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Quantifying Tree Canopy Gaps in Urban Forestry within University of Port Harcourt and Surrounding Communities

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ABSTRACT

Urban tree canopy gap plays a critical role in shaping the ecological health, climate resilience, and social well-being of cities. This study focuses on the quantification of tree canopy gaps within urban forests, specifically within the University of Port Harcourt and its surrounding communities. GPS was used to pick the location of urban trees in the study area. Random point sampling technique was used and the points were manually categorised to estimate the urban tree canopy cover. Data was collected from Landsat8 imageries using ArcGis10.4 Software for image classification of urban tree cover and its canopy area was computed in square meters. Canopy gaps were measured using spatial measurement tools in ArcGis 10.4 environment. Abuja campus had the highest number of trees (125) and total crown area (2230.785m2) while Omuoko had the least number of trees (22) and total crown area (134.645m2). The least canopy gap was observed in Abuja campus (11.9m) while the highest canopy gap was observed in Rumuekini community (234.43m). Fruit trees such as *Cocus nucifera, Mangnifera indica, Persea americana* were common in the surrounding communities within study area unlike other timber trees that are concentrated in the University environment alone. Neighborhoods with less tree cover often experience harsher environmental conditions, such as higher temperatures and lower air quality, emphasizing the need for equitable green space initiatives. Measuring the extent and distribution of canopy gaps, the study identifies areas lacking adequate tree cover, highlighting disparities in green space access and revealing socio-economic inequalities. The findings demonstrated that well-managed canopy gaps support biodiversity, promote plant regeneration, and contribute to environmental services, such as carbon sequestration and microclimate regulation. However, excessive or unmanaged gaps can lead to ecological instability, allowing invasive species to thrive and reducing carbon storage capacity. By quantifying canopy gaps, urban planners and policymakers can develop targeted strategies to enhance canopy cover.

Keywords: Canopy gaps, Communities, Spatial, Urban Forestry

INTRODUCTION

Urban Tree Canopy is the leafy, green, overhead cover from trees that community groups, residents, and local governments maintain in the landscape for beauty, shade, fruit production, wildlife habitat, energy conservation, storm water mitigation, and a host of public health and educational values. Urban greening provides a range of environmental and social benefits across several scales, from local to global (Dobbs et al., 2017). These benefits includes: cooling the neighborhoods they are located in, reducing urban heat islands (Elmes et al., 2017; Heidt & Neef, 2008), an increasing concern in cities due to climate change (Mitchell & Chakraborty, 2018). Trees in the city help to control stormwater, reducing the risk of flooding and the need to install costly “gray” infrastructure (Berland et al., 2017). Urban trees also improve urban air quality, removing pollution and particulate matter (Nowak et al., 2013).

Urban forests are now recognised as a key asset for maintaining liveable cities in the face of rapidly expanding populations and climate change (Endreny et al., 2017; Davies et al., 2011). Among urban foresters, arboriculturists, and others interested in urban tree health, it is often assumed that urban forests suffer significantly from the effects of urban sprawl. Bryant (2001), highlights the negative effects of building construction on individual trees, as well as the stress experienced by urban trees in general, especially those located in areas of increased population density. Changes in the urban forest are reflected by tree canopy loss, replacement of native by non-native species, replacement of established stands by pioneer species, or conversion of native stands to vegetation commonly found in populated areas. From the perspective of a medium-scale aerial photo image, natural forest stands become urban forest patches over time, with the size, shape or composition of these patches changing as urbanization proceeds.

One simple remedy for correcting tree canopy loss due to urban encroachment is to replant as many trees as possible after development has occurred. Many grassroots groups throughout the country promote such a remedy and are quick to point out the benefits of replanting trees, including lessening of the heat island effect, control of soil erosion, and improvement of air and water quality (Maco and McPherson, 2002). Urban Tree Canopy assessment provides a measure of a community's tree canopy cover as a percentage of the total land area and serves as a baseline for setting tree canopy goals and measuring progress. Communities assess their tree canopy to determine the extent of their tree resources at various scales or by location, ownership, neighborhood, watershed, zoning, or land use. A potentially useful tool for identifying canopy gaps at different spatial scales is remote sensing. The University of Port Harcourt and its surrounding environs represent a unique urban landscape where the interaction between urban development and natural ecosystems is evident. As urbanization continues to expand, there is a growing need to understand the dynamics of tree canopy gaps within this context and their implications for urban forest management. These gaps, defined as openings in the canopy cover caused by various factors such as tree mortality, storm damage, or human activities which can significantly influence the structure, function, and resilience of urban forests.

