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Urban Tree Structure and Characteristics in Two Transport Corridor Case Studies in Sydney, Australia

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Abstract

This paper investigated urban tree structure and characteristics in two main transport corridors case studies, the Pacific Highway and the Parramatta Road in Sydney, Australia. In these case studies, the parameters explored were tree distribution, composition, canopy cover, land use-based tree densities, DBHs, ground land cover, and oxygen production potential of urban trees. Pacific Highway had 40.3% tree canopy cover with an estimated 30,500 trees, while the same on the Parramatta Road had 9,580 trees with 14.2% tree canopy cover. Two case studies had shown significant variations in land use patterns and others. Raising awareness of the community and incentives and support from the government and other organisations are essential for understanding the importance of urban trees.

Keywords: Urban greening; Tree canopy; Tree species; Tree composition; Green infrastructure; Sustainability

Abbreviations: NGIA: Nursery Gardens Industry Australia; HAL: Horticulture Australia Limited; DBH: Diameter at Breast Height; GIS: Geographic Information Systems; LGAs: Local Government Areas; AOI: Areas of Interest; CRBM: Commercial, Retail, Business and Mixed uses; IRO: Recreation, and Institutional and Other; GIS: Geographic Information Systems; IV: Importance values; HREC: Human Research Ethics Committee

Introduction and Context

Trees provide environmental and ecological benefits of carbon storage and sequestration, air pollution reduction, biodiversity protection, rainfall interception, urban heat island mitigation, and building energy savings through shading and oxygen production [1-5]. Urban trees offer visually pleasing views; assist in improving public health, including mental health; create liveable environments; increase property values and support the cultural heritage and identity of communities [4, 6-10].

This research was a part of a larger collaborative research project with several Australian universities and Nursery Gardens Industry Australia (NGIA) and was funded by Horticulture Australia Limited (HAL) (currently HortInnovation Australia), Australian Government. This research estimated the environmental benefits of carbon sequestration, carbon storage, and air pollution and associated economic benefits in two main transport arteries, the Pacific Highway and the Parramatta Road in Sydney, Australia. This part of the research had already been published as a separate publication. The research in this article built on this publication and presented a different set of tree data that had not been published before. The main aims of this part of the research in this article were to estimate tree structure, characteristics and composition, and tree canopy cover in selected sections of two transport corridors in Sydney. The key objectives of this research were to identify the tree species, diameter at breast height (DBH), distribution of the tree species in the case studies in different land uses, and growing conditions determined by the land cover patterns. The analysis was conducted using Geographic Information Systems (GIS) methods to measure land use distributions and 'iTree Eco' software to quantify the structure and functions of urban forests. The following sections provide details of the methodology of this research.

Research Methodology

Pacific Highway and Parramatta Road, two main transport corridors of Sydney, were selected as case studies. Selection criteria were that the two roads are important transport corridors in Sydney, had mixed land use patterns vary along these roads, had varied environments for the trees and had been adopted for urban renewal corridor development (New South Wales Government, 2014). The Pacific Highway case study was 19 kilometres in length, while the Parramatta Road case study was 11 kilometres and both the case studies lay across several Local Government Areas (LGAs). The selected transport corridors are shown in Figure 1.

Figure 1: Pacific Highway and Parramatta Road corridors selected as case studies in Sydney.

'i-Tree Eco' software developed by USDA was applied in this research as it can calculate tree characteristics such as urban forest structure, tree composition such as species, and age and tree density. A plot-based sample inventory method of assessment was adopted for this study following the i-Tree Eco v5.0 protocol [11]. Areas of Interest (AOI) included 200 meters wide area on either side of Pacific Highway and Parramatta Road, which was determined using GIS methods. Ethics approval was obtained from the University Human Research Ethics Committee (HREC) prior to conducting the fieldwork. The most suitable approach for this research, 'pre-stratification by land use', was conducted using GIS analysis. Different land uses were consolidated and pre-stratified into three categories: residential, commercial, retail, business, and Mixed uses (CRBM), recreation, and Institutional and Other (IRO).

Sample plots were generated by a random sampling method, and 61 plots for the Pacific Highway and 30 plots for Parramatta Road were sampled [12]. Field work for data collection was conducted following i-Tree Eco protocols (USDA Forest Service et al., 2022). A total of 332 trees across 91 plots along the two corridors were surveyed. Along the Pacific Highway, a total of 250 trees and 82 trees on Parramatta Road were recorded. Individual tree was documented in detail using photographs, and tree specimen samples were collected (e.g, leaves, branches, barks, fruits, and flowers) from all the trees on the sample plots. The tree species were identified by the Royal Botanic Garden Sydney.

