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Integrating geo-spatial analysis with cultural and social dynamics of green space access in durban central business district, South Africa

Tolulope Ayodeji Olatoye*
University of KwaZulu-Natal, Durban, South Africa
Email: olatoyetolu@gmail.com

Maheshvari Naidu
University of KwaZulu-Natal, Durban, South Africa

Corresponding author

Abstract
This study examines the intricate relationship between green space access, population dynamics, and socio-cultural factors in the Durban Central Business District (CBD), South Africa, from 2004 to 2024, with projections for 2034. Amid rapid urbanization and population growth, the preservation and equitable distribution of urban green spaces have become pressing challenges. Green spaces are not only crucial for environmental sustainability and public health but also play a pivotal role in fostering social cohesion and cultural identity. Grounded in Urban Ecology Theory and socio-spatial theories, this research integrates geo-spatial analysis with an exploration of the cultural and social dimensions of green space access, focusing on how urban expansion and demographic changes affect both physical and social landscapes. Utilizing GIS, remote sensing, and population data, the study revealed a significant reduction in green spaces—from 1,104.4 km² in 2004 to 203.2 km² by 2024—especially in densely populated areas of the CBD, which correlates with a population growth from 2.57 million in 2004 to 4.85 million in 2024, and a projected 5.32 million by 2034. This urban expansion has exacerbated socio-environmental inequalities, particularly in lower-income neighborhoods, limiting access to green spaces and intensifying social divisions. The study highlights the multifaceted impacts of green space reduction, including biodiversity loss, rising urban temperatures, and deteriorating air quality. It advocates for an inclusive and strategic urban planning approach that integrates green infrastructure, ensures equitable green space distribution, fosters community engagement, and utilizes geo-information technologies for adaptive policymaking. Ultimately, the research calls for a balance between urban growth and environmental sustainability, ensuring that green spaces remain accessible to all, nurturing both the ecological and social fabric of the city. The study recommends the transformation of green spaces into cultural hubs, fostering of social cohesion and equity in green space policies, and integrating spatial humanities to reflect human narratives in urban planning among others.

Key words: Cultural Dynamics; Environmental Sustainability; Geo-Spatial Analysis; Green Space Accessibility; Population Dynamics; Social Equity; Durban Central Business District

Introduction

According to Mamajonova et al. (2024), urban green spaces, including parks, gardens, and recreational areas, play a pivotal role in shaping sustainable cities. These spaces contribute to ecological balance by supporting biodiversity, mitigating urban heat island effects, and facilitating carbon sequestration (Addas, 2023). Additionally, they offer social benefits by promoting physical activity, reducing stress, and enhancing mental health, which collectively improve public health and the overall quality of urban life (Vargas-Hernández, et al. 2023). However, in cities experiencing rapid urbanization, such as Durban Metropolis in South Africa, these benefits are under threat (Feltes, 2020). The city's growing population exerts pressure on land resources, leading to the encroachment of green areas and the prioritization of development over conservation. The dynamic relationship between population growth and green space distribution can result in social inequities, where access to these vital areas becomes limited for lower-income communities (Vidal et al. 2020). This disparity contributes to environmental injustice, where marginalized groups bear the brunt of inadequate urban planning and insufficient green infrastructure (Mubangizi, 2021). Despite an acknowledgment of the importance of urban green spaces for sustainable city living, there remains a shortage of comprehensive research on how population trends impact their spatial distribution in Durban, thus posing challenges for urban planners and policymakers who seek to create cities that balance development with ecological integrity (Jagarnath et al. 2020). Thus, this study employs a geo-spatial analysis approach, utilizing GIS and remote sensing technologies to systematically examine the correlation between population changes and urban green space distribution in Durban. By mapping and analyzing temporal and spatial data, the research aims to reveal patterns, pinpoint areas lacking green infrastructure, and assess the implications of population dynamics on urban sustainability. The study will provide actionable insights for urban planners, policymakers, and stakeholders, guiding the development of informed, equitable strategies that prioritize environmental resilience and community well-being.

Aim of Study

The study analyses the relationship between urban green spaces and population dynamics in Durban Metropolis, South Africa, using geo-spatial analysis tools and mapping/evaluating the spatial distribution of green spaces in relation to population trends over time.

Theoretical Framework

The Urban Ecology Theory (UET)

According to Klaus and Kiehl, (2021), the Urban Ecology Theory (UET) provides a foundational lens for examining the intricate relationships between humans and their urban environments, recognizing cities as dynamic, interconnected ecosystems. According to this theory, urban areas are not merely built environments but are composed of complex systems where human actions and natural processes are intertwined (Shackleton et al. 2021). In urban ecosystems, the natural environment (including green spaces, water bodies, and vegetation) interacts with human systems (population, infrastructure, and land use) in ways that shape both the ecological and social characteristics of the city (Zhao et al. 2020). In the context of Durban Metropolis, the UET is particularly relevant for understanding how the expansion of urban populations impacts the distribution and quality of urban green spaces (Gandy, 2022). As population grows, urbanization typically leads to land-use changes, where natural areas like parks, forests, and wetlands are replaced by residential, commercial, and industrial developments (Nath et al. 2021). This transformation disrupts the ecological functions of green spaces, such as regulating temperature, improving air quality, and providing habitats for local wildlife (Humbal et al. 2023). These ecological processes are essential for maintaining environmental health, especially in rapidly growing cities like Durban. UET further emphasizes that urban ecosystems are shaped not just by physical interactions but also by social dynamics (Des Roches et al. 2021). In a densely populated urban environment, access to green spaces is often unequal (Valente et al. 2022). The distribution of green areas tends to be skewed, with more affluent neighborhoods having greater access to well-maintained parks and recreational areas, while lower-income communities may lack such amenities (Gandy, 2022). These social inequities are critical to understanding the broader implications of urbanization on the population's health and well-being (Des Roches et al. 2021). UET thus allows the study to highlight the disparities in access to green spaces and their environmental and social consequences (Shackleton et al. 2021). The application of UET to this research goes beyond merely mapping green areas. It focuses on the interconnections between population growth, land use, and environmental change. The study examines how urban expansion, driven by rising population densities, alters the landscape and challenges the sustainability of green spaces, especially in areas with already limited resources. Furthermore, it explores the way population growth can exacerbate the loss of biodiversity and ecological services provided by urban green spaces, leading to a reduction in the overall quality of life for city dwellers. UET also emphasizes the importance of considering both ecological sustainability and social equity in urban planning. The study's focus on using geo-spatial tools to analyze how population growth influences the availability and quality of green spaces aligns with the theory's call for integrated approaches to urban management. Understanding the spatial dynamics of green space distribution in relation to population trends provides critical data for urban planners and policymakers seeking to create sustainable cities (Diemer and Nedelciu, 2020). The research draws on the UET to argue for policies that not only preserve and expand green spaces but also ensure equitable access for all communities, particularly those most vulnerable to the negative impacts of urbanization.

