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(Research Article)

Evaluation of Urban Temperature Moderation in University of Port Harcourt and Surrounding Communities

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Abstract

Urban heat islands are a growing concern globally, with cities experiencing rising temperatures due to limited vegetation, increased paved surfaces, and human activities. This study investigates urban temperature moderation across the University of Port Harcourt (Uniport) and its neighboring communities: Aluu, Rumuekine, Omuokho, Alakahia, and Choba. Remote sensing techniques, including Landsat 8 satellite imagery, were employed to map land surface temperature and land cover. Field surveys were conducted to ground-truth the remote sensing data and collect additional information. The study revealed significant temperature moderation within Uniport's campus, attributed to its organized green spaces and higher tree density (125 trees). In contrast, surrounding areas had spared tree distribution, largely confined to private properties (Omuokho, 22 trees). Land surface temperatures (LST) ranged from 30°C to 41°C. Notably, areas with higher tree densities, such as Uniport, exhibited more consistent cooling effects, while neighboring communities experienced isolated cooling around individual trees. This study highlights the crucial role of intentional green space planning in mitigating urban heat islands. The findings provide valuable insights for urban planning strategies, aiming to reduce heat stress and enhance environmental quality across Uniport and its surrounding Communities.

Keywords: Cooling; Green Area; Heat; Species; Temperature; Urban

1. Introduction

Urban forests are the main component of green infrastructure, providing diverse social and aesthetic advantages – such as recreation, physical and mental health, cultural and historical value, landscape variety, and seasonal dynamics – along with climatic, physical, ecological and economic benefits (Tyrväinen *et al.*, 2005). They are defined as networks or systems which connect all individuals and groups of trees located in urban and peri-urban areas, including urban woodland, trees planted along streets, and those growing in parks and gardens. Urban trees affect city's climate, control wind, temperature and humidity, and thereby improving the cooling capacity of the city. Alexandri and Jones (2008) indicate that heat flows on vegetated surfaces are very different to those on non-vegetated surfaces, and that this results in lower temperatures on green surfaces than on those made of concrete.

The 21st century has witnessed an unprecedented rate of urbanization and global urban population growth, especially in the African and the Asian continents. In 2014, it was estimated that 54 percent of the global population lives in cities and that number is projected to reach 66 percent in 2050 (UN 2014). People are attracted to urban areas for several reasons such as increased economic activities, abundant life-support infrastructure and bustling social life. University of Port Harcourt and its environs is like every other large city with economic activity which have experienced a series of environmental changes attributed to urbanization. Urbanization induces changes in the mechanism of the energy

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balance within urban areas thus giving an increase to temperature rise, thereby contributing to global warming (Tokairin, *et al.,* 2010). Changes to the urban microclimate produce higher temperatures compared to non-urbanised surroundings, a phenomenon known as the urban heat island (UHI) (Sarricolea and Romero, 2010; Tumini, 2012). This build-up of heat over the city can be mitigated by the presence of green areas (Sarricolea and Martín-Vide, 2014).

The impacts of global warming can be particularly obvious or even exacerbated in cities due, to the UHI effects and the unique socioeconomic character of the urban environments. Literature has documented the consequences of extreme heat events on human health, physical infrastructure, animals and the general wellbeing of urban dwellers (Kovats & Ebi, 2005, Withman *et al.*, 2006). With a projected 4^{o}C rise in average annual global temperature in the nearest future (Martinez-Austria, *et al*., 2018) and given the rapidly increasing rate of urbanization especially in the developing world, it becomes pertinent to understand the complex processes and factors driving the UHI phenomenon. Research has convincingly documented that increased temperatures are a function of proportional coverage and spatial configuration of impervious surfaces within dense urban sites (zheng *et al*., 2014: Solecki *et al*., 2005; Weng, 2009; Weng *et al*., 2007). However, less attention has been given to temperature elevations in residential areas, which have a comparatively greater proportional cover of grass and other non-tree vegetation. Quantification of the temperature effects of land cover in these areas is critically important due to the large amount of energy used in home cooling (Akbari, 2009; Pandit and Laband, 2010).