There is limited availability of data on tree canopy gaps within the study area, making it difficult to assess the extent and distribution of canopy openings accurately. There is a scarcity of quantitative information on the size, distribution, and spatial patterns of tree canopy gaps within Port Harcourt and its environs. Without accurate data, it is difficult to assess the magnitude of canopy gap formation and its implications for urban forest regeneration. Hence the study aims at quantifying tree canopy gaps in urban forest within the University of Port Harcourt and surrounding communities.

MATERIALS AND METHOD

Study area

This study was carried out at the University of Port Harcourt and surrounding communities. The study area is situated on Latitude 4.90794⁰ and 4.90809⁰N and longitude 6.92413⁰ and 6.92432⁰E in Obio/Akpor Local Government Area of Rivers State, Nigeria. The surrounding communities include Aluu (Omuokho), Alakahia, Choba and Rumuekine.

Sample and Sampling Techniques

Purposive sampling technique was used in selecting the communities in the study area. Reconnaissance survey was carried out in the study sites to access woody tree species composition and diversity so as to provide baseline data for the location in form of primary data.

Instrument for Data Collection

The instruments that were used for this study are Global Positioning System (GPS), measuring tape and Field note book for data collection.

Data Collection

GPS was used to pick the location of urban trees in the study area. Random point sampling technique was used in this study. The randomly sampled points was manually categorised to estimate the urban tree canopy cover.

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Data was collected from Landsat8 imageries using ArcGis10.4 Software for image classification of urban tree cover and its canopy area was computed in square meters. Canopy gaps were measured using spatial measurement tools in ArcGis 10.4 environment. Physical count of sprouting seedlings was counted

Data Analysis

The acquired landsat imageries was pre-processed and supervised classification was carried out on the False Color Composite using the Maximum Likelihood Classification Technique in ArcGis environment. Analysis of variance (CRD) was used to compare the canopy width across surrounding communities in the study area.

Crown Projection Area was computed for all sampled trees using the fomular

$CPA = \pi(CD^2)/4$. Eq. 1

Where

CPA: Crown Projection Area

CD: Crown Diameter

RESULTS

Tree canopy areas and the spatial distribution

The result shows that Abuja campus had the highest number of trees (125) and total crown area (2230.785m^2) compared to the number of trees and crown areas in the other location (Table 1). Higher canopy coverage was observed in built-up areas within the University compared to the surrounding communities where trees were limited to streets and private yards.

Table1: Urban tree canopy areas in the study area

Location	No. of trees	Average Crown area	Total crown area
Abuja Campus, Uniport	125	17.8463	2230.785
Delta Campus, Uniport	58	17.3254	1004.873
Choba Campus, Uniport	43	18.1476	780.347
Alakahia	28	9.9173	277.684
Rumuekeni	58	5.6758	329.195
Omuoko	22	6.1202	134.645

The Spatial distribution of the trees in the study area is shown in Fig 1. Canopy gaps may indicate areas where tree cover is insufficient, potentially impacting biodiversity, soil health, and microclimate regulation. Analyzing the size and location of these gaps can help inform tree planting and management strategies aimed at enhancing canopy cover, improving ecological functions, and promoting urban resilience. Understanding the spatial distribution of trees and the extent of canopy gaps can guide future landscaping and urban planning efforts, ensuring that green spaces are optimized for both aesthetic value and environmental benefits.