Outcomes and Discussion

Tree canopy cover and tree densities

Land use is an important determinant of tree density in an urban area. Land use distribution total site of 287 ha of Pacific Highway included Commercial, Retail, Business and Mixed uses (CRBM) (50.6ha, 17.6%), IRO (Institution, Recreation, and other uses) (68.3ha, 23.8%), and Residential (168.1ha, 58.6%). The total site of 138 ha on Parramatta Road, included CRBM (71.1ha, 51.7%), IRO (44.8ha, 32.5%), and Residential (21.7ha, 15.8%) [3]. On the Pacific Highway and Parramatta Road, a total of 81 and 28 different tree species, respectively were documented. The overall tree density on the Pacific Highway with 106 trees per hectare which was considerably higher than that on the Parramatta Road at 70 trees per hectare [3]. IRO land use had the highest values of tree densities on Pacific Highway, with 112 trees per hectare, and on Parramatta Road, IRO had 93 trees per hectare. The recreational and institutional land uses, such as churches, schools, and parks have opportunities for having more trees as they have open spaces within the site area. This study established that this land use contained higher numbers of trees. The tree density of residential land use on Parramatta Road, with 45 trees per hectare, was the lowest compared to the other two land use categories, IRO and CBRM [3]. A comparison of tree densities is presented in Table 1.

Tree characteristics, distribution, and composition

The urban forest on the Pacific Highway was estimated to contain 30,500 trees with a tree canopy cover of 40.3% of the total site of 287 hectares. The three most common species are Queen palm (10.6%), Camellia (9.8%), and Sydney blue gum (9.2%). The urban trees on Parramatta Road were estimated to have 9,580 trees with a tree canopy cover of 19.4 hectares or 14.2% of the total site of 138 hectares. The three most common species on the Parramatta Road were grey ironbark (14.0%), Weeping

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bottlebrush (9.8%), and Australian tallowwood (9.7%) (Figure 2). On Pacific Highway, trees with DBH less than 6-inches (15.2 cm) constituted 0.5 % of the population. 52% of trees had DBH ranging from 76.3 cm to 83.8 cm or more. This signified that Pacific Highway had mature trees. In the other nine DBH ranges, the percentages of tree DBH varied from 1% to 9% (Figure 3).

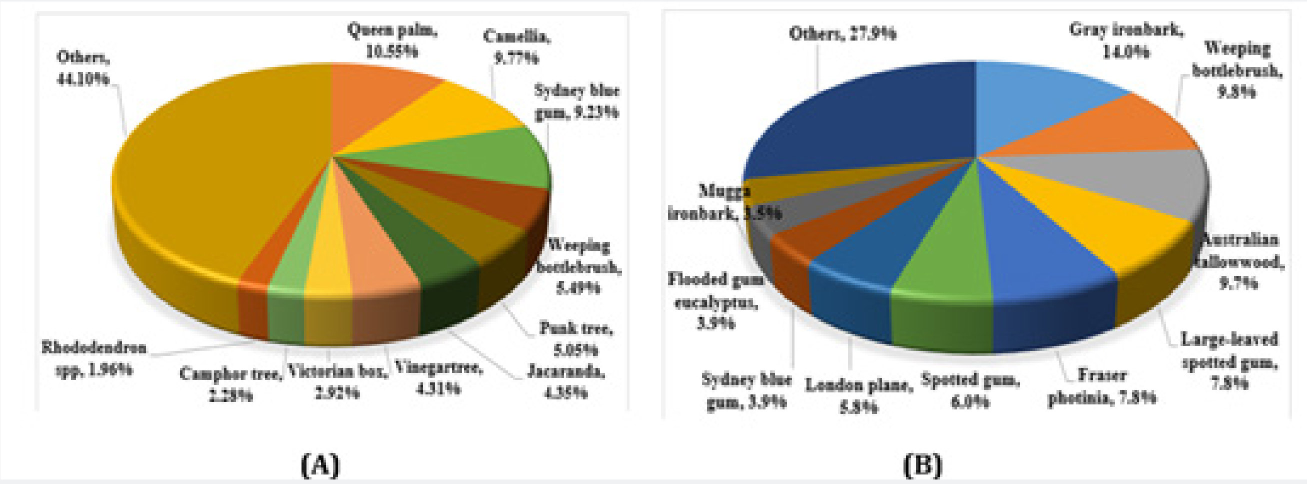

Figure 2: Tree species distribution in (A) Pacific Highway (B) Parramatta.