2. Materials and methods

2.1. Study Area

This study was conducted within the University of Port Harcourt and its surrounding communities, situated in the Obio/Akpor Local Government Area of Rivers State, Nigeria. It lies between Latitude: 4.90794^{0} - 4.90809^{0}N and Longitude: 6.92413^{0} - 6.92432^{0}E. The surrounding communities in this study include: Aluu (Omuokho), Alakahia, Choba and Rumuekine. These communities are characterized by a mix of urban and rural settings, with varying levels of infrastructure development and socioeconomic profiles.

2.2. Sampling Technique and Data Collection

Purposive sampling technique was used in selecting the communities in study area. Primary and secondary data was used for this study. Primary data was collected from the selected communities while the secondary data was collected from Landsat 8 imageries using ArcGis Software. GPS was used to pick the location of urban trees in the study area. Landsat 8 satellite imagery was acquired for the study period. This data provided multispectral and thermal infrared bands, essential for land cover classification and land surface temperature (LST) estimation. High-resolution Google Earth imagery was used for detailed land cover mapping and verification of remotely sensed data.

3. Data Processing and Analysis

3.1. Land Surface Temperature (LST) Retrieval

Thermal Infrared Bands: The thermal infrared bands of Landsat 8 were used to calculate LST. Spatial analysis techniques, such as spatial autocorrelation and hotspot analysis, were used to identify spatial patterns in LST. Analysis of variance was used to compare the extent of urban tree planting across surrounding communities.

4. Results

4.1. Delineate and enumerate urban trees across the study area

The result shows the number of trees in the various location in the study area (table 1 & 2) and spatial distribution (Fig 1). Abuja campus had the highest number of trees (126) in the University while Rumuekini had the highest number of tress (64) in the surrounding communities. The University environment had the highest number of trees compared to its surrounding communities. The spatial distribution of the trees in the study area shows that the university community, trees are clustered along the road (avenue trees) compared to the other communities where they are spare along the road (Fig 1)

Table 1 List of species found in study area (University of Port Harcourt)

Location	Species	Common name	Family name	frequency
Abuja campus	*Azadiracthta indica*	Neem	Meliaceae	105
	Pinus spp	Pine	Pinaceae	1
	Gmelina arborea	Gamhar	Lamiaceae	1
	Mangifera indica	Mango	Anacardiaceae	2
	Persea americana	Avocado	Lauraceae	1
	Terminalia mantaly	Umbrella tree	Combretaceae	12
	Delonix regia	Flamboyant	Fabaceae	1
	Terminalia catappa	Tropical almond	Combretaceae	3
	Total			126
Choba campus	*Pinus spp*	Pine	Pinaceae	7
	Terminallia mantaly	Umbrella tree	Combretaceae	6
	Terminallia catappa	Tro[pical almond	Combretaceae	13
	Persea americana	Avocado	Lauraceae	3
	Hura crepitans	Sandbox tree	Euphorbiaceae	1
	Caesalpinia pulcherrima	Peacock flower	Fabaceae	5
	Robinia pseudoacacia	Black locust	Fabaceae	3
	Tetrapleura tetraptera	Aridan	Fabaceae	1
	Mangifera indica	Mango	Anacardiaceae	2
	Chrysophyllum albidum	African star apple	Sapotaceae	2
	Total			43
Delta Campus	*Terminalia mantaly*	Umbrella tree	Combretaceae	29
	Mangifera indica	Mango	Anacardiaceae	19
	Caesalpinia pulcherrima	Peacock flower	Fabaceae	4
	Dacryodes edulis	African pear	Burseraceae	5
	Terminalia catappa	Tropical almond	Combretaceae	4
	Ficus lyrata	Fiddle-leaf tree	Moraceae	1
	Hura crepitans	Sandbox tree	Euphorbiaceae	6
	Moringa oleifera	Drumstick tree	Moringaceae	1
	Cocos nucifera	Coconut palm	Arecaceae	1
	Tetrapleura tetraptera	Aridan	Fabaceae	7
	Irvingia gabonensis	Bush mango	Irvingiaceae	1
	Azadiracthta indica	Neem	Meliaceae	1
	Elaeis guinensis	Oil palm	Arecaceae	7
	Spondias dulcis	Golden apple	Anacardiaceae	7
	Total			93

