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EXPLORING THE STREET TREE DIVERSITY, DENSITY, COMPOSITION, AND SHADE IN URBAN RESIDENTIAL AREAS OF VISAKHAPATNAM.

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ABSTRACT

Street trees form an essential part of green infrastructure which contributes to the resilience of the city. Stewardship and stake holder preferences are one of the factors in 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 is taken to compare and assess for diversity, density, composition, and distribution along with the shade analysis across the six zones of the city of Visakhapatnam, India. A total stem count of 1896 trees accounting to 83 species, 73genus and 25 families are recorded across the selected neighborhoods. The diversity is rated high when evaluated against the Shannon index and 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 metre 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 is 60-40% respectively. As the neighborhood character keeps changing with re-densification, there are frequent replacement of trees resulting in younger trees accounting for more percentage as against old trees. The recent plantation drives also replace them with 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 become indicators for evolving a framework and enable better practices.

Keywords: Street Trees, Diversity, Density, Composition Distribution and Neighborhoods

INTRODUCTION

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. (Cities4Forests, miller et al.,2015). Urban forests can contribute to 9SDGS – create employment (SDG1), food security (SDG2), good health and wellbeing (SDG3), regulation of hydrological cycles (SDG6), renewable energy source (SDG7), economic growth (SDG8), liveability (SDG11), climate change mitigation (SDG13) and biodiversity conservation and land restoration (SDG15) (Salbitano et al., 2016). The cities across the world are emphasizing on the green programs given the enormous benefits they receive. The introduction of soft natural assets into the hard cityscape would provide an urban biome which can provide ecosystem services (Pincetl, S., 2015).

Street trees form a crucial part of the urban forest. They provide environmental, ecological, social, and economic benefits. Urban environments create challenges for growing trees and trees pose problems for urban infrastructure and maintenance (J Mullaney et al., 2015). Trees provide shade reducing exposure to sun and increasing walkability (M. White et al.). They filter dust, absorb carbon dioxide, reduce temperature, removes air pollutants, and absorb noise (David J. Nowak, 2000). Urban heat island a complex phenomenon arising out of urban development and activities - Built form, mobility and materials all contributing to the affected can be ameliorated and mitigated through trees and the canopy to a great extent (Schwaab, J., 2021, Ve Westendorf., 2020). Trees create a cooling effect due to evapotranspiration and shading which effects the microclimate (L. Shashua-Bar et all. 2009). The tree size, canopy, and the tree density in a street relates to the cooling effect. 80% of the cooling effect is created by the shade and as much as 5-20degrees change is noticed due to the presence of trees (Killicoat, Puzio & Stringer, 2002; Burden, 2006). All these contribute towards outdoor thermal comfort which increases the liveability at street level.

Street trees form the Urban green ways which become habitats and contribute to the movement of fauna as wildlife corridors. (P G 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 & Saari, 2001). Trees could also provide for food, a goal contributing towards food security (Britto et al, 2020). Presence of trees presents a wide- ranging health benefit- from physical health to mental health. Increasing social cohesion, safety, and community interaction (O'Brien, 2010). 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, and habitat and landscape connectivity for urban fauna (J Mullaney et al., 2015). Social benefits include sense of community and safety, and reduced rate of crime.

There are many ways in which trees do disservice to the urban environments – leaf fall and the litter of fruit and flower not only cause unpleasant surroundings but also clog the drainage. The tree roots damage the pavements, kerbs and drains by uplifting and crack 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 certain research suggests planting smaller tree species and increasing planting distance from the pavement can help in decreasing the damage. (Wager & Baker, 1983).

Urban environments can be exceedingly difficult for tree growth. The conflicting nature of needs wherein tree need porous soil whereas the subsurface of movement be it pedestrian or vehicular needs compaction makes it difficult for the tree survival(Grabosky, Bassuk, Irwin, &Van Es, 1998b).There is a lot of vandalism on trees, heavy dust settling on the leaves making it difficult for the functioning, pollution and in countries where there is snow, salt is used for de- icing all of which make it difficult for the tree health (Blunt, 2008; Lu et al.,2010). For the establishment of tree, its health and successful survival stewardship plays a vital role. (Boyce, 2010) despite the challenges there is a concerted effort in tree plantations because of the value it renders for urban life.