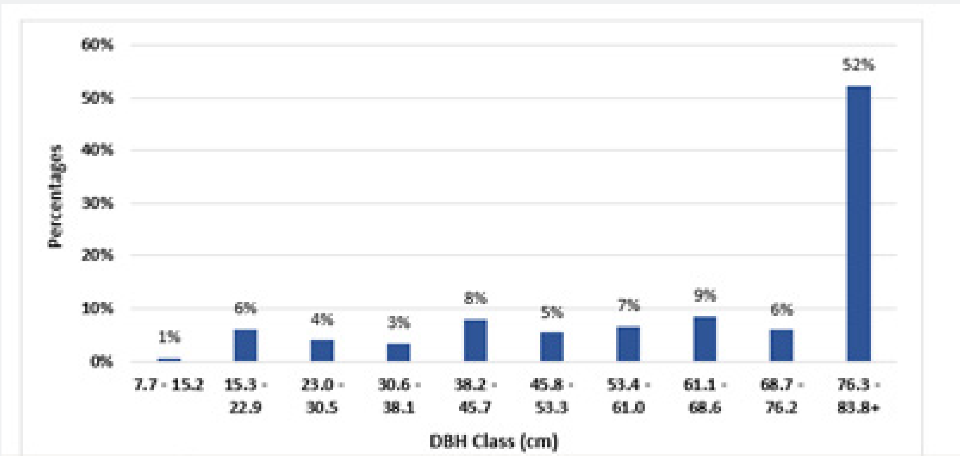

Figure 3: Percentages of tree population by diameter class in Pacific Highway.
(Note: DBH= stem diameter at 1.37 metre height from the base).

Table 1: Tree canopy cover, tree densities, and land use-based distribution.

<table>
<tr><th></th><th>Pacific Highway</th><th colspan="2">Parramatta Road</th></tr>
<tr><td>Total land area (hectares) of the selected case studys</td><td>287</td><td colspan="2">138</td></tr>
<tr><td>Total number of trees</td><td>30500</td><td colspan="2">9580</td></tr>
<tr><td>Total tree canopy cover as a percentage of total land area (%)</td><td>40.30%</td><td colspan="2">14.20%</td></tr>
<tr><td>Total oxygen production (metric tons per year)</td><td>2120</td><td colspan="2">1060</td></tr>
<tr><td>Rate of oxygen production (metric tons per hectare per year)</td><td>7.4</td><td colspan="2">7.7</td></tr>
<tr><td rowspan="4">Tree density based on land use (number of trees per hectare)</td><td>Commercial, Retail, Business and Mixed uses (CRBM)</td><td>88.9</td><td>62.7</td></tr>
<tr><td>Recreation, Institutional & Other (IRO)</td><td>112.5</td><td>92.5</td></tr>
<tr><td>Residential</td><td>108.9</td><td>45</td></tr>
<tr><td>Total</td><td>106.2</td><td>69.6</td></tr>
</table>

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On Parramatta Road, none of the trees had DBH less than 6-inches or 15.2 cm. 50% of trees had DBH ranging from 76.3 cm to 83.8 cm or more in Parramatta Road. In the other nine DBH ranges, the tree DBH percentages varied from 3% to 12% (Figure 4). The amount of healthy leaf surface area of a tree is an important indicator for measuring multiple tree benefits. Importance values (IV) are calculated as the sum of relative leaf area and relative composition. Tree canopy cover was 115.7 hectares 0r 40.3% of Pacific Highway, and shrubs covered 11%. In this case study, the three most dominant species in terms of leaf area are Sydney blue gum, Queen palm, and Sweetgum. On Parramatta Road, tree canopy covered 14.2%, and shrubs covered 4.8%. The three most dominant species in terms of leaf area are London plane, Spotted gum, and Australian tallowwood. The ten most important species on the Pacific Highway and Parramatta Road are presented in Table 2 & 3 respectively.

Table 2: Ten most important species on Pacific Highway.

Species Name	Tree Population (%)	Leaf Area (%)	Importance Value (IV)
Sydney blue gum	9.2	38.3	47.5
Queen palm	10.6	6.8	17.4
Camellia	9.8	1.3	11.1
Jacaranda	4.4	5.8	10.2
Vinegartree	4.3	5.5	9.8
Weeping bottlebrush	5.5	3.4	8.8
Sweetgum	1.7	6.7	8.3
Punk tree	5	2	7.1
Victorian box	2.9	1.4	4.3
Camphor tree	2.3	1.8	4.1

Table 3: Ten most important species on Parramatta Road.

