highest aboveground biomass was recorded in site C, while site A had the least value (**Table 1**). The size class 21-50 cm contributed most to the tree aboveground biomass in site C with a mean value of 5062.29 ± 730.90 Kg C ha^{-1} (5.06 ± 0.73 t C ha^{-1}), while site C recorded the highest aboveground value for >100 cm with a mean value 134531.84 ± 29018.85 Kg C ha^{-1} 134.53 ± 29.02 t C ha^{-1}). Generally, the size class 10-20 cm contributed the least to the aboveground biomass in all the land use (**Table 3**). The contributions of ten species with the highest aboveground biomass were recorded in **Table 1** where *C. albidum* (site C) had the highest AGB. This is attributed to its large size and height. (131 cm and 47 m respectively). *M. excelsa* also had a mean DBH of 88.6 cm and a height of 28.2 m while its carbon content was estimated as 94,237.25 Kg C ha $^{-1}$ (94.24 t C ha $^{-1}$). These are examples of native species with high carbon content. Protective and maintenance measures are necessary for the conservation of native species that could promote the uptake of high carbon in the atmosphere. Moreover, the highest AGB values for site C were contributed to by the highest girth sizes of the trees which also relates to the management practice of tree preservation within the site. Size,

	Species	BA	VOL	RDo	RDe	RF	IVI
SITE A	*Albizia zygia*	0.03	0.27	3.23	10.20	50	63.43
	Anthonotha macrophylla	0.07	1.17	7.53	2.04	25	34.57
	Ceiba pentandra	0.16	2.65	17.20	2.04	25	44.25
	Cola acuminata	0.08	0.77	8.60	2.04	25	35.64
SITE B	*Albizia adianthifolia*	0.10	0.42	4.00	5.26	100	109.26
	A. zygia	0.17	1.97	6.84	28.95	100	135.79
	C. pentandra	0.30	2.48	12.21	5.26	50	67.47
	Chrysophyllum albidum	1.35	21.12	54.69	2.63	50	107.32
SITE C	*Brachystegia eurycoma*	1.13	16.25	21.46	2.70	25	49.16
	Delonix regia	0.77	7.28	14.69	5.41	25	45.09
	Holarrhena floribunda	0.41	4.38	7.75	8.11	75	90.86
	Milicia excelsa	0.75	9.51	14.31	13.51	100	127.82

Table 2.
The first four species with highest growth characteristics in the different sites.

Size class (cm)	Riparian vegetation (Kg C ha^{-1})	Industrial site (Kg C ha^{-1})	Residential site (Kg C ha^{-1})
10-20	1062.77 ± 134.83	885.27 ± 156.48	620.88 ± 118.69
21-50	5062.29 ± 730.90	6855.49 ± 1323.02	4272.29 ± 1073.59
51-100	0	36742.80 ± 6005.92	43720.21 ± 7629.14
>100	0	0	134531.84 ± 29018.85

Table 3.
Size-class distribution of tree aboveground biomass (kg C ha^{-1}) recorded across the study sites.

age and species are major factors that influence the amount of carbon that trees can absorb. [43] reported that matured trees can absorb up to 48 lbs. of CO_2 per year. [44] reported that at maturity, trees can store approximately 1000 times more than saplings. The result of the Analysis of Variance (ANOVA) performed on the aboveground biomass among the three study sites revealed that there was no significant difference between sites A and B. There was also no significant difference between sites B and C. However, a significant difference occurred between sites A and C at probability level 0.01 (99% confidence interval).

4. Conclusion

Protection of urban tropical forest trees, as noticed within the residential and industrial sites, contributes effectively to tropical urban vegetation, urban diversity and ecosystem benefits. Therefore, proper urban planning, preservation and sustainable utility of biodiversity within the urban areas is also a way to decelerate the rapid rate of biodiversity loss that results from population explosion, urban expansion and pressure on the ecosystem.

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