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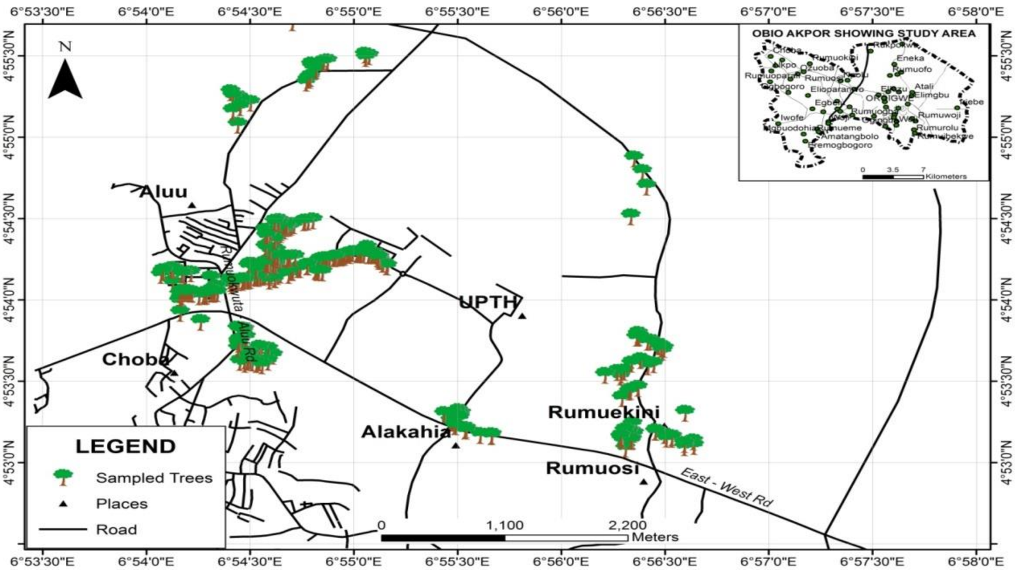

Fig1: Spatial distribution of trees in the study area

Tree species observed in the study area is presented in Table 2 which revealed that fruit trees spread more across the location than any other urban tree (Fig 2-4). The abundance of fruit trees can contribute to improved urban aesthetics, environmental quality, and food security for local residents. Additionally, their presence may foster community engagement in tree planting and maintenance activities. Overall, the dominance of fruit trees in the urban landscape highlights their importance in creating sustainable and productive urban environments.

Table 2: Tree species found in study area

Location	Trees Speices
Abuja campus	*Mangifera indica, Dacryodes edulis, Azadirachta indica, Delonix regia, Terminalia catappa, Pinus caribaea, Gmelina arborea, Terminalia mantaly, Cocos nucifera, Elaeis guineensis, Caesalpinia pulcherrima, Ficus elastica, Hura crepitans, Moringa oleifera, Irvingia gabonensis, Tetrapleura tetraptera, Prunus domestics, Polyalthia longifolia.*
Alakahia	*Delonix regia, Gmelina arborea, Terminalia mantaly, Mangifera indica, Cocos nucifera*
Choba campus	*Pinus caribaea, Terminalia mantaly, Persea americana, Hura crepitans, caesalpinia pulcherrima, Terminalia catappa, Gmelina arborea, Robinia pseudoacacia, Tetrapleura tetraptera, Mangifera indica, Chrysophyllum albidum, Terminalia ivorensis, Polyalthia longifolia.*
Delta campus	*Elaeis guineensis, Terminalia ivorensis, Cocos nucifera, Pterocarpus macrocarpus, Pinus caribaea, Persea americana, Azadirachta indica, Mangifera indica, Dacryodes edulis, Delonix regia, Polyalthia longifolia, Gmelina arborea, Terminalia catappa.*
Omuoko	*Chrysophyllum albidum, Mangifera indica, Terminalia mantaly, Dacryodes edulis, Cocos nucifera, Polyalthia longifolia, Persea americana, Terminalia catappa, Elaeis guineensis, Citrus sinensis.*
Rumuekini	*Mangifera indica, Cocos nucifera, Moringa oleifera, Citrus sinensis, Dacryodes edulis, Garcinia kola, Harpullia arborea, Ficus fistulosa, Polyalthia longifolia, Terminalia mantaly, Persea americana.*

Fruit trees such as *Cocus nucifera, Mangnifera indica, Persea americana* are common in the study area unlike other timber trees that are concentrated in the University environment alone (Fig 2- fig 4)

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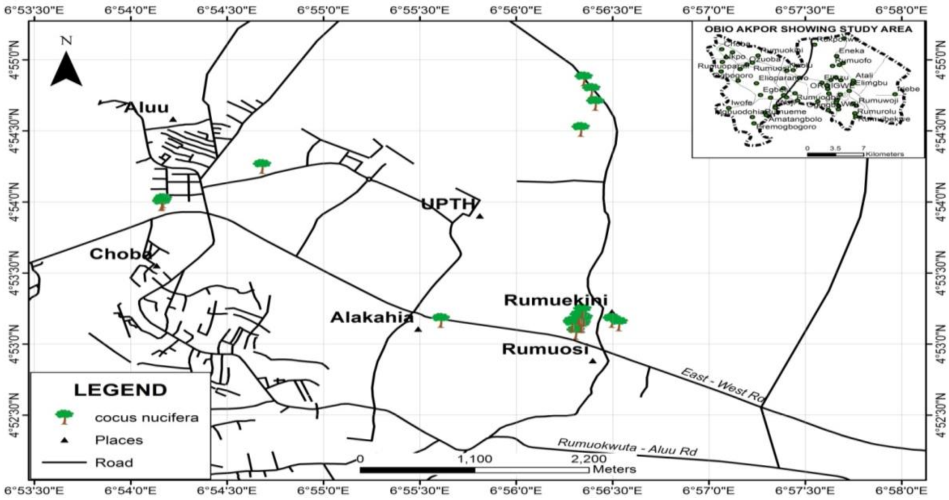