Source: Field Survey, 2024

Table 2 List of species found in study area (Surrounding communities)

Location	***Species***	**Common name**	**Family name**	**frequency**
Omuoko	*Chrysophyllum albidium*	African star apple	Sapotaceae	1
	Mangifera indica	Mango	Anacardiaceae	6
	Terminalia mantaly	Umbrella tree	Combretaceae	2
	Persea americana	Avocado	Lauraceae	4
	Dacryodes edulis	African pear	Burseraceae	1
	Cocos nucifera	Coconut palm	Arecaceae	2
	Polyaltha longifolia	Indian mass tree	Annonaceae	3
	Elaeis guineensis	Oil palm	Arecaceae	1
	Total			**20**
Alakahia	*Delonix regia*	Flamboyant	Fabaceae	16
	Gmelina arborea	Gamhar	Lamiaceae	7
	Terminalia mantaly	Umbrella tree	Combretaceae	1
	Mangifera indica	Mango	Anacardiaceae	1
	Cocos nucifera	Coconut palm	Arecaceae	2
	Total			**27**
Rumuekini	*Mangifera indica*	Mango	Anacardiaceae	15
	Cocos nucifera	Coconut palm	Arecaceae	19
	Moringa oleifera	Drumstick tree	Moringaceae	3
	Citus sinensis	Sweet orange	Rutaceae	1
	Garcinia kola	Bitter kola	Clusiaceae	1
	Dacryodes edulis	African pear	Burseraceae	4
	Harpullia pendula	Tulipwood	Sapindaceae	1
	Gmelina arborea	Gamhar	Lamiaceae	2
	Polyaltha longiflora	Indian mass tree	Annonaceae	3
	Ipomoea nil	Morning glory	Convolvulaceae	3
	Terminalia mantaly	Umbrella tree	Combretaceae	11
	Persea americana	Avocado	Lauraceae	1
	Total			**64**

