The Diversity of Street Trees: Density, Composition and Shade in the Urban Residential Areas of Visakhapatnam, India

Allu Revathi Devi[1], Vijayalaxmi J[2]. Ramesh Srikonda[3].
Department of Architecture, School of Planning and Architecture, Vijayawada, Andhra Pradesh India.
Email: allurevathidevi@yahoo.com, vijayalaxmij@spav.ac.in, ramesh.srikonda@spav.ac.in
:

Abstract

Street trees form an essential part of a green infrastructure which contribute to the resilience of a city. Stewardship and stake holder preferences are some of the factors in the sustainability of street trees and their diversity and composition in residential areas. This study aims to understand the existing conditions and practices in the plantation of street trees in residential areas.

Plotted residential layouts of areas ranging between 18-25acres with road widths less than 9mtrs., 9mtrs to 12mtrs and greater than12mtrs are taken to compare and assess for diversity, density, composition, and distribution along with the shade analysis across six zones of the city of Visakhapatnam, India. A total stem count of 1903 trees accounting to 86 species, 73 genus and 32 families are recorded across the selected neighborhoods. The diversity is rated high when evaluated against the Shannon index and the Simpson's index.

It is found that the Sant amour formula of the species diversity as indicated 10/20/30 is not met with. The density of the trees per 100-meter length ranged from 9 trees to 20 trees, but the tree sizes differ, which would have varying results in the ecosystem services provided. The composition of native to exotic trees are 60-40% respectively. As the neighborhood character keeps changing with re-densification, there are frequent replacements of trees resulting in younger trees accounting for a higher share as against the old trees. The recent plantation drives also replace them with the fast growing trees. The parameters assessed gives us evidence to the approach residents of the neighborhood take in the planting patterns. The patterns that evolve in this process can indeed become indicators for evolving a framework and enable better practices of planting trees.

key words: street trees, diversity, density, composition distribution and neighborhoods

Introduction

An urban forest comprises of the trees and shrubs in an urban area - trees in yards, along streets and utility corridors, in protected areas, and in watersheds. (Miller et al., 2015). Urban forests can contribute to nine sustainable development goals (SDG): create employment

(SDG1), provide food security (SDG2), ensure good health and wellbeing (SDG3), regulate the hydrological cycles (SDG6), use renewable energy sources (SDG7), contribute to economic growth (SDG8), improve liveability (SDG11), ensure climate change mitigation (SDG13) and promote biodiversity conservation and land restoration (SDG15) (Salbitano et al., 2016). The cities across the world emphasize on the green programs given the enormous benefits they receive. Indeed, the introduction of soft natural assets into the hard cityscapes would provide an urban biome which can provide great ecosystem services (Pincetl ,2015).

Street trees form a crucial part of an urban forest. They provide environmental, ecological, social, and economic benefits. Urban environments create challenges for growing trees, and they pose problems for urban infrastructure and maintenance (Mullaney et al., 2015). Trees provide shades reducing the exposure to sun while increasing walkability (White et al., 2017). They filter dust, absorb carbon dioxide, reduce heat, remove air pollutants, and absorb noise (Nowak et al., 2006). It is well known that urban heat island: a complex phenomenon arising out of urban development and activities like built forms, mobility and materials all contributing to, can be ameliorated and mitigated through trees and the canopies to a great extent (Westendorff, 2020). Trees create cooling effects due to evapo-transpiration and shading which affect the microclimate (Shashua-Bar et al., 2009). A tree size, canopy, and the tree density in a street relates to this cooling effect. In fact, 80% of the cooling effect is created by the shade and as much as 5- 20 degrees change is noticed due to the presence of the trees (Killicoat et al., 2002). All these contribute towards outdoor thermal comfort which increases the liveability of the streets.

Street trees form the urban green ways which become habitats and contribute to the movement of fauna as wildlife corridors (Angold et al., 2006). Human intervention can happen through vegetation/ plant material which can help in creating biological communities thereby leading to the increase in biodiversity (Faeth et al., 2011). Trees could also provide for food, a goal contributing towards food security (Britto et al., 2020). The presence of trees offers a wide-ranging health benefits from physical health to mental health, increasing social cohesion, safety, and community interactions (O'Brien et.al., 2010). In fact, street trees play a significant role in supporting healthy urban communities through the provision of environmental, social, and economic benefits. They improve liveability of towns and cities through shade provision, stormwater reduction, improved air quality, habitat, and landscape connectivity for urban fauna (Mullaney et al., 2015). Social benefits include sense of community and safety, and reduced rates of crime.

However, there are many ways in which trees do a disservice to the urban environments. Leafs fall and the litter of fruits and flowers not only cause unpleasant surroundings but also clog the drainage. The tree roots damage the pavements, kerbs and drains by uplifting and cracking them (Day, 1991). During natural calamities, their branches break and sometimes uproot themselves causing huge damage to property and people. Tree size and its damage to properties is proportional as some research suggest that planting smaller tree species and increasing planting distances from the pavement can help in decreasing such damage (Wager & Baker, 1983).

In fact, urban environments can be exceedingly difficult for the growth of trees. The conflicting nature of needs such as a tree depending on porous soil whereas the subsurface of movement; be it pedestrian or vehicular, needs compaction makes it difficult for trees to survive (Grabosky et al.,2001). Moreover, there is a lot of vandalism affecting trees in India. Heavy dust settling on the leaves make it difficult for the functions such as the removal of pollution and in countries where there is snow, salt is used for de-icing all of which do not help tree health (Lu et al.,2010). For the establishment of a tree, its health and successful survival stewardship plays a vital role (Boyce, 2010). However, despite the challenges, there is a concerted effort in tree plantations because of the values they render in urban life.ate the In this context, this paper aims to investigate and to understand the existing conditions and practices in the plantation of street trees in residential areas in India. The objective of this study is to understand the types of trees that exist in the residential streets. The difference in the street tree type and their densities with the changing road widths.

Theoretical Basis and the Review of Literature

Tree diversity is one of the key factors in establishing a resilient and healthy urban forest (Bingqian et al., 2020). There are examples of urban forests with monocultures getting infested with pests which cost dearly to a city. Diversity becomes important to support biodiversity as different trees help divergent bio-communities. This highlights the potential importance of street trees to act as connectors to the natural patches. Investigations of the diversity of the species, and the abundance and distribution of street trees might be an essential process towards environmental protection within an urban context (Jim & Chen, 2009).