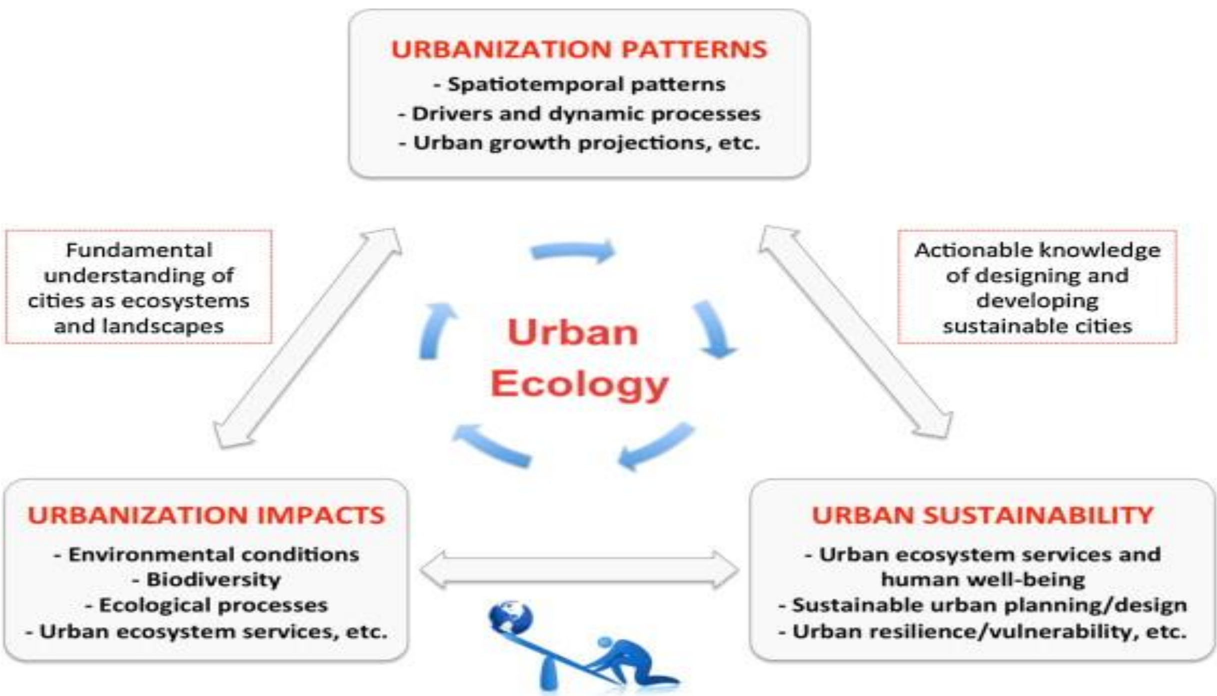

Figure 1: The Operationalization of the Urban Ecology Theory (Wu, 2014)

Figure 1 depicts the operationalization of Urban Ecology Theory, serves as a foundation for understanding how urbanization influences spatio-temporal patterns, sustainability, and ecological processes in urban settings like Durban. UET posits that cities function as complex, dynamic ecosystems where human and natural elements interact continually. By applying this theory, the study examines how rapid urbanization reshapes the distribution and quality of green spaces over time, affecting urban sustainability and ecosystem services such as air quality, climate regulation, and recreational areas. The theory enables an analysis of how population growth impacts the availability and spatial arrangement of green spaces, revealing disparities in access and ecological benefits that support human well-being. Furthermore, operationalizing the theory sheds light on urbanization's ecological processes, such as habitat fragmentation and biodiversity loss, showing how these changes undermine the resilience of urban environments. Ultimately, understanding cities as ecosystems and landscapes allows for a holistic perspective, emphasizing that the health of urban populations is intrinsically linked to the quality and distribution of their green spaces. This framework informs sustainable urban planning and policy-making that integrates ecological principles to balance urban growth with environmental stewardship.

Literature Review

Urban Green Spaces and their Importance

Urban green spaces such as parks, gardens, forests, and other green areas are crucial for the ecological, social, and economic health of cities (Vidal et al. 2020). Numerous studies highlight their importance in enhancing biodiversity, reducing urban heat islands, improving air quality, and promoting mental and physical well-being (Sopiana and Harahap, 2023). These spaces also provide critical ecosystem services such as water management, climate regulation, and noise reduction, which are particularly valuable in densely populated and industrialized areas (Olatoye et al. 2021). In rapidly urbanizing cities like Durban, these benefits are at risk due to the pressures of population growth and urban development.

Urbanization and the Loss of Green Spaces

According to Des Roches et al. (2021), urbanization, particularly in cities with high population growth rates such as Durban, results in the expansion of built environments at the expense of natural areas. Research by Colding et al. (2020) indicates that urban sprawl, which is often driven by increasing population densities, leads to the loss of vital green spaces. The conversion of these spaces for residential, commercial, and industrial use not only reduces the area available for recreation but also affects the natural services these spaces provide (Behnisch et al. 2022).

Population Growth and Its Impacts on Green Space Distribution

Population growth is a key factor driving changes in the distribution and accessibility of green spaces in urban areas (Dinda et al. 2021). According to studies by Rastandeh and Jarchow, (2021), population density correlates strongly with the conversion of open spaces into built environments. In metropolitan areas such as Durban, this growth often leads to the concentration of population in central urban areas where green spaces are limited (Des Roches et al. 2021). Moreover, the unequal distribution of green spaces exacerbates social inequalities, as lower-income areas tend to have fewer green spaces compared to wealthier districts (Diemer and Nedelciu, 2020). This spatial inequality in the availability of green spaces has been linked to health disparities, as access to these areas is critical for the well-being of urban residents.