Fig 2: Spatial distribution of *Cocus nucifera*

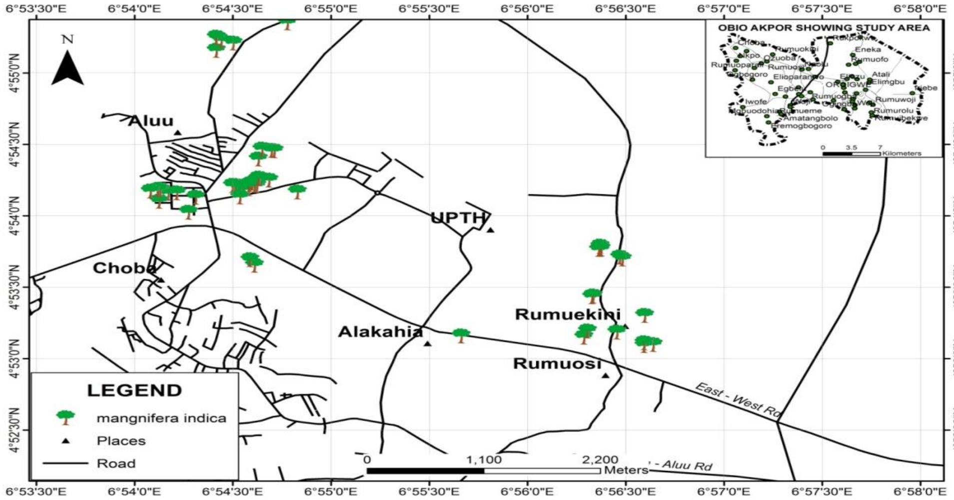

Fig3: Spatial distribution of *Mangnifera indica*

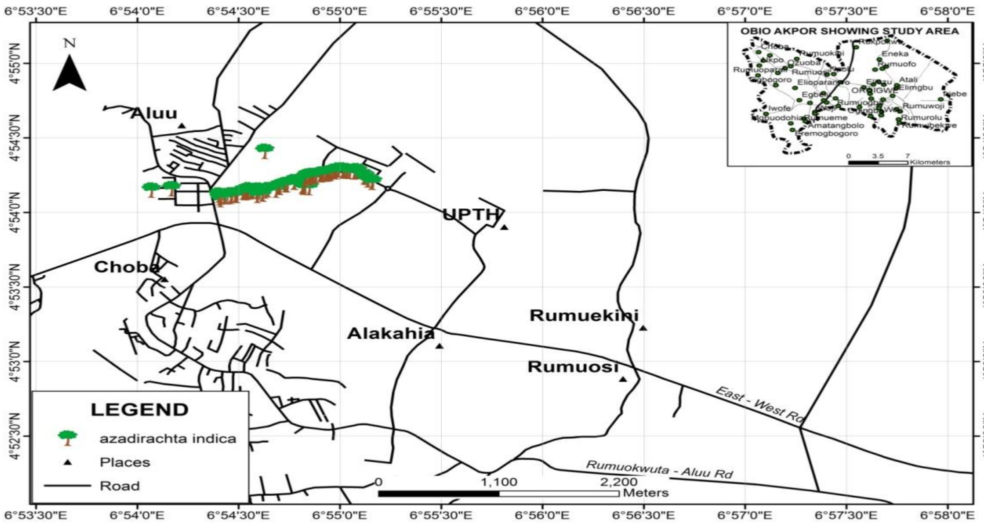

Fig 4: Spatial distribution of *Azadirachta indica*

Dynamics of canopy width across the communities in the study area

Canopy distance across the communities was compared. The analysis of variance result shows that there are significant variations among the crown area of trees across the study location. Mean separation using Least Significant Different shows that there is no significant difference in the tree canopy across the University

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campuses (Abuja, choba and Delta) but tree canopy differs between the university campuses and the surrounding community (table 3).