Tree diversity is one of the key factors in establishing a resilient and healthy urban forest. (Bingqian Ma., et al 2020) examples of urban forest with monocultures getting infested with pest cost dearly to the 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. 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).

Tree features such as tree height, green coverage, shape, and permeability of the crown can influence the visual and landscape character, and their effects on neighborhood environment could be observed through simulation. Some studies confirm that specific plant species features, such as tree canopy structure and density, leaf size, shape, and color, tree age and growth, can influence the performance of solar radiation attenuated by canopy, air temperature, and air humidity (Abreu-harbich, Labaki, & Matzarakis, 2012; B; Shashua-Bar, Pearlmutter, & Erell, 2009).Because of solar radiation reflection, transmission, and absorption, tree canopies may adapt to microclimatic conditions and regulate wind speed (Steven, Biscoe, Jaggard, & Paruntu, 1986). The form and density of the canopy influence the amount of shadow cast by trees as well as the amount of radiation filtered. The amount of radiation intercepted is determined by the density of the twigs, branches, and leaf cover. These elements have an impact on the overall form and density of trees (Abreu-harbich et al., 2012).

Mcpherson & Simpson, (2003) defined 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.). (Henry F. 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 visual disorder, and Arnold goes as far as to claim that people do not prefer planting schemes that include a diversity of tree species. (Sæbø, Benedikz, & Randrup, 2003) identified biotic and abiotic factors which have significant impacts on tree structure in urban streets. In this context, (Kuper, 2017) employed digital composition models for trees on streets and in parks, with different species diversity (complexity) and plant distribution (coherence). Therefore, he 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.

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 make a clear and concise appreciation of tree species suitability for a particular urban environment and for future recommendations on planting. Based upon these presumptions, this study was to evaluate the existing status of urban street tree planting in the city. This work is therefore a baseline for research into the planting structure in the residential pockets of Visakhapatnam City, Andhra Pradesh. The objective if 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.

MATERIALS AND METHODOLOGY

The Methodology for data collection of this study is based on qualitative and quantitative data collection from physical environment of the site, local community, and official authorities. The major data collection is through the primary survey. Six sample neighborhood units are selected within six different administrative zones of Greater Visakhapatnam Municipal Corporation (GVMC). In this tree inventory contained only street trees and the tree inventory of geo tagged data with the location type. Distance between trees was calculated using latitude and longitude information gathered for each surveyed tree by using a Mobile device. In general, geographic positioning attempts to show the "real" position but due to satellite availability and other potential problems the position is mostly given with an accuracy value. During my data collection I attempted to gain GPS accuracy values less than 1 meters Tree inventories were imported from various geospatial or comma separated values (CSV) file formats to Arc GIS shape files for 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, total number of trees was calculated per 100m length both for main and link roads. After identification, the list of the species was recorded and categorized into alien for introduced tree species and indigenous for trees native to India.

Tree Species Diversity

Preliminary data analyses (descriptive statistics) were conducted using Microsoft Excel 2010. All inventories used were conducted using field surveys and had information at the species- genus-level, and 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 that of 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, 1992). The Simpson's Index of Diversity represents the probability of two individuals belonging to the same species when drawn randomly from a sample (Magnusson, WE & Mourao, G. (2004)). 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 transects.

Shannon's Index (H'):

We apply the Shannon diversity index (H') as a measure of species abundance and richness to quantify diversity of the Tree species. Shannon's Index for diversity is calculated based on the abundance value of 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

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

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

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

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

Study Area

This study is conducted in Visakhapatnam Metropolitan City, which is one of the largest cities in Andhra Pradesh state and 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 (Figure 1). The total Geographical area of the reconstituted Greater Visakhapatnam Municipal Corporation is 540 sq. Km with a population of with a population of 17.3 lakh (Census 2011) and there are 72 wards distributed in six zones.