Geo-Spatial Analysis and Remote Sensing Technologies

According to Olatoye and Fru, (2024), geo-spatial analysis using Geographic Information Systems (GIS) and remote sensing technologies has become an essential tool for studying urban landscapes, particularly in assessing the distribution and changes in green spaces over time. GIS enables the mapping and analysis of spatial data, which is useful in tracking land-use changes and identifying areas of green space loss or degradation (Song et al. 2021). Remote sensing technologies, through satellite imagery and aerial photography, provide valuable data for monitoring large-scale urban transformations. Studies have utilized these technologies to assess green space loss in cities like Cape Town and Johannesburg (Adesina et al. 2024), offering insights into how urban expansion affects green spaces. Geo-spatial tools have been used in various studies to track land-use changes, though comprehensive research integrating population dynamics with green space distribution remains limited (Mariye et al. 2022). A study by Makesha et al. (2020) utilized GIS and remote sensing to analyze land-cover changes in Northwestern, Ethiopia, revealing trends of decreasing green spaces as urban areas expanded.

Durban's Urban Development Challenges

Durban, one of South Africa's largest and most economically significant cities, faces a unique set of urbanization challenges (Feltes, 2020). The city has experienced rapid growth, driven by both internal migration and the expansion of suburban areas, leading to increased demand for land. According to the 2021 census, Durban's population has grown substantially, placing increasing pressure on land resources and the preservation of green spaces (McLean et al. 2024). While Durban has invested in urban greening programs, much of the city's green infrastructure remains under threat from urban sprawl and limited public funding for conservation. Research on Durban's urban green spaces has largely focused on isolated aspects, such as individual parks or local environmental management practices (Chipungu et al. 2022). However, there is a need for more integrated studies that examine the broader impact of population dynamics on green space distribution across the entire metropolitan area (Ally, 2021). Such research is crucial for developing policies that ensure the sustainability of green spaces and their equitable distribution in a growing urban environment.

Research Methodology

This methodology aims to provide a comprehensive analysis of how population dynamics affect the distribution and accessibility of green spaces in Durban. The study generated valuable insights that contribute to sustainable urban planning and equitable green space management in South African cities. The methodology involves the collection of spatial and demographic data, the use of Geographic Information Systems (GIS) and remote sensing technologies, as well as statistical analysis to identify trends and patterns over time.

Spatial Data Collection

Spatial data for this study was collected using advanced remote sensing technologies, Geographic Information Systems (GIS), and satellite imagery to ensure accuracy and comprehensive analysis.

Satellite Imagery: High-resolution Landsat imagery, complemented by other available datasets where higher resolution was necessary, was utilized to analyze land cover and land-use changes in Durban from 2004 to 2024. This 20-year period provided sufficient scope to study long-term urbanization trends and green space dynamics, including patterns of loss or expansion. The selected imagery included spectral bands suitable for distinguishing between urban, vegetative, and other land-cover types.

Land-Use Data*:* Urban planning and land-use datasets were sourced from the United States Geological Survey (USGS). These datasets facilitated the categorization of land cover into urban areas, green spaces, residential, commercial, industrial, and vacant land, ensuring a detailed mapping of the metropolitan landscape.

Population Data: Demographic data were obtained from the South African Census (Stats SA) and additional relevant sources. These datasets included key indicators such as population density, growth trends, and socio-economic variables at various spatial scales (e.g., municipal levels and census tracts). The inclusion of socio-economic data was crucial for assessing disparities in green space access, particularly in lower-income areas.

Data Processing and Analysis

GIS tools, such as ArcGIS and QGIS, were employed to process, analyze, and visualize the spatial data effectively. The steps involved in the analysis were as follows:

Mapping Green Spaces*:* GIS was used to create detailed maps illustrating the location, size, and distribution of green spaces within Durban. These maps categorized green spaces, including parks, gardens, forests, and open areas, based on their size, type, and ecological function. This classification provided insights into the variety and accessibility of green spaces.

Population Density Mapping: Population data were spatially visualized to reveal patterns of population distribution across the metropolitan area. This analysis was conducted at multiple scales, allowing for an understanding of how population density interacts with the availability and accessibility of green spaces.

Land-Use and Green Space Change Detection: Multi-temporal remote sensing data were processed to detect land cover changes over the study period. Change detection techniques, such as supervised classification and post-classification comparison, were applied to highlight trends in urban growth and green space transformation. The results correlated population growth with the observed changes in land cover, revealing the pressures of urban expansion on green spaces.

Spatial Statistical Analysis: Advanced spatial statistical techniques, including correlation analysis, spatial autocorrelation, and hot spot analysis, were utilized to explore relationships between population density and green space distribution. These methods identified critical areas with high population density but limited green space access, highlighting potential zones of social inequality.

Multi-Temporal Analysis: Temporal trends in green spaces and population dynamics from 2004 to 2024 were examined. This analysis quantified changes in green space size, distribution, and accessibility over time. By integrating these changes with population growth patterns, the study identified long-term trends and their implications for urban planning and sustainability.

Justification for Dataset Selection

The choice of datasets was guided by their relevance, accuracy, and availability, and are further explained below.

Satellite Imagery: Landsat imagery provided a balance between spatial resolution and temporal coverage, making it suitable for monitoring long-term changes. The availability of free, high-quality imagery further supported its selection.

Land-Use Data: The USGS datasets offered detailed land-use classifications, essential for mapping diverse urban land covers. Their credibility and global recognition ensured reliable analysis.

Population Data: Stats SA demographic data were chosen due to their comprehensive coverage of South African population dynamics, including socio-economic factors. These datasets allowed for granular analysis, critical for addressing disparities in green space access in lower-income areas.