Tree features such as tree heights, green coverage, shape, and permeability of the crown can influence the visual landscape character. Their effects on the neighborhood environments could be observed through simulations. Some studies confirm that specific plant species features, such as the tree canopy structure and density, leaf size, shape, and color, as well as tree age and growth can influence the performance of solar radiation attenuated by canopy, air temperature, and air humidity (Abreu-harbich et al., 2012)**.** Because of solar radiation reflection, transmission and absorption, tree canopies may adapt to microclimatic conditions and regulate the wind speed (Steven et al., 1986). The form and density of a canopy influences the amount of shadow cast by the trees as well as the amount of radiation filtered. The amount of radiation intercepted is determined by the density of the twigs, branches, and the leaf cover. In fact, these elements have an impact on the overall form and the density of the trees (Abreu-harbich et al., 2012).

Mcpherson & Simpson (2003) define tree structure in urban areas in terms of species composition and spatial array of vegetation in relation to other objects (e.g., buildings, roads, pavements, etc.). Arnold (1980) emphasizes the importance of order in urban design and criticizes "variety" and "diversity" in landscapes. Diversity in planting materials is referred to as a visual disorder, and Arnold goes as far as to claim that people do not like planting schemes that include a diversity of tree species. Arne Sæbø &Thorarinn Benedikz (2003) has identified biotic and abiotic factors which have significant impacts on tree structures in urban streets. In this context, Kuper (2017) has employed digital composition models for trees on streets and in parks, with different species diversity (complexity) and plant distribution (coherence). He has discovered a relationship between citizen preferences and estimations of the complexity of the virtual environment, and that people prefer more diverse landscapes with groupings of plants over formal compositions with repetition or random rhythm.

The quantitative study of vegetation known as phytosociology can be used to analyze the species diversity and community structure of an area (Khesoh & Kumar, 2017). Urban forests and trees create healthy environments for stressed urban residents in addition to providing environmental benefits to people's physical and psychological well-being (Schroeder et al., 1984; Hunter, 2001). Studies show that urban foresters in the US have shifted to planting smaller trees to reduce tree maintenance and increase species diversity (McPherson & Rowntree, 1989). Due to the pressures of the urban environment, street trees typically have shorter lifespans than trees growing in more "natural" settings and even compared to trees in other urban locations like parks. Despite the unavailability of quantitative data on street tree issues, tree quality, growth concerns, and growth performance over time, along with visual evidence indicate that inadequate drainage, poor soil conditions, frequent pruning, and exposure to traffic pollution negatively affect tree survival and growth. As a result, these stressed trees are more likely to be attacked by insects and other pests. Areas with a diverse mix of species are more resistant than areas dominated by a limited group of species because high species diversity is one strategy for protecting against such pest invasions (McPherson & Rowntree, 1989; Thaiutsa, et al., 2008).

According to a recent research conducted in Bangalore, India, data on tree distribution, including species composition, size and age structure and spatial inventories, are required for more efficient management of street trees and the species diversity they represent (Nagendra & Gopal, 2010). Recently, 108 different types of street trees have been counted. While species diversity was higher than in most developing nations, species density was lower. This highlights the potential importance of street trees to urban biodiversity. In a century-old academic institution in Chennai, plant diversity was qualitatively measured by Udaya Kumar et al. (2011). Investigation of the species diversity, abundance and distribution of street trees might be an essential process towards environmental protection within in the urban context (Jim & Chen, 2009). Urban planners have strengthened this by recognizing the value of creating green spaces in urban environments (Nagendra & Gopal, 2010).The City of Visakhapatnam focused mostly on establishing monoculture-type vegetation, particularly quickly growing species as Peltophorum pterocarpum, Samanea saman (rain tree), Polyalthia longifolia (False Ashoka), Eucalyptus, Cassia siamea, Delonix regia (Gulmohar), Thespesia populnea, etc. Globalization has established a space for the introduction of alien species, which are currently replacing local flora and posing a threat to the survival of native biodiversity, which unfortunately has not yet been recognized and appreciated (Reddy, 2008)

Hence, all these factors determine the distribution, composition, and density of tree species in urban street plantings. The richness of urban vegetation could be assessed by studying the composition, distribution, and density of species. This type of research is necessary to produce a clear and concise appreciation of tree species suitable for a particular urban environment and for future recommendations on planting. Based upon these presumptions, this study aims to evaluate the existing status of urban street tree planting in a city in India. This work is therefore a baseline for research into the planting structure in the residential pockets of Visakhapatnam City, Andhra Pradesh.

Research Methodology

This research employed both qualitative and quantitative data collection methods to gather data from the site, the local community, and the official authorities. The major data collection is through the primary survey. Six sample neighborhood units are selected within six different administrative zones of the Greater Visakhapatnam Municipal Corporation (GVMC**)** in which tree inventories were prepared. A tree inventory contained only street trees and the tree inventory of geo tagged data with the location type. The distance between trees was calculated using latitude and longitude information gathered for each surveyed tree by using a Mobile device. In general, geographic positioning shows the "real" position but due to the satellite availability and other potential problems, the position is often given with an accuracy value.

During the data collection, an attempt was made to gain GPS accuracy values less than 1 meters. The tree inventories were imported from various geospatial, or comma separated value (CSV) file formats to Arc GIS shape files for the tree point data and for geographic units of analysis. Within each sample neighborhood, all the streets are surveyed using google maps and local maps. Within each transect, the numbers of trees on either side of the road were counted, and the number of trees present in each neighborhood indicates the density of the trees. To estimate the tree density, the total number of trees was calculated per 100m length both for the main and the link roads. After the identification, the list of known species was recorded and categorized. A suffix 'alien' was assigned for the tree species newly introduced and 'indigenous' was assigned for the trees native to India. The unidentified or unknown species were not characterized into either of these categories, as it was impossible to do so without identifying the name or the family of the species. The unknown species were then coded for differentiation and ease of analysis.

Tree Species Diversity

Preliminary data analyses (descriptive statistics) were conducted using Microsoft Excel 2010. All inventories used field surveys to gather data and had information at the species and the genus level, as well as the family-level. Tree species diversity is a measurement derived from species richness and species evenness within a given area. A diverse tree asset may offer more habitat variety than a less diverse tree asset.