Six sample neighborhood clusters are selected from each representative zone as highlighted in Figure 2. We obtained inventories of urban trees in the neighborhood sample units mostly plotted developments executed by the urban development authority, 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 fairly represent the overall vegetation conditions of the city, tree density, diversity, and distribution. The areas of these colonies ranged from15- 20 Acres. All 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 are in the residential neighborhoods were analyzed for further insights. Data was collected through primary field studies involving, counting, and identifying the trees which are more than 3m are marked and the species identified. Trees that occur between the property lines and the right of way are taken into consideration

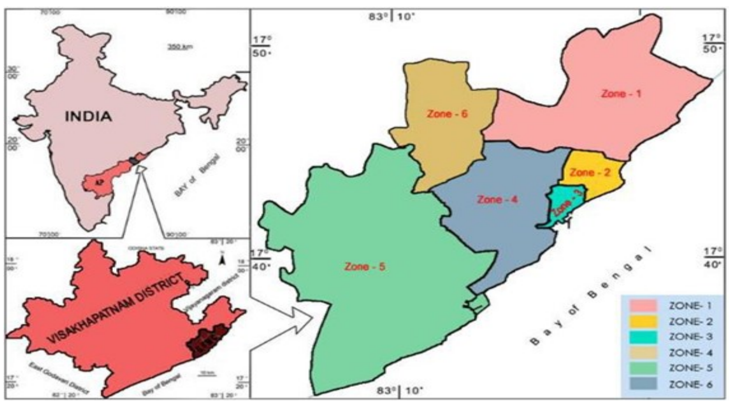


Figure 1: Location of Study Area Within the GVMC Limits

Figure 2: Location of Selected Neighborhoods

RESULTS

The study includes a total of 1896 trees accounting to 83species,73genus and 25families 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 count of 320 with 38 species and 26 families. Pongamia pinnata, Albizia saman, and

Azadirachta Indica accounts to around 40% of the stem count. They are large trees planted by municipal managers at the time of making the layout. Alstonia scholaris, milingtonia and terminalia mentalis which account to 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, fruit bearing trees. There are naturalised trees which are small and not planted but the residents let them grow like Annona Squamosa and Psidium. East Point Colony (zone 2) residential plotted development is part of city where there is change towards densification of the plots where in individual houses mostly have converted into multi- dwelling units. The stem count is 230 but accounts to 43 species. The adjacent land uses in this layout was institutional which could be the reason large trees were retained. The process of re-densification usually leads to loss of many trees. So, the placement of tree in relation to the property line might help in protecting trees and increase their lifetime. Peltaphorum accounts to 32% of the total tree population Mimusops elengi, Thespesia, milingtonia and termilinia cattappa accounted to 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: Researcher, 2022

No	Name of the Residential Colony	Area (acre)	No. of Species	No. of Genus	No, of Families	No. of Trees
1	Midhilapuri	20	38	34	24	344
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

Official colony (zone 3) is a plotted layout in old town area primarily residential area with ground +four floors with apartment culture. This layout had the lowest stem count which is 161 with 36 species and 20 families. **Madhavadhara (zone 4)** This site has the highest number of street trees recorded in the survey and in its majority are placed along streets with a variety of size. 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 %). Tecoma and Nyctanthes both are small flowering plants. **Pedagantyada (zone 5)** Among the recorded most dominated species, 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 (zone 6)** A total of 356 trees belonging to 43 species from 23 families are recorded within a sampled area. Mangifera indica L. is predominant at all roads (15%), followed by Psidium guajava L. (12%), Pongamia pinnata (9%) and Parkia biglandulosa.