The exclusion of qualitative data in this study was a deliberate choice to maintain a focused, objective analysis of urban expansion and green space dynamics through GIS and remote sensing. These methods allowed for a comprehensive, data-driven assessment of land-use changes and population growth across Durban CBD and over a long period. This approach prioritized clarity, precision, and consistency in understanding spatial patterns and trends. Hence, the study's goal was to provide a solid, quantifiable foundation for future research that could integrate these perspectives. Ultimately, the decision to exclude qualitative data ensures a rigorous, standardized analysis that serves as a stepping stone for more in-depth, community-driven research in the future.

The Study Area

The study focused on Durban Metropolis, the third-largest city in South Africa, known for its coastal location, rapid urbanization, and demographic diversity (McBride, 2022). Durban, located on the eastern coast of South Africa, has a subtropical climate, characterized by mild, wet winters and hot, humid summers. The city is known for its warm temperatures, high humidity, and rainfall, influenced by its proximity to the Indian Ocean (Bond and Galvin, 2023). Durban is situated at approximately 29.8587° S latitude and 31.0218° E longitude on the southeastern coast of South Africa (Ndlovu et al. 2021). This strategic location places it along the eastern seaboard, making it one of the country's most important port cities. Durban's geographical positioning contributes significantly to its tropical climate and its status as a major commercial hub. Durban's climate is classified as humid subtropical (Cfa) according to the Köppen climate classification system (Mgadle, 2022). This type of climate is characterized by warm, humid summers and average temperatures ranging from 24°C (75°F) to 30°C (86°F) during the summer months

(November to March), with highs occasionally exceeding 30°C (86°F). The heat is often tempered by sea breezes from the Indian Ocean, providing some relief from the intense heat, while the winter season (June to August) are warm and pleasant, with average daytime temperatures ranging between 14°C (57°F) and 25°C (77°F) (Abel, 2022). Nights can be cooler, but freezing temperatures are extremely rare. Humidity levels in Durban are generally high throughout the year, particularly during the summer months, with averages around 70-80% but can rise above 90% during periods of rainfall. The city's proximity to the ocean exacerbates the humidity, making the heat feel more intense in the summer. While Durban experiences relatively mild temperature variation between seasons, the differences in humidity and rainfall levels play a larger role in distinguishing summer and winter months. The warm ocean currents and trade winds contribute to Durban's relatively mild winters and humid, rainy summers (Yasini, 2020).

Durban experiences a moderately high annual rainfall, with the wettest months typically being from October to April, aligning with the Southern Hemisphere's summer season. Average annual precipitation is approximately 1,000 mm (39 inches), but this varies across different parts of the city. The city receives most of its rainfall during the warmer months, with afternoon thunderstorms being common. This results in a peak rainfall period from November to March. December and January are typically the wettest months, contributing to the humid, tropical environment. Rainfall in winter (from May to September) is much lower, and these months are drier, with average monthly rainfall dropping to 50 mm or less. Despite being the dry season, light showers can still occur, particularly in the early mornings or late evenings. The amount of rainfall varies slightly across Durban's different regions. Areas closer to the coast receive more rainfall compared to inland regions due to the orographic effect, where moist air is forced up by the terrain, leading to increased precipitation. Humidity in Durban is notably high throughout the year due to its coastal location. The proximity to the Indian Ocean means that there is a constant influx of moisture into the air, which increases the perceived temperature during the summer months. The average relative humidity is typically 70%–80% during the summer months: This results in the air feeling warmer and heavier, with a higher chance of discomfort during peak daytime hours. The humidity remains relatively high (about 60%–70%) during the winter months when compared to many inland cities, contributing to a mild and comfortable climate, although it can feel cooler in the early mornings and evenings. Humidity is generally highest during the afternoon in the summer, especially during or after rainfall, contributing to the humid tropical feel of Durban's summer weather. This is often compounded by the heat, leading to a more intense feeling of warmth and sometimes discomfort. Durban's coastal position means it is significantly influenced by the Indian Ocean, both in terms of temperature regulation and weather patterns. The Benguela current, which flows northward along the coast of South Africa, brings cooler water to Durban during the summer, mitigating some of the heat. Additionally, the city often experiences south-easterly winds during the summer months, which can bring relief from the humidity and moderate high temperatures. Durban's location on the eastern coast also means that it receives a fair amount of sunshine throughout the year. The combination of sunshine, high humidity, and ocean breezes gives Durban its characteristic warm, subtropical climate that supports lush vegetation and a thriving ecosystem. Figure 2 depicts the Map of the Study Area.