Diversity can be measured in several ways including the indices. Many species diversity indices describe evenness based on the relationship between the number of individuals and the number of species. The Simpson's Index of Diversity and Shannon-Wiener Index have been applied in several urban environmental studies (e.g., Jim & Liu, 2001; McPherson & Rowntree, 1989; Sun, 1991). The Simpson's Index of Diversity represents the probability of two entities belonging to the same species when drawn randomly from a sample (Magnusson & Mourao, 2009). In contrast, the Shannon-Wiener-Index considers species abundance and evenness to specify diversity. Initially, both indices were adopted for the analysis of tree species diversity.

Calculation of tree diversity

Two measures are often used to evaluate diversity. The Shannon index of diversity at the species level and Species richness (the number of tree species per transect) are calculated for all the transects.

Shannon's Index (H')

The Shannon diversity index (H') was applied as a measure of the species abundance and richness to quantify the diversity of the Tree species. Shannon's Index for diversity is calculated based on the abundance value of the Tree species and it is commonly used to characterize species diversity and accounts for both abundance and relative evenness of the species present.

The Shannon Index increases as the community's richness and evenness increase. The Shannon index ranges from zero to infinity, but in most research studies, typical values range from 1.5 to 3.5, and rarely exceed four.

$$\text{The Shannon index of diversity } (\boldsymbol{H'}) = -\sum_{i=1}^{N} \boldsymbol{pi} \times \boldsymbol{ln\,pi}$$

Where, Pi = the proportion of the important value of the i th species

$$\mathbf{Pi} = \frac{\mathbf{ni}}{\mathbf{N}}$$

ni = importance value of ith species.
N = importance value of all the species.
Total number of species and pi is the proportional abundance of the ith species.

a) Simpson's index of diversity is calculated as:

$$Simpson's\ index\ (D) = \frac{\sum n(n-1)}{N(N-1)}$$

Where, N is the total number of species and 'n' is the total number of individuals of a particular species. In the present study, the reciprocal of Simpson's index was used to find out the species diversity of a place.

The Study Area

This study is conducted in the Visakhapatnam Metropolitan City, which is one of the largest cities in Andhra Pradesh and the seventh largest in India. it is located at 17°41'18″ North latitude and 83°13'07″ East longitude and 900 m Altitude along the coast of the Bay of Bengal Sea (Fig. 1). The total Geographic area of the reconstituted Greater Visakhapatnam Municipal Corporation is 540 sq. Km with a population of 17.3 lakhs (Census 2011) and there are 72 wards distributed in six zones.

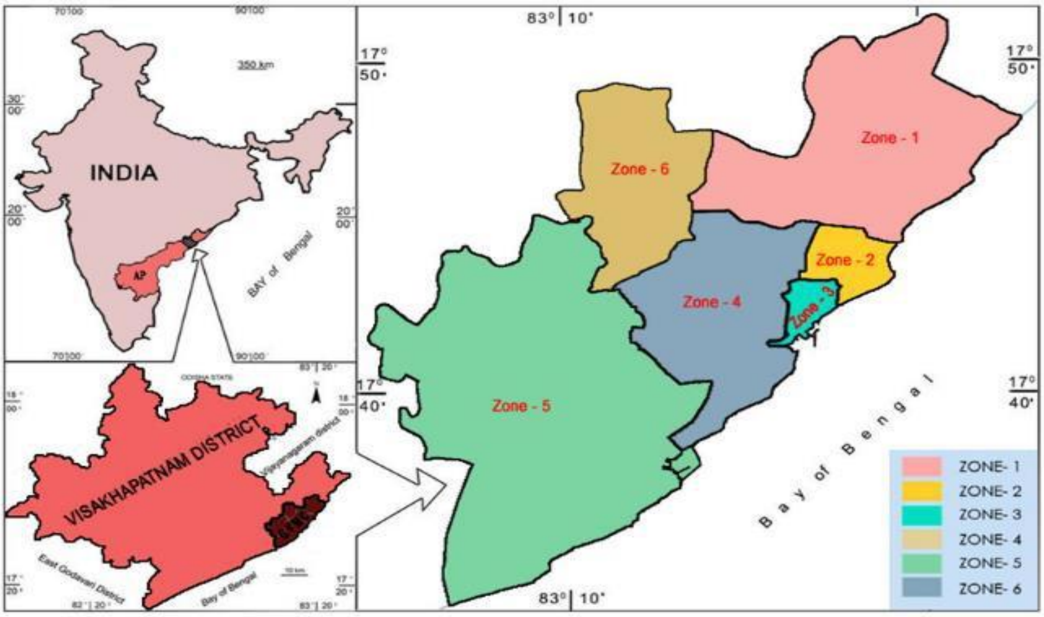


Fig. 1: Location of Study Area Within the GVMC Limits
Source: Author, 2022.

Six sample neighborhood clusters are selected from each representative zone as highlighted in Fig. 2. We obtained inventories of urban trees in the neighborhood sample units as mostly plotted developments executed by the urban development authority, involving Visakhapatnam - Midhilapuri Vuda Colony (zone 1); East Point Colony (zone 2); Official

Colony (zone 3); Madhavadhara (zone 4); Pedagantyada (zone 5); Simhapuri Vuda Colony (zone 6). The identified study areas represent the overall vegetation conditions of the city, tree density, diversity, and distribution. The areas of these colonies ranged from15-20 Acres. All the streets in the neighborhood were studied for comparing the attributes of street trees depending on their widths. The streets were classified broadly as <9m, 9-12m and >12 as the road widths differed. Patterns of how diverse and rich the species exist in the residential neighborhoods were analyzed for further insights. Data was collected through the primary field studies involving, counting, and identifying the trees which are more than 3m. They are marked and the species identified. Trees that occur between the property lines and the right of way are taken into separate consideration.