Source: Field Survey, 2024

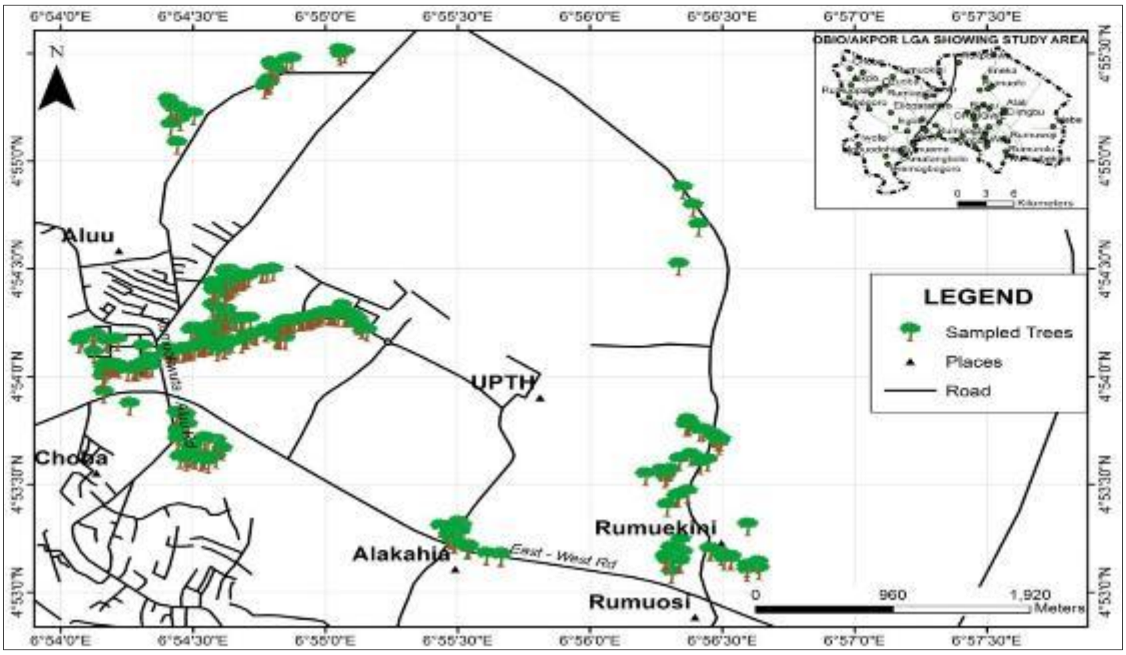

Figure 1 Urban trees positioning across the study area

4.2. Nature of land surface temperature across the study area

The spatial distribution of Land Surface Temperature (LST) of the study area is shown in Figure 2. LST ranges from minimum to maximum LST in Degree Celsius. The values range from minimum (130C) to maximum (410C) LST inDegree Celsius.

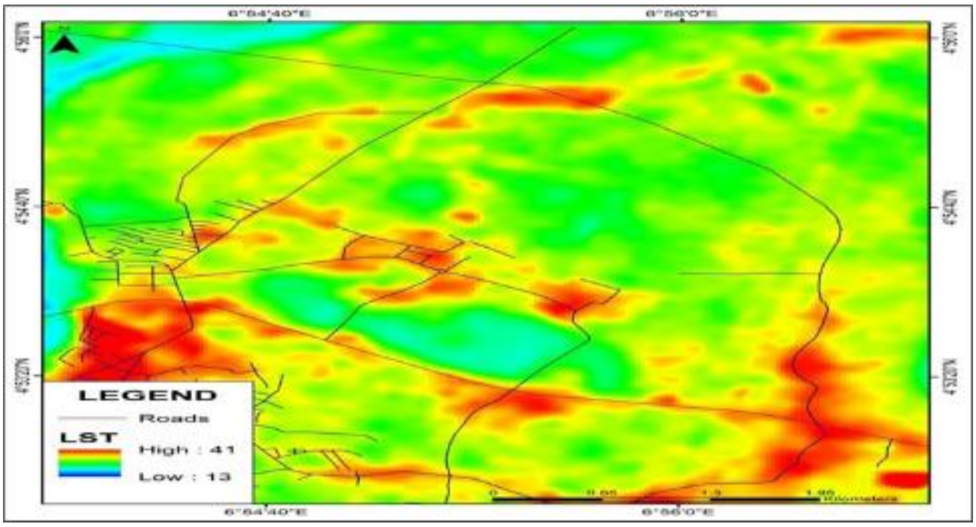

Figure 2 Land surface temperature for the study area

4.3. Impact of urban forest in moderating land surface temperature

The spatial distributions of Land Surface Temperature (LST) within the study area are presented in fig 3. The result shows that although the surface land temperature of the study area ranged between $13^{0}C$ to $41^{0}C$, the presence of urban trees in the area moderated the temperate (table 3 and fig 3).

Table 3 Land surface temperature (ºC) under urban tree canopy

Location	Minimum LST	Maximum LST
Abuja Campus, Uniport	25.27	28.75
Delta Campus, Uniport	26.44	29.12
Choba Campus, Uniport	27.38	29.33
Alakahia	26.36	29.12
Rumuekeni	26.91	29.27
Omuoko	26.80	28.62