Table 3: Mean separation of crown area measured across the study area

Location	Average Crown area
Abuja Campus, Uniport	17.8463^{a}
Delta Campus, Uniport	17.3254^{a}
Choba Campus, Uniport	18.1476^{a}
Alakahia	9.9173^{b}
Rumuekeni	$5,6758^{b}$
Omuoko	6.1202^{b}

Means with different alphabets are are significantly different at $p<0.05$

Canopy distance and its influence in regeneration potentials

Trees in the study area were grouped in clusters and canopy distances were measured. Results in table 4 shows that the least canopy distance was observed in Abuja campus (11.9m) while the highest canopy distance was observed in Rumuekini community (234.43m)

Table 4: Average canopy distance (m) in the study area

Clusters	Rumuekini	Alakahia	Omuoko	Abuja	Choba	Delta
A	8.3	49.2	116.2	22.9	29	20.1
B	21.27	23.66	39.4	15.51	41.77	16.9
C	70.45	20.45	15.4	18.25	12.6	34.6
D	63.1		65.5	25.1	3.48	15.8
E	44.51		38.4	37.9		42.6
F	234.43			11.9		

DISCUSSION

Tree canopy area and the spatial distribution

Measuring tree canopy areas in the University of Port Harcourt and its surrounding environs, and examining their spatial distribution, is crucial for understanding urban forestry, biodiversity, and environmental quality in the region. This assessment involves identifying the extent of green cover, analyzing patterns, and understanding the impacts of canopy spread on local ecology, urban heat, and air quality. Urban canopy coverage often uses remote sensing techniques, GIS (Geographic Information Systems), and aerial photography to map canopy size and distribution (Odeh et al., 2019). Ground surveys may complement remote data. Field data, like tree species, height, diameter, and health, can help validate remote measurements and give a more comprehensive picture. Nowak et al. (2008) highlights how spatial canopy data can inform urban planners about green space accessibility and help identify areas needing ecological restoration or afforestation. Within the University campuses, clusters of high canopy areas were observed indicating protection of the trees. Clusters of high canopy cover could indicate protected areas, while low canopy areas might show sites of urban development or deforestation. This distribution reflects the urban planning approach in managing green spaces within the university and its surroundings.

Compare the dynamics of canopy width across communities in the study area

Comparing the dynamics of canopy width across communities provides valuable insights into vegetation patterns, ecosystem health, and urban development impact. McPherson et. al., (2017) have shown that canopy width impacts ecosystem benefits, with wider canopies providing more shading and cooling effects. Canopy width, or the spread of tree branches, is crucial for understanding how much ground area a tree shades. Wider canopies cover more land area, contributing significantly to ecological benefits such as reducing soil erosion, enhancing biodiversity, and cooling the environment. Factors influencing canopy width is tree species, age, health, and environmental conditions. Urbanization, deforestation, and land-use changes are also major factors affecting the dynamics of canopy spread across communities.

Comparative Analysis Across Communities

In urban communities, canopy width is often limited due to space constraints, construction, and pollution. Trees in these areas may have narrower canopies because of reduced growth space and resources. Within the University of Port Harcourt, wider canopy trees were observed due to more favorable growing conditions and less human interference. Communities with significant green zones or parks tend to maintain larger canopy widths compared to densely populated areas with limited green spaces. Public policy on land use and zoning, including tree protection laws, can heavily influence canopy dynamics.

Environmental and Socioeconomic Implications

Impact on Microclimate and Air Quality: Communities with wider canopy coverage benefit from reduced urban heat island effects, cleaner air, and higher humidity levels, improving residents' quality of life. Tree canopies provide shade, reduce surface temperatures, and improve air quality by filtering pollutants like particulate matter and ozone (Akbari et al., 2001). In areas with narrow canopies or sparse vegetation, these benefits are reduced, potentially leading to hotter, drier, and more polluted environments which can exacerbate health issues like respiratory problems (Nowak et al., 2013).