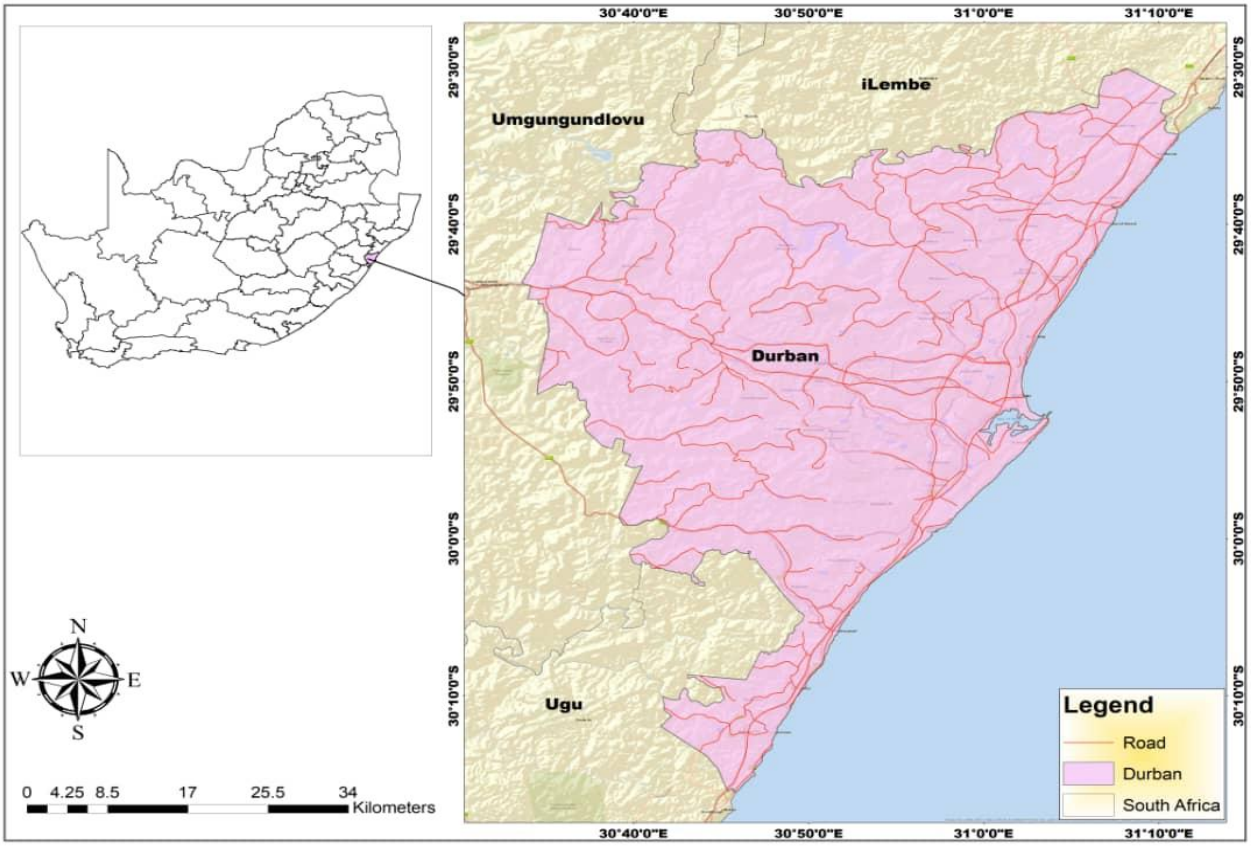

Figure 2: Digitized Political Map of the Study Area (Source: Authors)

Impact of the Durban Climate on Urban Green Spaces

Durban's warm, humid, and sometimes rainy climate supports a variety of lush vegetation, making urban green spaces an important part of the city's ecosystem. However, the city's tropical climate also presents challenges for urban planning. The high temperatures and humidity can place stress on green spaces, as they require regular maintenance, irrigation, and proper care to remain sustainable, especially during periods of intense heat or rainfall. In terms of population dynamics, the accessibility and quality of green spaces in Durban are also influenced by seasonal changes in weather. For instance, during the summer months, urban parks and open spaces may experience heavy rainfall, which can limit access or usage, while in the winter, the relatively mild weather encourages outdoor activities and may increase the use of public green spaces. The city's population has been increasing steadily, putting pressure on both the urban infrastructure and green spaces. The study will cover the entire metropolitan area, including central urban zones, suburban regions, and peri-urban areas. This comprehensive approach allows for an in-depth analysis of how population growth influences green space availability across different socio-economic regions of the city.

Data Collection

Spatial data for the study was gathered through remote sensing technologies, GIS, and satellite imagery. The data sources included:

Satellite Imagery: Landsat imagery (or higher-resolution imagery where available) was used to analyze land cover and land-use changes in Durban from 2004 to 2024. This time frame allowed for the examination of long-term trends in urbanization and green space loss or expansion.

Land-Use Data: Available urban planning and land-use datasets were used to map land-cover categories, including urban areas, green spaces, residential, commercial, industrial, and vacant land. These datasets were sourced from the United States Geological Survey (USGS) website.

Population Data: Population data were sourced from the South African Census (Stats SA) and other relevant demographic datasets. The data included population density, growth trends, and socio-economic indicators at different spatial scales (e.g., municipal level, census tracts).

Data Processing and Analysis

The geo-spatial analysis was carried out using GIS software, such as ArcGIS or QGIS, to process and analyze the collected spatial data. The following steps were involved:

Mapping Green Spaces: GIS was used to map the location, size, and distribution of urban green spaces in Durban. This included parks, gardens, forests, and open spaces categorized by their size, type, and ecological function.

Population Density Mapping: Population data were mapped to visualize the distribution of the population across Durban's metropolitan area. This was done at multiple levels to understand population concentration and its relationship to green space availability.

Land-Use and Green Space Change Detection: Remote sensing data were processed to detect changes in land cover, particularly in relation to urban growth and the loss of green spaces. Multi-temporal analysis using images from different time periods identified trends in green space reduction or expansion, correlating these changes with population growth.

Spatial Statistical Analysis: Spatial statistics, such as correlation analysis, spatial autocorrelation, and hot spot analysis, were conducted to determine the relationship between population density and the distribution of green spaces. These techniques helped identify areas of high population density with limited access to green spaces.

Multi-Temporal Analysis: A key part of the analysis involved examining temporal changes in green spaces and population dynamics from 2004 to 2024. This helped identify long-term trends in urbanization and the resulting pressures on green spaces. Changes in green space size, distribution, and accessibility were analysed alongside population growth patterns to understand their interaction over time.

Analysis of Results

LULC Processing of Satellite Images

Landsat 7 ETM data from 2004, along with Landsat 8 and 9 OLI/TIRS data from 2014 and 2024, covering path 168 row 081 and Path 168 row 080, were spatially georeferenced with a 30-meter spatial resolution. The Landsat imagery for the study period (2004-2024) was acquired in November, 2024. Radiometric correction was applied, followed by clipping the raster to align with the study area's boundaries. The imagery was resampled to a 5-meter pixel resolution to correct any potential distortions or inaccuracies, a method supported by studies from Quan (2020) and Yan et al. (2020). A multispectral composite was then created to ready the data for image classification.

Image Classification

A supervised image classification approach was carried out in ArcGIS 10.8 environment, which is crucial for change detection studies as it enhances the accuracy of identifying and mapping land cover changes through training algorithms with labelled data. This method refines the precision of detecting and analysing transformations over time. The image was categorized into six distinct classes: built-up areas, agricultural land use, grassland, dense vegetation, water bodies, and barren land, based on their spectral signatures. Training samples were developed on the composite image to establish a classification signature. Using the maximum likelihood algorithm, pixels were allocated to the class with the highest probability according to their spectral characteristics, consistent with findings by Rimal et al. (2020) and Liang et al. (2022). Figure 3 provides a detailed description of the LULC for the study area in 2004.