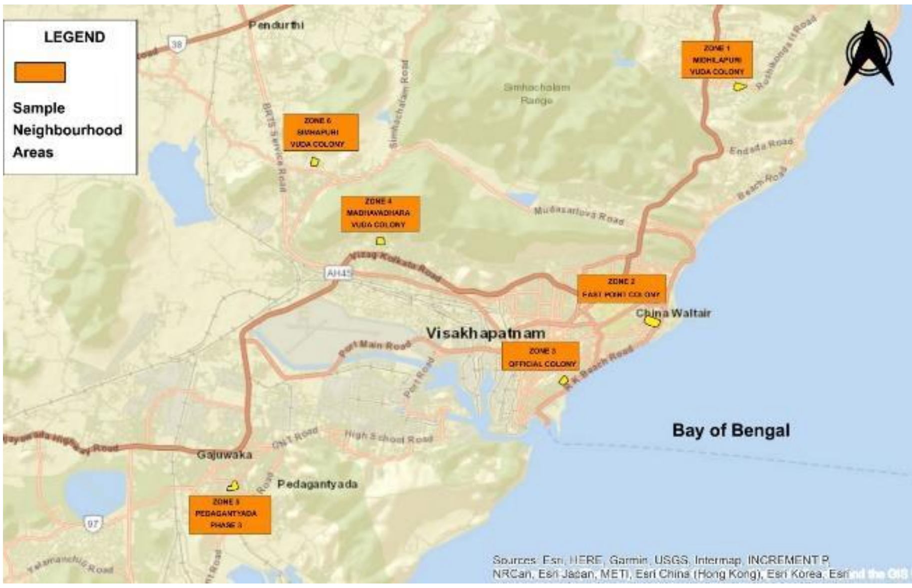


Fig. 2: The location of the selected Neighborhoods'
Source: Author, 2022.

Findings

The study includes a total of 1903 trees accounting to 86 species,73 genus and 32 families of the street trees in urban areas of The Greater Visakhapatnam Metropolitan City. Midhilapuri Vuda Colony is one of the growing residential neighbourhoods with individual houses and few vacant plots. A tree counts of 320 with 38 species and 26 families exist: Pongamia pinnata, Albizia saman, and Azadirachta Indica account for around 40% of the stem count. They are large trees planted by the municipal managers at the time of making the layout. Alstonia scholaris, milingtonia and terminalia mentalis which account for 20% are recent fast-growing trees added to the tree palate in the plantation programmes. The rest of the 40% are small trees with the influence of human legacies like individual choices like aesthetics, flowering, and fruit bearing trees. There are naturalized trees which are small and not planted but the residents let them grow like Annona Squamosa and Psidium.

The East Point Colony (zone 2) residential plotted development is part of the city where there is a change towards densification of the plots where the individual houses have mostly been converted into multi-dwelling units. The stem count is 230 but accounts for

43 species. The adjacent land uses in this layout was institutional which could be the reason why the large trees were retained. The process of re-densification usually leads to the loss of many trees. Thus, the placement of a tree in relation to a property line might help in protecting the trees and increasing their lifetime. Peltaphorum accounts to 32% of the total tree population while Mimusops elengi, Thespesia, milingtonia and termilinia cattappa accounted for around 5%. The rest of the 50% accounts for the individual choices of the residents belonging to the respective areas.

Table 1: Tree species abundance and composition
Source: Author, 2022.

No	Name of the residential colony	Area (acres)	No. of species	No. of genus	No, of families	No. of trees
1	Midhilapuri	20	38	34	24	320
2	East point colony	19	43	41	24	230
3	Official colony	17.5	35	31	19	161
4	Madhavadhara	17.3	53	48	26	520
5	Pedhagentyada	22.8	43	39	22	316
6	simhapuri	17.8	43	40	23	356

The official colony zone 3 is a plotted layout in the old town area which is a primarily residential area with ground +four floors having an apartment culture. This layout had the lowest stem count of 161 with 36 species and 20 families. Madhavadhara (zone 4) site has the highest number of street trees recorded in the survey and in the majority are placed along streets with a variety of sizes. The results indicate the presence of 520 trees belonging to 53 species and 26 families at selected roads of the Neighbourhood. Mimusops elengi L was predominant at all roads (14%), followed by Tecoma stans (8 %), Pongamia pinnata re (6 %) and Nyctanthes arbor-tristis (6 %). Both Tecoma and Nyctanthes are small flowering plants. Pedagantyada (zone 5) was among the most recorded and dominated species, while Senna siamea (41%) had the highest number of species (13%) followed by Annona squamosa L (10%), Azadirachta indica. (10%), Psidium guajava L (9%) and Cocos nucifera L (9%).

Simhapuri Vuda Colony in the zone 6 has a total of 356 trees belonging to 43 species from 23 families which are recorded within a sampled area. Mangifera indica L is predominant at all roads (15%), followed by Psidium guajava (12%), Pongamia pinnata (9%) and Parkia biglandulosa (7%). Pongamia pinnata is predominant at all roads (10%), followed by Peltophorum pterocarpum (6%), Mimusops elengi (6%), Azadirachta indica (6%), Psidium guajava (6%), Mangifera indica (5%), Annona squamosa (5%), Tecoma stans (4%), Senna siamea (4%), Nyctanthes arbor-tristis (4%), Cocos nucifera (3%) and Alstonia scholaris (3%).