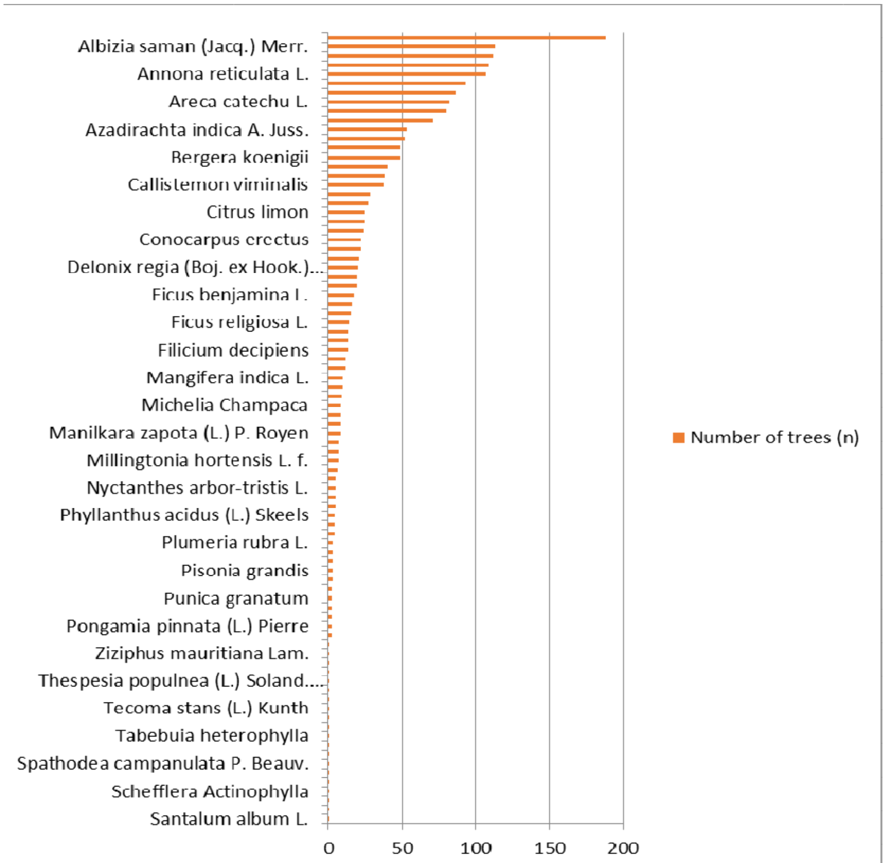


Figure 3: Tree Species Abundance. Source: Researcher, 2022.

Pongamia pinnata (L.) Pierre is predominant at all roads (10%), followed by Peltophorum pterocarpum (DC.) (6%), Mimusops elengi L. (6%), Azadirachta indica A. Juss. (6%), Psidium guajava L. (6%), Mangifera indica L. (5%), Annona squamosa L. (5%), Tecoma stans (L.) Kunth (4%), Senna siamea (Lam.) H.S. (4%), Nyctanthes arbor-tristis L. (4%), Cocos nucifera L. (3%) and Alstonia scholaris (L.) R. Br (3%).

In terms of origin of species, 60% of the trees belonged to native species, while only 40% of the trees belong to exotic species. Of the 87 species countered, 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 in occasional, 30 (35%) species are in common, and 24 (28%) species are in rare.

Out of the total tree species present near 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 six neighbourhood areas, Data in bold indicates the most abundant species, genus, or family that met the proposed 10/20/30 benchmark. Source: Researcher, 2022.

Neighbourhood name	Area (acre)	Tree Count (n)	Most Abundant Species (%, Name)		Most Abundant Genus (%, Name)		Most Abundant Family (%, Name)	
Midhilapuri Vuda Colony	20	344	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 is indicated 10/20/30 percentage as species/genera/family to have a healthy forest. which 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 city of Portland, Oregon. But the study does not meet this criterion. Replacements of trees when done need take the diversity formula into consideration. Tree palettes need to develop for the choice of the citizens and nurseries that have the species available as per 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 total tree count, none of the neighbourhoods met the 5/10/ 15 benchmark, but 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 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 proposed benchmarks at the species -level (10 %).

Table 3: Diversity of Street Trees Between and within Study area: Source: Researcher, 2022.

S.No	Neighbourhood Name	Number of Street Trees	Species Richness per Neighbourhoo 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

The diversity is high in Madhavadhara Neighbourhood study area with 462 species, followed by Simhapuri vuda colony, Midhilapuri vuda colony and Pedagantyada Neighbourhood areas (as in Table 3). The same is reflected through the dominance index (Simpson) where high diversity is in Official colony followed by Madhavadhara Neighbourhood area and Pedagantyada Neighbourhood areas. While as per the Shannon index that considers even rare species, highly diverse stratum is road followed by institutions and parks and garden (Table 3). Thus, Madhavadhara Neighbourhood study area is significantly diverse based on both Shannon and Simpson index, followed by Official colony. East point colony on the other side is low in diversity with lower evenness and high variation in abundance of species. Considering the sample sizes of both sample neighbourhoods are same. While Official colony study area has high degree of evenness where all species are equally common with extremely low variation in abundance followed by Madhavadhara and Pedagantyada Neighbourhood areas. Species richness (S) varied among urban neighbourhood 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. ("1. Simpson's Diversity Index Simpson's index (D) is a | Chegg.com") As species richness and evenness increase, so diversity increases. The value of D ranges between 0 and 1. ("Simpson's Diversity Index - geography fieldwork") When examined against the Simpson's index for the stem counts values ranging from .04 to