Wider canopies provide better habitats for wildlife, supporting higher biodiversity. Jim and Chen (2009) stated that urban areas with extensive tree cover and diverse species provide valuable resources that support various life forms. In contrast, communities with narrow or sparse canopies may lack sufficient habitats for certain species, affecting local biodiversity. Wider canopies capture more carbon dioxide, enhancing a community's capacity for carbon sequestration. This makes canopy dynamics crucial in strategies for local climate change mitigation, particularly in densely populated areas with limited green cover. Nowak and Crane (2002) highlight that urban tree, especially those with broader canopies, significantly enhance a community's capacity for carbon sequestration, which is particularly valuable in densely populated areas with limited green space. This corroborates the results of other researchers that carbon sequestration potential is directly associated with DBH, tree height, crown diameter, basal area and wood density (Terakunpisut et al. 2007; Stegen et al. 2009; Tagupa et al. 2010; Eguakun and Adesoye 2015)

Conservation and Urban Planning Considerations

By comparing canopy width dynamics across communities, urban planners and policymakers can identify areas needing intervention to boost canopy coverage, either by planting trees or by conserving existing ones. Canopy dynamics may also vary due to differences in tree species, planting practices, and community engagement in green space management (Escobedo & Nowak, 2009). Areas with declining canopy widths may benefit from programs that promote tree growth and minimize urban sprawl impacts. Educating residents about the importance of trees and canopy preservation can encourage community involvement in green space initiatives. Programs aimed at promoting wider canopy growth, like community tree-planting days, can foster long-term ecological sustainability.

Determine the canopy distance among the urban trees and its influence in regeneration potentials among communities across the study area.

Determining canopy distance among urban trees and assessing their influence on regeneration potential is essential for understanding the dynamics of forest structure and tree health in urban environments. Canopy gaps, which are open spaces within the forest canopy, affect light availability, species diversity, and growth patterns. Runkle (1982) suggests that gap size and frequency influence the growth of different plant species and can be critical in species composition. By analyzing these gaps in communities around the study area, we can gain insights into how urbanization impacts regeneration, ecological resilience, and biodiversity. Canopy gaps are breaks in the continuity of tree crowns, which allow sunlight to reach the understory. These gaps often form naturally due to tree falls, aging, or disease. In urban areas, however, gaps are often created by human activities such as tree removal, pruning, construction, and landscaping. The size and shape of a canopy gap determine how much light penetrates to the ground and what kind of species may grow there. Small gaps may favor shade-tolerant species, while larger gaps promote growth of sun-loving species, influencing regeneration potential across the urban landscape.

Canopy gaps increase light availability, which can significantly influence regeneration. In areas with larger gaps, tree seedlings and understory plants have higher growth rates due to increased sunlight. Understanding these gaps is essential for urban regeneration strategies, as highlighted in studies by Jim (2001), which explore how urban gaps promote diversity in regeneration patterns. This effect is vital in urban settings where dense canopies may otherwise limit light and inhibit regeneration. Canopy gaps can contribute to species diversity by creating microenvironments that favor various species based on their light and growth requirements. In urban communities, where tree diversity may already be limited, gaps provide opportunities for both native and non-native species to establish. Gaps also impact soil moisture and nutrient cycling. In urban areas where soil compaction and pollution are common, gaps may offer slightly improved soil conditions for seedling establishment by reducing competition for water and nutrients. University of Port Harcourt campuses, canopy gaps result from landscaping and the maintenance of open areas. These controlled gaps can support targeted regeneration programs, where selected tree species are planted to fill gaps strategically, thus ensuring the growth of species with desired characteristics, like shade provision or aesthetic appeal. In communities surrounding the university, canopy gaps may be less controlled, often created by tree removal for construction or utility maintenance. These unplanned gaps may affect regeneration unpredictably, with gaps favoring fast-growing, often invasive species rather than native species, which could alter the ecological composition over time.

CONCLUSION

Quantifying and understanding the spatial dynamics of tree canopy gaps in urban forests, such as those within the University of Port Harcourt and surrounding communities helps in identifying areas with limited canopy cover, highlighting opportunities for regeneration, highlighting disparities between communities, and underscoring the ecological and social benefits of well-managed urban green spaces. Ultimately, this quantification serves as a critical tool for urban planners and policymakers aiming to create more resilient, climate-adaptive cities with improved air quality, cooler microclimates, and enhanced biodiversity. The presence of canopy gaps allows for natural regeneration, contributing to biodiversity but also risking invasive species establishment if not managed carefully. Conclusively, quantifying tree canopy gaps is a foundational step in building greener, more resilient urban environments that offer both ecological and social benefits to all residents.

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