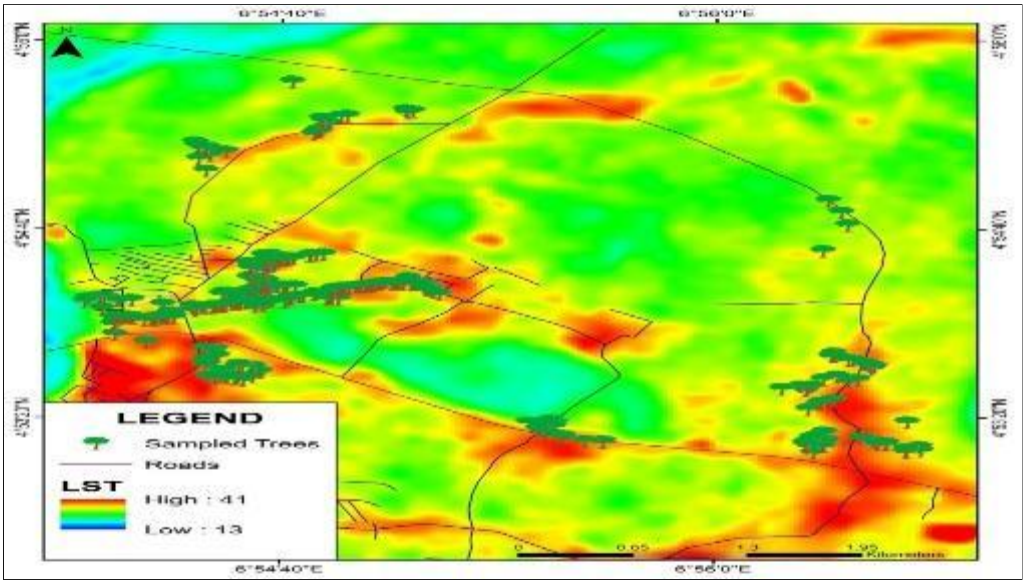

Figure 3 Land surface temperature under urban trees in the study area

4.4. Extent of urban tree planting among communities across the study area

It was observed that in the University community trees were planted around the entire environment compared to the surrounding community (Fig 4 and 5). In the Surrounding communities tree planting were in clusters depending on the owner of the property.