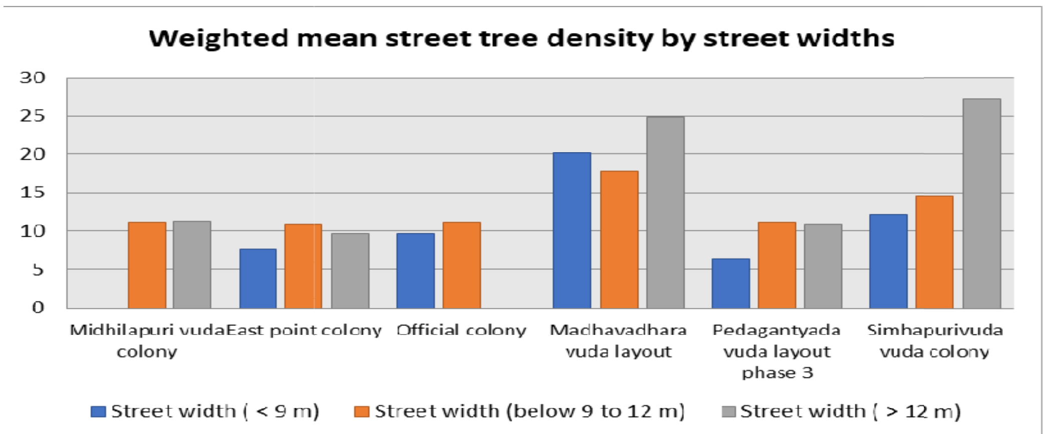
.12 indicating high diversity.

Data were collected from the entire main and local transects of 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 official colony (Table 4).

Table 4: Summarizes Differences in Tree Density Across both Road Categories.

S.No	Name of the residential Colony	No of Transects	Total Road Length	Total Road Area	No. of Street Trees	Density of Tree 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%

While differences in tree densities are not significant between neighborhoods, the number of trees in each 100 m transect of main roads was more than that of local roads. Overall, there was a significant difference in tree density between neighborhoods. The density was high in Madhavadhara Neighborhood area with 20.33 trees per 100m transect, followed by Simhapuri vuda colony (18.93) and Midhilapuri vuda colony (11.12) (as in Table 4).



When compared to the stem count as against the shading percentage in the old settlement of official colony is equal to the Midhilapuri layout where the stem count is double. Indicating that the size and canopy need to be considered while planting decisions. Planting of smaller trees with flowering like Tecoma stans and Nyctanthes arbortistis, are in abundance in newer settlements where the people took decisions. Naturalized trees like Psidium guajava and Annona squamosa are retained for their fruiting nature. Certain trees like Aegle marmelos are seen in abundance in localities where there is a temple indicating their value in religious rituals. Tall trees like Pongamia pinnata Pierre Peltophorum pterocarpum, Mimusops elengi, Azadirachta indica, which were planted 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 being favored for their fast-growing and flowering nature.

CONCLUSION

An analysis of the neighbourhoods revealed a certain similarity. Visakhapatnam a tier II city and a port city in India which is rapidly growing and there are land-use land cover changes bringing in a loss in vegetative cover. An understanding in the existing type of street vegetation would help us in developing a roadmap for development of urban forest esp. street trees to maximize the benefits they give. The streets categorized as <9m 9-12m and >12m had conspicuous differences. Trees on >12m had large trees and old trees 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 are growing natural. There is no attempt to remove them, this can be interpreted that the citizens are not averse to trees, and they let them grow. The densification process of the neighborhood also seems to add to the reduction of large trees as there is growing trend of beautifying it with hedges and small trees. Further studies dwelling into the preferences of the neighborhoods would give a direction and attitude towards street trees citizens adopt which can also to lead developing a palette for everyone, as that would mean a better surviving urban forest.

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