Species Name	Tree Population (%)	Leaf Area (%)	Importance Value (IV)
London plane	5.8	21.9	27.7
Spotted gum	6	14	20
Australian tallowwood	9.7	9.9	19.6
Gray ironbark	14	3.7	17.8
Weeping bottlebrush	9.8	4.8	14.6
Large-leaved spotted gum	7.8	6.1	13.8
Sydney blue gum	3.9	4.8	8.7
Fraser photinia	7.8	0.5	8.3
Jacaranda	3.4	4.6	8.1
Flooded gum eucalyptus	3.9	3	6.9

Existing Ground cover impacting tree-growing conditions

On Pacific Highway, land cover types were tar (20.1%), cement (12.0%), buildings (22.8%), and grass (23.6%) and tar, cement, and building as impervious surfaces covered 55% of the total land area. On Parramatta Road, land cover types were tar (32.1%), cement (29.8%), buildings (11.1%) and grass (17.0%), and tar, cement and building covered 73% of the total land area. The higher proportion of impervious land cover on Parramatta Road was influenced by land use distributions and had impacts on the growing potential of urban trees. This explained why the tree density was lower and contained a smaller total number of trees on Parramatta Road. (Figure 5) presents land cover distributions in the Pacific Highway and Parramatta Road case studies.

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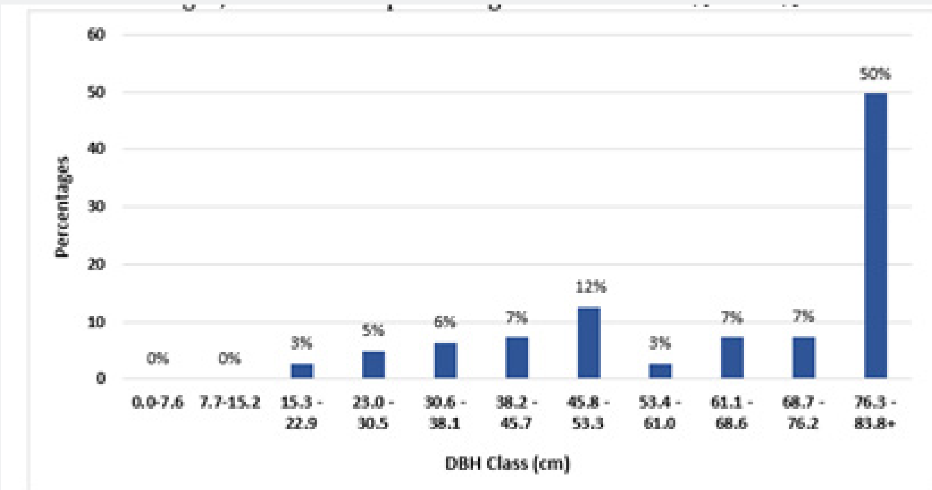

Figure 4: Percent of tree population by diameter class in Parramatta Road.
(Note: DBH= stem diameter at 1.37 metre height from the base).

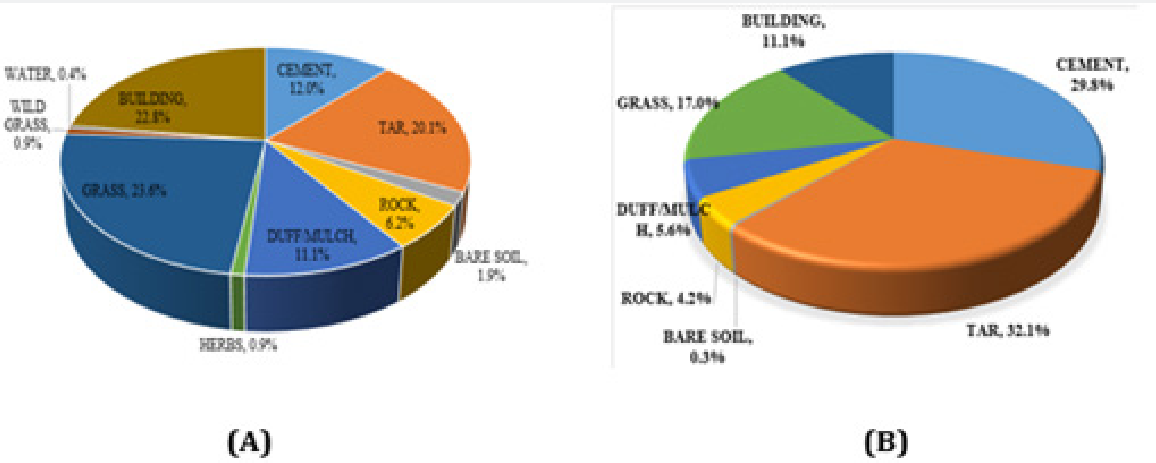

Figure 5: Ground Cover in (A) Pacific Highway (B) Parramatta.
(Source: Ghosh & Yung [3]).