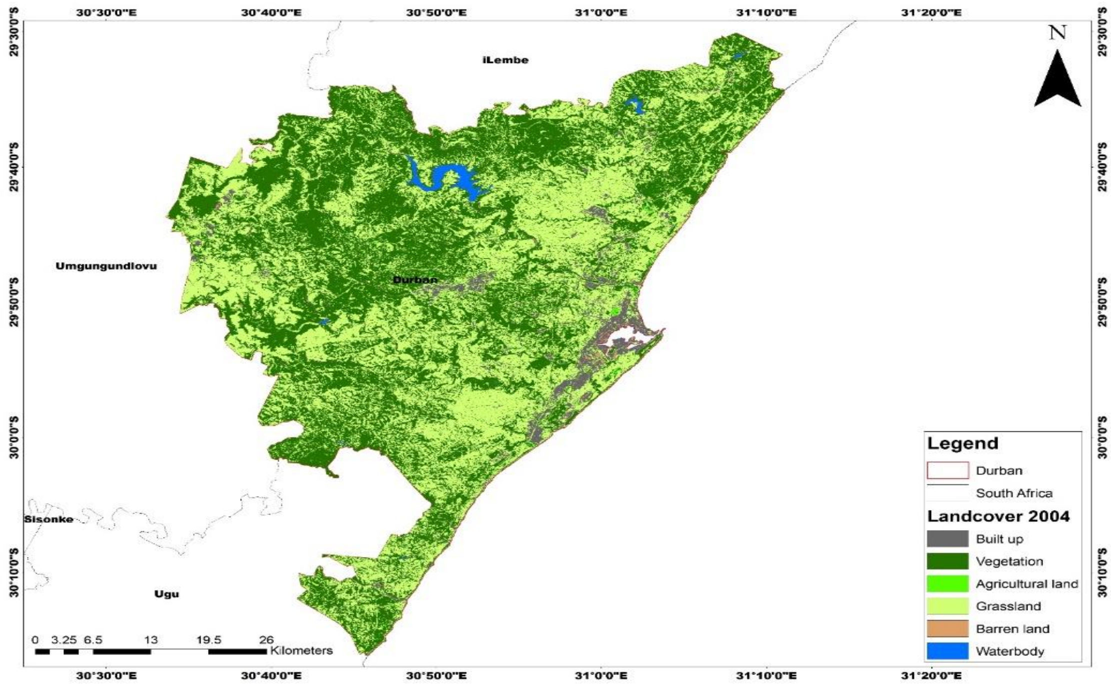

Figure 3: The LULC for the Study Area in 2004 (Source: Authors, 2024).

The LULC results for 2004, as depicted in Figure 3, indicate the spatial distribution and extent of various land cover types within the study area. The data show that Built-up Areas covered approximately 80.31 km^2, representing areas developed for urban or residential purposes. This relatively small proportion suggests limited urban expansion at that time. Vegetation was the most extensive class, occupying around 1104.40 sq km. This indicates that dense vegetation, including forests or other natural plant cover, was predominant in the landscape. Agricultural Land accounted for 7.66 km^2, signifying that cultivated areas were minimal compared to natural vegetation and grasslands. Grassland covered about 1051.23 km^2, showing a significant portion of open, non-forested areas, which could include fields and savannas. Barren Land, with only 5.96 km^2, represented areas with minimal to no vegetation, such as rocky or sandy regions. Waterbodies occupied approximately 15.46 km, indicating the presence of lakes, rivers, or other water sources, which were limited in extent compared to vegetation and grassland. Figure 4 provides a detailed description of the LULC for the study area in 2014.

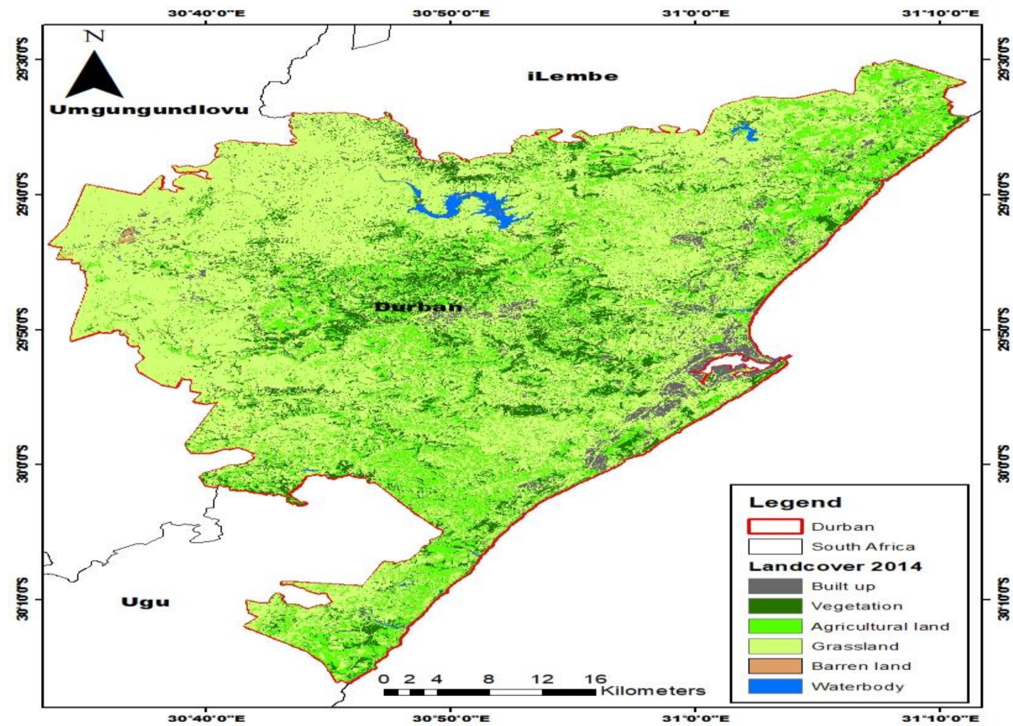

Figure 4: The LULC for the Study Area in 2014 (Source: Authors, 2024).