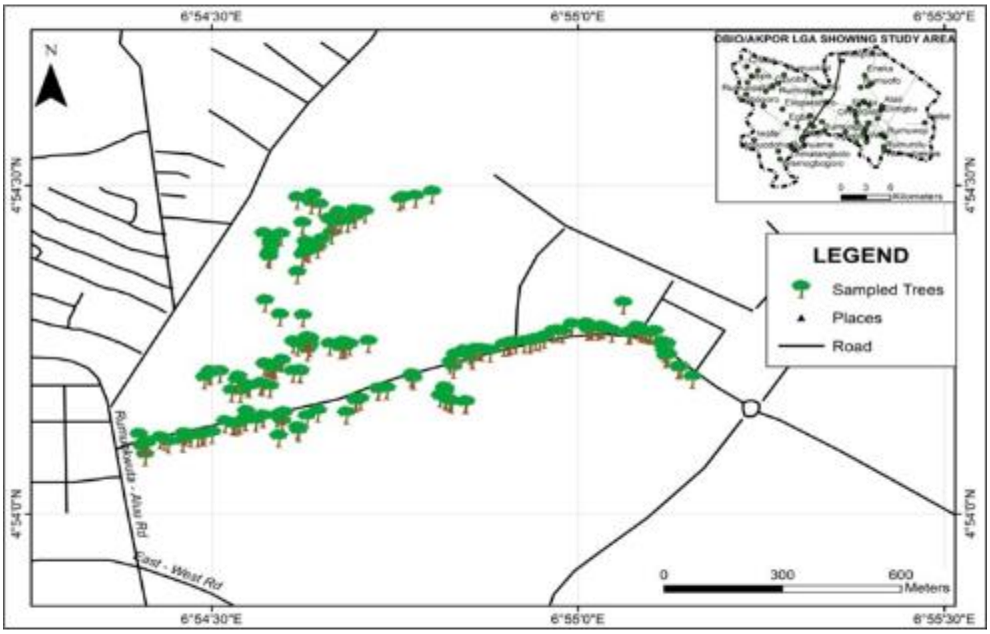

Figure 4 Urban trees spread in Abuja campus, Uniport

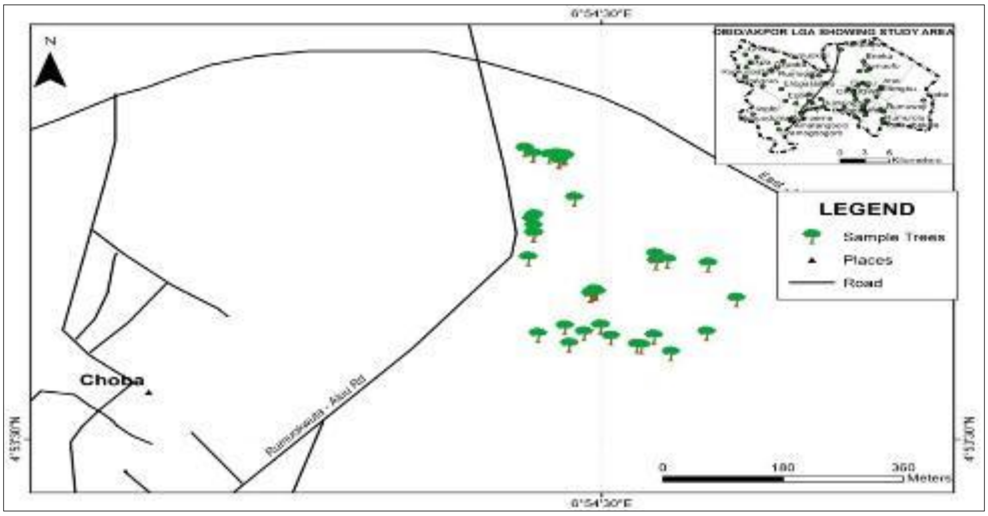

Figure 5 Urban trees spread in Choba campus, Uniport

5. Discussion

Urban areas face increasing challenges with heat retention due to extensive paved surfaces, limited vegetation, and concentrated human activities that create and trap heat. This phenomenon which is known as the Urban Heat Island (UHI) effect, results in urban areas being warmer than their rural surroundings, affecting thermal comfort, increasing energy demands, and even posing health risks during extreme heat events (Oke, 1982; Arnfield, 2003). Research has shown that a key solution to UHI is the presence of trees and green spaces, which naturally cool their surroundings based on two main mechanisms: shading, which reduces direct solar radiation, and evapotranspiration, a process where trees release moisture, which cools the air as it evaporates (Akbari *et al.,* 2001; Armson *et al.,* 2012). In evaluating Uniport and its surrounding communities (Aluu, Omuoku, Rumuekine, Choba, Delta Park, and Abuja), we find these cooling effects are markedly stronger in areas with higher tree density, as seen in Uniport, compared to neighboring communities, where tree coverage is more sporadic.

5.1. Delineation and Enumeration of Urban Trees Across the Study Area

The study identified and mapped urban trees within University of Port Harcourt (uniport) and surrounding communities. Findings indicate that Uniport has a significantly higher density of organized green spaces, including various tree species planted along pathways, around buildings, and in recreational areas (Oke & Maxwell, 2021). This dense canopy coverage contributes to more uniform and extensive green spaces. In contrast, the surrounding communities of Aluu, Rumuekine, Omuku, Alakahia, and Choba show more sporadic tree distributions, where vegetation is generally limited to private compounds and individual homesteads, which results in limited area for temperature moderation.

Urban tree distribution is critical for maintaining ecological balance and providing temperature regulation. Studies have shown that urban areas with higher tree densities tend to experience more consistent cooling effects (Akbari, 2009). The discrepancy between Uniport's organized green spaces and the surrounding communities' private compound-based vegetation highlights the influence of institutional planning and communal resource availability. The organized planting at Uniport allows for more consistent cooling, whereas the patchy distribution in neighboring areas restricts the benefits of a broad canopy cover. This difference in tree distribution is likely influenced by land use and institutional planning. Uniport's organized layout of green spaces reflects an intentional design to support both aesthetic and environmental functions, allowing for consistent temperature moderation across the campus. In contrast, surrounding communities rely on private tree planting within compounds, resulting in limited, localized cooling effects.