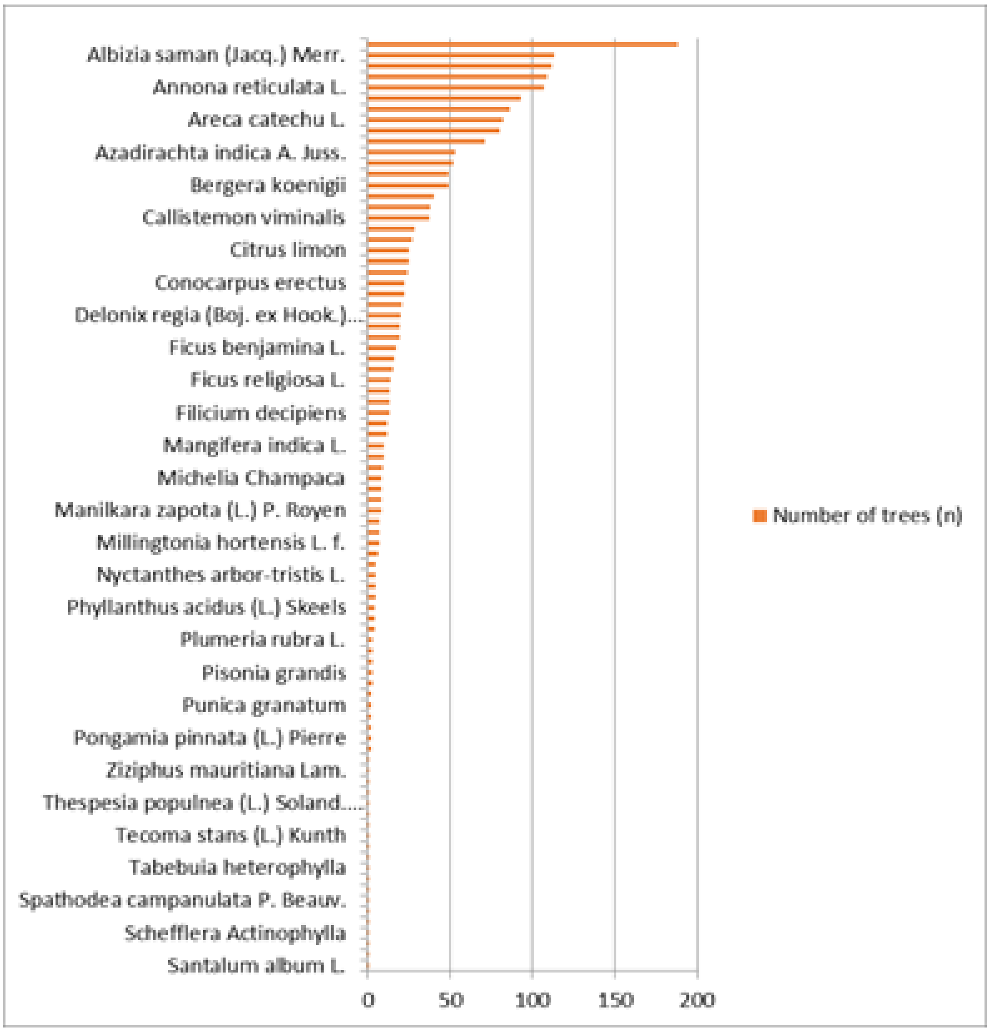


Fig. 3: Tree species abundance.
Source: Author, 2022

In terms of the origin of the species, 60% of the trees belonged to the native species, while only 40% of the trees belonged to the exotic species. Of the 86 counted, from a total of 32 families with the Pongamia pinnata (L.) Pierre being the most common, 34 species are introduced and only 52 are native species from the region. Among the 43-tree species in the study area, 32 (37%) species are occasional, 30 (35%) species common, and 24 (28%) species are rare.

Out of the total tree species present near the selected neighbourhood roads, 52 % of the trees are evergreen broad leaved (45 species), 32 % deciduous broadleaved (27 species), 9 % evergreen /deciduous broadleaved (8 species) and 7 % Perennial broadleaved (6 species).

Table 2: Diversity benchmarks of street tree inventories across the six neighbourhood areas. Data shows the most abundant species, genus, or family that met the proposed 10/20/30 benchmark.
Source: Author, 2022.

Neighbourhood name	Area (acre)	Tree Count (n)	Most Abundant Species (%, Name)		Most Abundant Genus (%, Name)		Most Abundant Family (%, Name)	
Midhilapuri Vuda Colony	20	320	Pongamia pinnata (L.) Pierre	26%	Ficus	11%	Moraceae stood	11%
East point colony	19	230	Peltophorum pterocarpum (DC.)	33 %	Annona	7%	Bignoniaceae	12%
Official colony	17.5	161	Pongamia pinnata (L.) Pierre	11%	Ficus	11%	Bignoniaceae stood	17%
Madhavadhara vuda colony	17.3	520	Mimusops elengi L.	14%	Ficus	9 %	Moraceae stood	11 %
Pedagantyada Study	22.8	316	Senna siamea (Lam.)	13%	plumeri a	7%	Annonaceae and Bignoniaceae stood	9 %
Simhapuri vuda colony	17.8	356	Mangifera indica L.	15%	Citrus	7%	Rutaceae	9 %

As per Santamour, the species diversity should indicate 10/20/30 percentage as species/genera/family to have a healthy forest. This reads as not having more than 10%of any species, 20% of any genus and 30% of any family which was later changed and adopted to 5/10/15 by the city of Portland, Oregon, USA. However, this study does not meet this criterion. Replacements of trees when done need to take the diversity formula into consideration. Tree palettes need to develop the choices of the citizens and nurseries that have the species available as per the Santamour. The species diversity need to be more expansive. This also could lead to variety and biodiversity.

However, when the most abundant species, genus, and family is calculated using the total tree count, none of the neighborhoods met the 5/10/ 15 benchmark. The official colony neighbourhood came close with 11/11/17, meeting the 10/20/30 benchmark. No other neighbourhoods met the 10/20/30 benchmark. All others failed to meet the proposed benchmark. In general, in line with the findings from the research study, the relative abundance at the genus and family species-level are much lower than the proposed 20 % and 30 % benchmark respectively, but comparable with the proposed benchmarks at the species level (10 %).

Table 3: Diversity of street trees between and within study area**:**
Source: Author, 2022.

S.no	Neighbourhood name	Number of street trees	Species richness per Neighborhood d (S)	Shannon Diversity Index (H)	Evenness (E)	Simpson's index		
						D	(1-D)	(1/D)
1	Midhilapuri	320	38	2.88	0.79	0.10	0.899	9.94
2	East point colony	230	43	2.88	0.76	0.12	0.875	8.03
3	Official colony	161	35	3.27	0.92	0.04	0.958	23.94
4	Madhavadhara	462	49	3.33	0.85	0.05	0.952	20.85
5	Pedagantyada	314	44	3.11	0.82	0.06	0.937	15.88
6	Simhapuri	356	43	3.04	0.80	0.07	0.933	14.84
	Average			3.085	0.823			15.58

The Shannon-Weiner index (H) for the study area ranged from 2.88 to 3.33 with an average of 3.085. The highest 'H' index of 3.33 was observed at madhavadhara street roads followed by the official colony neighbourhood street roads with 'H' as 3.27. The lowest value of the 'H' as 2.88 observed at the midhilapuri vuda colony and the East point colony street roads.

The diversity is high in the Madhavadhara Neighbourhood study area with 520 species, followed by the Simhapuri vuda colony, the Midhilapuri vuda colony and the Pedagantyada Neighbourhood areas (Table 3). The same is reflected through the dominance index (Simpson) where the high diversity is in official colony followed by the Madhavadhara Neighbourhood area and the Pedagantyada Neighbourhood areas. Reciprocal Simpson's Index (1/D) ranged from 8.3 to 23.94 with an average of 15.58. Official colony neighbourhood street roads possessed the highest 1/D with a value of 23.94 followed by the madhavadhara street roads (20.85) while the East point colony street roads were found with the lowest 1/D of 8.3 followed by the midhilapuri vuda colony street roads (9.94). The Shannon's evenness index (HE) ranged from 0.76 to 0.92 with an average of 0.823. East point colony street roads possessed the lowest HE at 0.76 and the highest HE was observed at the official colony neighbourhood street roads (0.95).