The LULC results for 2014 in the study area, as shown in Figure 4, reflect significant shifts in land cover types compared to 2004. For example, Built-up Areas expanded to 96.17 sq km, showing an increase from 2004. This growth indicates ongoing urbanization and development, possibly due to population growth or economic expansion. Vegetation decreased substantially to 273.01 km^2, a notable reduction from the 1104.40 km^2 recorded in 2004. This decline suggests a significant loss of dense natural vegetation, likely due to urban expansion, agricultural activities, or deforestation. Agricultural Land saw a dramatic increase to 450.96 km^2, up from 7.66 km^2 in 2004. This growth implies that a large portion of the natural landscape was converted into farmland, which could be linked to increased agricultural demands or shifts in land use practices. Grassland increased to 1442.70 km^2, showing bigger proportion from 1051.23 km^2 in 2004. This rise could be due to vegetation being cleared or altered into less dense grassland types, supporting grazing or transitional land use. Water Bodies decreased to 4.57 km^2 from 15.46 km^2 in 2004, indicating a reduction in water coverage. This could be due to changes in water management, reduced rainfall, or land development impacting natural water sources. Figure 5 provides a detailed description of the LULC for the study area in 2024.

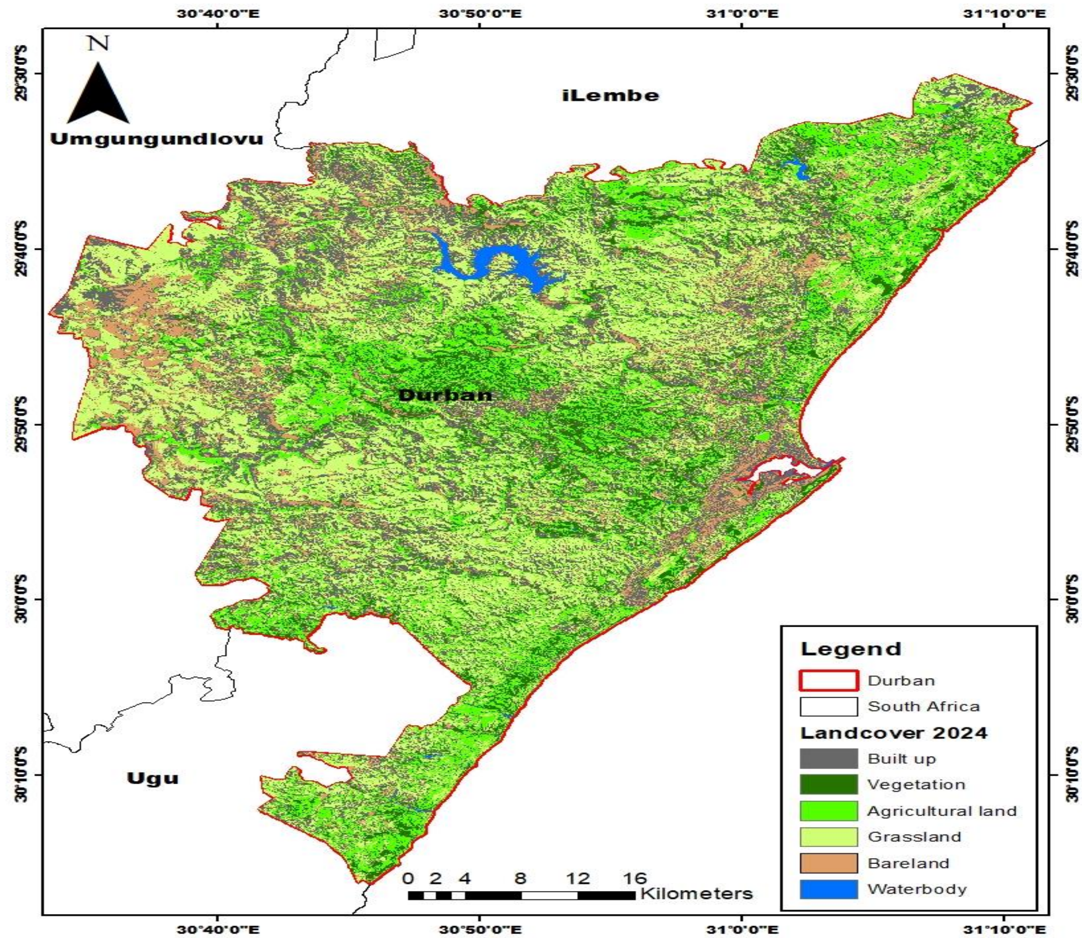

Figure 5: The LULC for the Study Area in 2024 (Source: Authors, 2024).

The LULC results for 2024, in the study area as depicted in Figure 5 reveal continued and significant land cover changes over the 20-year period. For example, Built-up Areas increased to 150.93 km^2, showing substantial growth from 96.17 km^2 in 2014 and 80.31km^2 in 2004. This trend reflects ongoing urban expansion, likely driven by population growth, infrastructure development, and economic activities. Vegetation further declined to 203.20 km^2, continuing its downward trend from 273.01 km^2 in 2014 and 1104.40 km^2 in 2004. This significant reduction suggests continued deforestation or land conversion for development and agriculture, indicating a loss of dense natural cover. Agricultural Land expanded slightly to 485.01 km^2, up from 450.96 km^2 in 2014 and 7.66 sq km in 2004. This growth points to sustained agricultural development, likely reflecting increased food production or land reallocation for farming. Grassland decreased to 757.43 km^2 from 1442.70 km^2 in 2014, marking a notable decline. This suggests that grasslands may have been converted into agricultural land or developed into built-up areas, further indicating land-use pressures. Barren Land emerged significantly, reaching 201.39 km^2, a notable increase compared to its negligible presence in 2004 and absence in 2014. This could indicate areas affected by land degradation, deforestation, or other disturbances resulting in exposed soil or rocky terrain. Water Bodies increased to 16.10 km^2, up from 4.57 km^2 in 2014 and comparable to 15.46 km^2 in 2004. This rise might be due to restoration efforts, improved water management, or natural changes such as increased rainfall or expanded water bodies.