Table 4: The top twenty oxygen-producing tree species on Pacific Highway.

Tree Species	Total oxygen (metric tons)	Number of trees	Leaf Area (square kilometres)
Camellia	250.45	2979	0.11
Punk tree	188.53	1539	0.17
Weeping bottlebrush	155.97	1672	0.28
Jacaranda	129.07	1326	0.48
Japanese maple	115.31	426	0.02
Victorian box	84.99	890	0.12
Chokeberry spp	67.31	213	0.05
Camellia spp	64	213	0.02
Rhododendron spp	62.27	596	0.04
Lagerstroemia spp	59.44	213	0.05

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Oxygen production

Oxygen production is one of the important benefits of urban trees. A tree's net annual oxygen production is directly related to the amount of carbon sequestered by the tree, which is tied to the accumulation of tree biomass. Trees on the Pacific Highway were estimated to produce 2120 metric tons and on Parramatta Road 1,060 metric tons of oxygen per year. (Table 4 & 5) present the twenty top oxygen-producing tree species on Pacific Highway and Parramatta Road, respectively.

Table 5: The top twenty oxygen-producing tree species on Parramatta Road.

Tree Species	Total oxygen (metric tons)	Number of trees	Leaf Area (square kilometres)
Large-leaved spotted gum	153.76	744	0.12
Weeping bottlebrush	144.69	937	0.1
Gray ironbark	135.57	1,343.00	0.07
Australian tallowwood	119.57	931	0.2
Mugga ironbark	49.84	336	0.02
Fraser photinia	48.16	744	0.01
Sydney blue gum	40.51	372	0.1
Southern mahogany	36.48	112	0.03
Beakpod euclayptus	35.89	124	0.04
Vinegartree	35.28	124	0.03

Urban trees were composed of a mix of native and exotic tree species. Thus, urban forests often have a tree diversity higher than surrounding native landscapes. Increased tree diversity can minimise the overall impact or destruction by a species-specific insect or disease, but it can also pose a risk to native plants if some of the exotic species are invasive plants that can potentially out-compete and displace native species. On the Pacific Highway, about 36% of the trees were from species native to Australia. Most exotic tree species had an origin in Asia (21%). On Parramatta Road, about 75% of the trees were from species native to Australia. Most exotic tree species had an origin in Asia (11.2%). This comparison between the two case studies established that tree species composition is shaped by people's preferences and land use patterns.

Barriers to data collection through fieldwork in the two Sydney case studies included obtaining written consent before accessing trees on private properties, and the process was time-consuming and challenging. In some cases, owners refused to grant permissions, some plots required multiple approvals, and a small number of trees already had tree removal approval from the council at the time of the field survey [3]. Socio-economic conditions, lifestyle choices, and awareness of the resident community, business, and landowners had influenced tree species choices and the protection and maintenance of trees over a longer term. A higher percentage of residential land use on Pacific Highway supported a better tree canopy cover [3].

The benefits depended on the tree characteristics, tree health, and existing tree canopy cover and its future potential for maintaining and increasing the urban tree canopy through appropriate government initiatives and incentives and collaborative efforts of the community and other stakeholders. Future research should explore to identify suitable tree species that could grow well in these case studies while deciding on the objectives of meeting tree canopy goals through planting new trees. For the existing urban trees, new ways should be investigated in how the growing conditions could be effectively improved. A collaborative approach from the government, community and all stakeholders are essential to raising awareness about urban trees, the benefits the trees provide, and the need to protect urban trees.

Conclusions

This research presented tree characteristics and tree species composition, land use-based tree densities, DBHs, ground land cover patterns, and oxygen production potential of urban trees in two main transport corridor case studies in Sydney, Australia. It highlights the immense importance of growing conditions, the selection of new suitable tree species, species-specific % leaf area, and the Importance Values (IV) of different trees. This research provides a snapshot of the existing conditions of trees at a point in time and signifies the value of tree protection and maintenance.

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