These indices clearly indicate that the neighborhood streets of Visakhapatnam hold moderate species diversity and evenness and are in conformity with the observations of Nagendra and Gopal (2010) who studied the roadside tree diversity of Bangalore. Thus, Madhavadhara Neighborhood study area is significantly diverse based on both the Shannon and Simpson indexes, followed by the Official colony. East point colony on the other side is low in diversity with lower evenness and high variations in the abundance of species. The sample sizes of both the neighbourhoods are the same. The official colony study area has a high degree of evenness where all the species are equally common with an extremely low variation in abundance followed by the Madhavadhara and Pedagantyada Neighborhood areas. Species richness (S) varied among the urban neighborhood areas. The highest species richness is found in Madhavadhara (49) and the lowest is in Official colony (35).

Simpson’s Diversity Index is a measure of diversity which considers the number of species present, as well as the relative abundance of each species. As species richness and evenness increase, the diversity increases. The value of the D ranges between 0 and 1. When examined against the Simpson’s index for the stem count, values ranged from 0.04 to 0.12 indicating high diversity. Data were collected from the entire main and local transects of the study areas. Of the 85 sample transects, 1896 trees were counted, with the highest number of trees (520) encountered in Madhavaram and the least (161) in the official colony (Table 3).

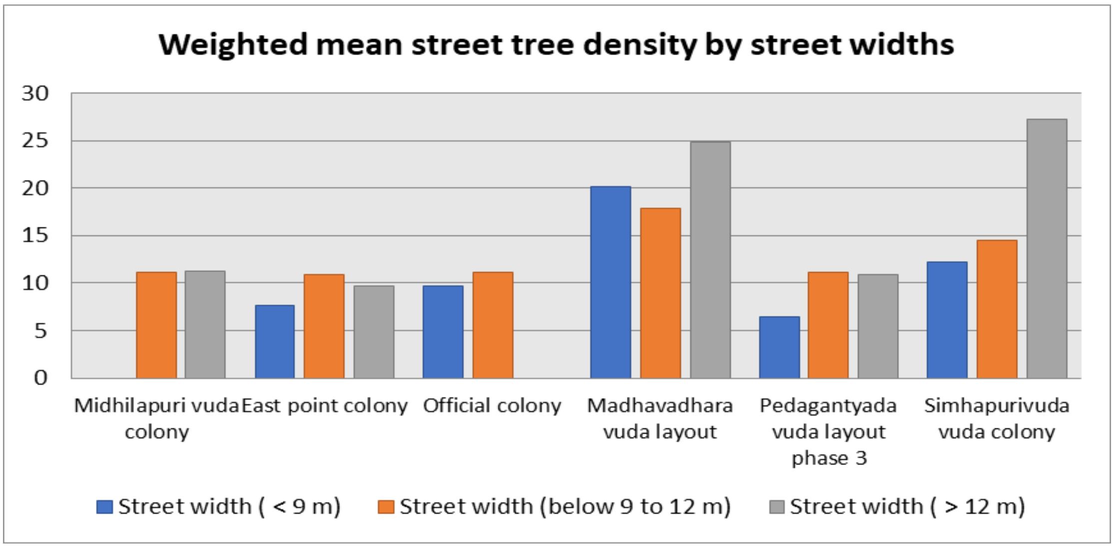
The streets categorized as <9m 9-12m and >12m had conspicuous differences. Trees at >12m were large and the older trees had been introduced by the municipal managers. The other street types had medium to small trees. There is a conspicuous absence of large trees in some streets with vegetation relegated to small flowering trees. Some trees like Annona squamosa were present which were not planted but grow naturally. There is no attempt to remove them. This can be interpreted as the citizens not being averse to trees, and allowing them to grow. The densification process of the neighborhood also seems to add to the reduction of large trees as there is a growing trend of beatifying it with hedges and small trees. Further studies dwelling into the preferences of the neighborhoods would give a direction and attitudes towards street trees citizens possess which can also lead to developing a palette for everyone, as that would mean a better survival of the urban forest.

A transect of 100 m in length was chosen for collecting the data on the street trees within the city and the data were collected from each neighborhood. Street tree density for the study areas ranged from 9.13 to 20.33 with an average of 13.19833. The number of trees in each 100 m transect, the Madhavadhara neighborhood (20.33) had the highest street tree density followed by the simhapuri vuda colony (18.93), while the East point colony (9.13) had the lowest street tree density followed by the Pedhagentyada street roads (9.82). Wider streets above the 12-meter road widths in all neighborhood areas, and the simhapuri colony had a higher street tree density than the other neighborhood streets. While differences in tree densities are not significant between the neighborhoods, the number of trees in each 100 m transect of the main roads was more than that of the local roads. Overall, there was a significant difference in the tree densities between the neighborhoods. The density was high in the Madhavadhara Neighborhood area with 20.33 trees per 100m transect, followed by the Simhapuri vuda colony (18.93) and the Midhilapuri vuda colony (11.12) (Table 4). Regarding the number of trees per 100 metres of the street, this study clearly shows that there are differences in urban street tree densities across the six neighborhood areas.

Table 4: The species density of trees per 100m and shade percentage of different neighborhood areas.
Source: Author, 2022.

No	Name of the residential colony	No of transects	Total Road length	Total road area	No. of street trees	Density of trees per 100m	Shade percentage
1	Midhilapuri	15	2595	36488	344	11.12	46.64%
2	East point colony	10	2336	26505	230	9.13	40.95%
3	Official colony	8	1708	16179	161	9.86	46.64%
4	Madhavadhara	16	2539	30297	520	20.33	38.87%
5	Pedhagentyada	15	3114	34856	316	9.82	17.15%
6	simhapuri	21	2258	23012	356	18.93	35.72%

Table 5: The differences in tree densities across the road categories.
Source: Author, 2022.



Among the 86 inventorized tree species in the selected neighborhoods, 37 street tree species are planted for ornamental purposes while the other tree species are planted for both ornamental and various other uses, such as the production of edible fruits, provision of shade, or medicinal properties. Similar studies have suggested that a variety of fruit-bearing trees can serve as an acceptable and important food source for the urban communities (Clark and Nicholas, 2013; Kohli et al., 1996). Species like Azadirachta indica, Carica papaya, Ficus benghalensis, Ficus racemosa, Ficus religiosa, Mangifera indica, Muntingia calabura, Pithecellobium dulce, Psidium guajava, Syzygium cumini, and Terminalia catappa are a few of the street tree species from the study areas that produce edible fruits to attract birds and animals. Usually, ornamental and fruit trees are planted in the narrow streets, while shade-bearing trees are planted on each side of the major streets or wider streets. In the study area, the fundamental guidelines for planting street trees were not followed. Some large and tall trees are planted in the narrow streets (below 9m roads). Due to the potential interferences with telephone and electrical poles, such large trees should not be planted in these types of streets.