5.2. Land Surface Temperature (LST) Patterns

The LST analysis reveals a marked difference between Uniport and the surrounding communities. Data indicate that Uniport's dense tree cover correlates with lower surface temperatures across its campus, while surrounding areas experience higher LSTs, especially in locations with limited vegetation and extensive built-up or paved surfaces. Higher LSTs in the communities align with studies on the Urban Heat Island (UHI) effect, where impermeable surfaces retain heat and contribute to increased temperatures in urbanized settings (Oke, 1982; Voogt & Oke, 2003). Previous research has highlighted that green spaces can mitigate UHI effects by providing shade and facilitating evapotranspiration, where vegetation releases moisture that cools the surrounding air (Zhang *et al*., 2017). In Uniport, these processes contribute to a relatively cooler environment, making it a practical model for understanding how green spaces impact urban temperatures. The study's findings suggest that areas with low vegetation density lack adequate cooling, which raises LST and affects thermal comfort in public spaces (Arnfield, 2003). The analysis of LST data across the study area revealed distinct temperature patterns. Uniport's dense tree cover contributes to relatively lower temperatures, particularly in areas with extensive canopy cover, such as green spaces, Temperature pathways, and building surroundings. Neighboring communities exhibit higher land surface temperature (LST), particularly in areas with sparse vegetation and extensive paved or built-up surfaces. This finding underscores the role of vegetation in mitigating urban heat, as Uniport's greener environment consistently registers lower surface temperatures compared to its less-vegetated surroundings.

5.3. Impact of Urban Forests in Moderating Land Surface Temperature

Urban forests within Uniport significantly moderate LST through mechanisms such as shading and evapotranspiration. Shading reduces the amount of direct solar radiation on surfaces, while evapotranspiration helps cool the air as water from plants is released and evaporates, which has been widely documented as an effective temperature-moderating process (Bowler *et al*., 2010; Gill *et al*., 2007). The more consistent green cover in Uniport leads to a noticeable cooling effect across the campus. In contrast, communities such as Aluu and Choba, with less dense and sporadic tree cover, benefit only from localized cooling effects, primarily within the immediate shaded areas. This pattern is in line with findings from studies on urban greenery, which show that extensive tree coverage is necessary to provide effective temperature moderation across larger areas (Konarska *et al*., 2016). Without continuous canopy cover, cooling effects remain localized, often limited to specific shaded spots, rather than contributing to an area-wide temperature reduction (Nowak & Dwyer, 2007).

5.4. Comparison of Urban Tree Planting Practices Among Communities

A comparison of tree planting practices reveals notable differences between Uniport and the surrounding communities. While Uniport has an organized approach to green space management, with designated planting areas that promote an even distribution of trees, the surrounding communities are more dependent on individual, private tree planting efforts (McPherson *et al*., 1997). This disparity affects the extent and quality of green spaces, as the communities around Uniport lack the coordinated, community-wide green infrastructure found on the campus. This study's findings suggest that institutional planning, like Uniport's organized planting, enhances the cooling benefits of urban greenery. Similar structured planting initiatives in surrounding communities could reduce LST more effectively by increasing green space continuity, thus creating a broader canopy (Gómez-Baggethun & Barton, 2013). Communal green spaces could also foster community engagement in environmental conservation, leading to greater social and environmental benefits for residents. Urban forests in Uniport play a critical role in reducing LST through shading and evapotranspiration. The campus's organized tree coverage creates shaded areas that reduce direct solar radiation on paved surfaces, while evapotranspiration from trees releases moisture into the air, further cooling the environment.

6. Conclusion

This study has shown that urban greening plays a critical role in moderating temperatures in built environments. The campus's organized tree planting and extensive canopy coverage contribute significantly to temperature moderation. Trees lower temperatures through shading, which blocks direct solar radiation, and evapotranspiration, a natural process where plants release moisture that cools the surrounding air. Consistent and carefully maintained green space network across the environment provides a more uniform cooling effect, creating a comfortable environment for humans. Built-up surfaces such as roads, concrete structures, and paved areas absorb and retain heat, raising LST and making urban spaces uncomfortably warm. The presence of trees in an urban area creates cooler microclimates within shaded spaces, yet without continuous canopy cover, the cooling effect does not extend across broader areas, resulting in higher overall temperatures and diminished thermal comfort in public spaces.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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