When compared to the stem count as against the shading percentage in the old settlement of official colony was equal to the Midhilapuri layout where the stem count is double. This indicates that the size and the canopy need to be considered while planting. Planting of smaller trees with flowers like the Tecoma stans and Nyctanthes arbortists, were in abundance in the newer settlements where the people took decisions on their own. Naturalized trees like Psidium guajava and Annona squamosa were retained for their fruits. Certain trees like Aegle marmelos were seen in abundance in the localities where there were temples indicating their value in religious rituals. Tall trees like Pongamia pinnata Pierre Peltophorum pterocarpum, Mimusops elengi, Azadirachta indica, which were planted by the development Authority are the one's giving more shade. As the residential settlement is getting redeveloped, these trees are being taken away and replaced with smaller trees. Sometimes trees like tabebuia rosea, millingtonia are favoured for their fast-growing nature.

Conclusions

The analysis of the neighborhoods reveals a certain similarity. Visakhapatnam, a tier II city and a port city in India which is rapidly growing is undergoing land-use land cover changes bringing in a loss of vegetation cover. An understanding in the existing types of street vegetation would help us in developing a roadmap for the development of the urban forest especially the street trees to maximize the benefits they give. This study assessed the distribution, densities, composition, and the diversity of tree species in neighborhood street trees within the urban area of metropolitan Visakhapatnam city, Andhra Pradesh.

The findings reveal an overwhelming species composition of 86 species and 73 genus distributed across 32 families, dominated by indigenous and evergreen species. The most dominant tree species and family are Pongamia pinnata (L.) Pierre (10%) and Arecaceae (7%) respectively. The species similarity varied from 0.76 to 0.92. The species richness and diversity ranged from 38 to 49 and 2.88 to 3.33 respectively. The study is useful for policymakers, conservation researchers, forest managers and landscape designers, especially those who are involved in the management of urban street trees and city planning for future urban forest conservation and effective management.

Reference

Abreu-harbich, L. V. De, Labaki, L. C. and Matzarakis, A. (2012) 'Different trees and configuration as microclimate control strategy in Tropics', International conference on Urban Climates. Dublin Ireland: ICUC8, (August), pp. 8–11.

Angold, P. G., Sadler, J. P., Hill, M. O., Pullin, A., Rushton, S., Austin, K., Small, E., Wood, B., Wadsworth, R., Sanderson, R., & Thompson, K. (2006). Biodiversity of urban habitat patches. Science of the Total Environment, 360(1-3), pp.196-204.

Arne Sæbø a, Thorarinn Benedikz b, T. B. R. c (2003) 'Selection of trees for urban forestry in the Nordic countries', Urban Forestry & Urban Greening, 2 (2), pp. 14.

Arnold, H. F. (1980) Trees in urban design. Edited by Landscape Journal. uk: Van Nostrand Reinhold Co. Ltd.

Bingqian Ma1, Richard J. Hauer2, Hongxu Wei3, Andrew K. Koeser4, Ward Peterson5, Ken Simons6, Nilesh Timilsina2, L. P. W. and 1 (2020) 'An Assessment of Street Tree Diversity: Findings and Implications in the United States.', Urban Forestry & Urban Greening, 56, pp. 1–29.

Boyce, S. E. (2011) 'Cities and the Environment (CATE) It Takes A Stewardship Village : Is Community-Based Urban Tree Stewardship Effective ? It Takes A Stewardship Village : Is Community-Based Urban Tree Stewardship', Cities and the Environment (CATE), 3 (1).

Brito, V.V., & Borelli, S. (2020) 'Urban food forestry and its role to increase food security: A Brazilian overview and its potentialities', Urban Forestry and Urban Greening. Elsevier GmbH, 56 (March), pp. 126835..

Campbell, Lindsay K , Sandberg, L.A, Bardekjian, A., Butt, S. (2007) 'Constructing New York City ' s Urban Forest The Politics and Governance of the MillionTreesNYC Campaign', Urban Forest, Trees and Green Space, p. chapter 16.

Clark, K. H. and Nicholas, K. A. (2013) 'Introducing urban food forestry: A multifunctional approach to increase food security and provide ecosystem services', Landscape Ecology, 28(9), pp. 1649–1669..

Faeth, S. H., Bang, C. and Saari, S. (2011) 'Urban biodiversity: Patterns and mechanisms', Annals of the New York Academy of Sciences, 1223(1), pp. 69–81.

Galle, Nadina J. Halpern, Dylan, Nitoslawski, Sophie, Duarte, Fábio, Ratti, Carlo.Pilla, Francesco. (2021) 'Mapping the diversity of street tree inventories across eight cities internationally using open data', Urban Forestry and Urban Greening, 61. doi: 10.1016/j.ufug.2021.127099

Hunter, I. R. (2001) 'What do people want from urban forestry ?— The European experience', Urban Ecosystems, 5, pp. 277–284.

Jason Grabosky Bassuk, Nina Irwin, Lynne Es, and Harold Van (2001) 'Shoot and Root Growth of Three Tree Species in', Department of Horticulture, Cornell University, Ithaca, NY 14853, 19(4), pp. 7.

Jim, C. Y. and Chen, W. Y. (2009) 'Diversity and distribution of landscape trees in the compact Asian city of Taipei', Applied Geography. Elsevier Ltd, 29(4), pp. 577–587.

Jim, C. Y. and Liu, H. T. (2001) 'Species diversity of three major urban forest types in Guangzhou City , China', 146.

Khesoh, P. and Kumar, H. (2017) 'Species diversity and community structure of trees and shrubs of Japfü mountain, Kohima: Nagaland', International Journal of Forestry and Crop Improvement, 8(2), pp. 97–105.

Killicoat P, Puzio E., S. R. (2002) 'The economic value of trees in urban areas: estimating the benefits of adelaide's street trees', School of Economics and Centre for International Economic Studies, University of Adelaide Introduction, (September), pp. 107.

Kohli, R. K., Singh, H. R., Sharma, A. and Batish, D. R. (1996) 'Panorama of trees in India in Eco friendly trees for urban beautification. Solan, India.', Indian Society of Tree Scientists and National Horticultural Board, 1(1), pp. 1–69.

Konijnendijk C.C, Robert M. Ricard, Andy Kenney, Thomas B. Randrup(2006) 'Defining urban forestry – A comparative perspective of North America and Europe',Urban

Forestry & Urban Greening, 4(3-4), pp. 93-103..

Kuhns, M. R. (2009) 'Are Native Trees Always the Best Choices?', in. Seeds of Change, TreeUtah Newsletter.

L. Anders Sandberg, Adrina Bardekjian, S. B. (2014) Urban Forests, Trees, and Greenspace A Political Ecology Perspective. 1st Edition. London.

Lai, D., Liu, W., Gan, T., Liu, K., & Chen, Q. (2019) A review of mitigating strategies to improve the thermal environment and thermal comfort in urban outdoor spaces. Science of the Total Environment, 661, pp.337-353.

Lu, J.W., Svendsen, E., Campbell, L.K., Greenfeld, J., Braden, J., King, K.L., & Falxa-Raymond, N. (2010). Biological, social, and urban design factors affecting young street tree mortality in New York City. Cities and the Environment, 3(1) pp. 1-15

M.D. Steven, P.V. Biscoe, K.W. Jaggard, J. P. (1986) 'Foliage Cover And Radiation Interception', Field Crops Research, 13, pp.75-87.

Magnusson, WE & Mourao, G. (2009) 'Statistics without Math, Editora Planta, Londrina.', journal of the international biometric society, (March), pp. 302–312.

Manatsa, D., Chingombe, W. and Matarira, C. H. (2008) 'The impact of the positive Indian Ocean dipole on Zimbabwe droughts Tropical climate is understood to be dominated by', International Journal of Climatology, 2029(March 2008), pp. 2011–2029.

McIntyre, S. and Hobbs, R. (1999) 'A framework for conceptualizing human effects on landscapes and its relevance to management and research models', Conservation Biology, 13(6), pp. 1282–1292..

McKinney, M. L. (2006) 'Urbanization as a major cause of biotic homogenization', Biological Conservation, 127(3), pp. 247–260.

McPherson & Rowntree (1989) 'Using Structural Measures to Compare'.

Mcpherson, E. G. and Simpson, J. R. (2003) 'Potential energy savings in buildings by an urban tree planting programme in California', Urban Forestry & Urban Greening, 2(2), pp. 73–86.

Mullaney, J., Lucke, T. and Trueman, S. J. (2015) 'A review of benefits and challenges in growing street trees in paved urban environments', Landscape and Urban Planning. Elsevier B.V., 134, pp. 157–166.

Nagendra, H. and Gopal, D. (2010) 'Street trees in Bangalore: Density, diversity, composition and distribution', Urban Forestry and Urban Greening. Elsevier, 9(2), pp. 129–137.

Nowak, D. J., Crane, D. E. and Stevens, J. C. (2006) 'Air pollution removal by urban trees and shrubs in the United States', Urban Forestry and Urban Greening, 4 (3–4), pp. 115–123.

O'Brien, L., Williams, K. and Stewart, A. (2010) 'Urban health and health inequalities and the role of urban forestry in Britain: A review', Forest Research, pp. 94.

Pincetl, S. (2015) 'Cities as novel biomes: Recognizing urban ecosystem services as anthropogenic', Frontiers in Ecology and Evolution, 3 (DEC), pp. 1–5.

Prakash, L., Ramarajan, S. and Manikandan, P. (2020) 'Avenue trees of urban landscape Tiruppur City, Tamil Nadu', Indian Forester, 146(7), pp. 642.

R.W. Day (1991) 'Damage of structures due to tree roots', Journal of Performance of Constructed Facilities., 5 (3).

Reddy, C. S. (2008) 'Biological invasion - Global terror', Current Science, 94(10), p. 1235.

Robert W. Miller, Richard J. Hauer, L. P. W. (2015a) ‘Planning and Managing Urban Greenspaces’, Waveland Press, Inc.Publisher of college-level textbooks and supplements, 3, pp. 560.

Robert W. Miller, Richard J. Hauer, L. P. W. (2015b) ‘Urban Forestry Planning and Managing Urban Greenspaces’, Waveland Press, Inc., Long Grove (Illinois), 2015, Third Edit (13), pp. XVI, 560 p. : ill.; 24 cm.

Ruper, R. (2017) ‘Landscape and Urban Planning Evaluations of landscape preference , complexity , and coherence for designed digital landscape models’, Landscape and Urban Planning. Elsevier B.V., 157, pp. 407–421.

SalbitanoF, BorelliS, Conigliaro M., C. (2016) Guidelines on Urban and Peri-Urban Forestry, Fao.

Schroeder, H. W. and Anderson, L. M. (1984) ‘Perception of Personal Safety in Urban Recreation Sites’, Journal of Leisure Research, 16 (2), pp. 178–194.

Shashua-Bar L, Potchter O, Bitan A, Boltansky D, Yaakov Y. (2009)' Microclimate modelling of street tree species effects within the varied urban morphology in the Mediterranean city of Tel Aviv, Israel'. International journal of Climatology. 30(1) pp. 44–57.

Sun, W. Q. and Bassuk, N. L. (1991) ‘Approach to determine effective sampling size for urban street tree survey’, Landscape and Urban Planning, 20 (4), pp. 277–283.

Thaiutsa, B., L. Puangchit, R. Kjelgren, and W. Arunpraparut. (2008.) Urban green space, street tree and heritage large tree assessment in Bangkok, Thailand. Urban Forestry Urban Greening 7(3) pp.:219-229.

Udayakumar, M., Ayyanar, M. and Sekar, T. (2010) ‘Herbal medicines used by the local traditional healers in Villupuram district of Tamil Nadu, Southern India’, Medicinal Plants - International Journal of Phytomedicines and Related Industries, 2(2), pp. 145–155.

Wager & Baker (1983) ‘Tree Root Damage to Sidewalks and Curbs’, Arboriculture & Urban Forestry..

Westendorff, V. E. (2020) ‘Role of trees in mitigating urban heat island in Charlotte, North Carolina, USA’, WIT Transactions on Ecology and the Environment, 245 (2020-July), pp. 73–83..

White, M., Kimm, G. and Langenheim, N. (2017) ‘Pedestrian Access Modelling with Tree Shade - Won’t Someone Think of the Children’, Procedia Engineering. Elsevier B.V., 198 (September 2016), pp. 139–151.