Table 1.
LULC of the Study Area from 2004-2024

LULC Category	2004 (in km^2)	Percentage of Total Area	2014 (in km^2)	Percentage of Total Area	2024 (in km^2)	Percentage of Total Area
Built-Up Areas	80.311971	3.545735942	96.166782	4.2457184	150.928001	8.3199506
Vegetation	1104.399817	48.75873518	273.013952	11.963547	203.197485	8.9041704
Agricultural land	7.662406	0.33829164	450.955915	19.761014	485.009072	21.253233
Grassland	1051.234491	46.41151091	1442.702377	63.21962	757.425907	33.190614
Barren land	5.957305	0.263012228	4.567042	0.2001291	201.390527	8.824989
Waterbodies	15.463677	0.682714104	14.642403	0.6416342	16.098242	0.7054295

Source: Authors, 2024

POPULATION DYNAMICS OF THE STUDY AREA (2004–2024) AND PROJECTIONS FOR 2034

The study area has experienced notable shifts in population dynamics over the past two decades, influenced by factors such as migration, urbanization, and natural population growth. These changes have significantly impacted land use and resource distribution, shaping social and economic conditions. Understanding the patterns and drivers of population change is crucial for assessing how they interact with land use and urban development, informing future planning and policy decisions to support sustainable growth and community well-being. Figure 6 provides a detailed description of the population dynamics for the study area from 2004 to 2024 and the projected population for 2034.

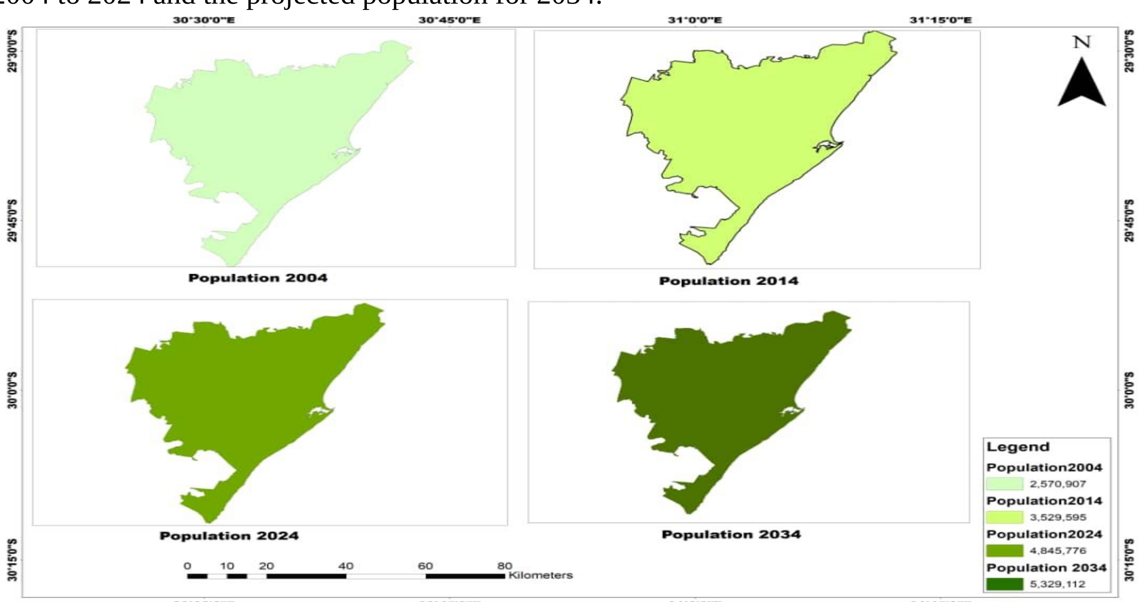

Figure 6: The Population Dynamics for the Study Area from 2004 to 2024.

Figure 6 illustrates the population dynamics for the study area from 2004 to 2024 and the projected population for 2034. Between 2004 and 2024, the study area has experienced a substantial increase in population, growing from 2,570,907 in 2004 to 4,845,776 in 2024. This surge represents a significant demographic change driven by natural population growth and migration, fueled by the attractiveness of urban centers due to better job prospects, education, and social services. By 2034, the population is projected to reach 5,321,112, suggesting a continued upward trend, albeit at a potentially slower growth rate than in previous decades. The implications of this growing population are profound, influencing various aspects of land use, urban development, and economic conditions. The formula for calculating the population dynamics for the study area for the study area is presented below:

Formula - P=P0×(1+r/100)t

where:

- P is the projected population,
- P0 is the initial population,
- r is the annual growth rate (expressed as a percentage, so it should be divided by 100 to convert to decimal form),
- t is the number of years for the projection. The population projection of Durban was projected using the formula above and the projection rate for each years.

Implications of the Population Dynamics of Durban Metropolis on Green Spaces and Socio-Economic Development

The rapid increase in population from 2004 to 2024 has had noticeable impacts on land use and green space availability, as reflected in the LULC results. The expansion of built-up areas, which more than doubled over the 20-year period, has come at the expense of green spaces and natural landscapes. This transformation underscores a shift towards urbanization that, while supporting economic growth and infrastructure development, poses significant challenges to environmental sustainability. The decline in vegetation cover and reduction in grassland areas indicate a loss of ecological spaces that provide critical benefits such as air quality improvement, temperature regulation, and recreational areas for residents. The implications of such LULC changes on population dynamics are substantial. The rising population density leads to increased demand for housing, transportation, and public services, which can strain existing urban infrastructure and lead to overcrowded conditions. The limited availability of green spaces can negatively affect residents' quality of life, contributing to urban heat island effects, decreased air quality, and reduced opportunities for leisure and physical activities. These conditions can further exacerbate health disparities and reduce overall urban livability. Economically, the expansion of urban areas suggests positive growth trends, with increased business activity, job creation, and investments in construction and other sectors. However, unplanned or poorly managed urban growth can lead to challenges such as insufficient infrastructure, informal housing, and economic inequality. Moreover, the conversion of green spaces into built-up areas may undermine long-term economic resilience, as ecological degradation can lead to higher costs related to environmental restoration and health care.

Future Implications (Projected for 2034)

With the population projected to reach 5,321,112 by 2034, the pressure on existing green spaces and urban infrastructure will only intensify. If the trend of urban expansion at the expense of vegetation and grasslands continues, the study area could face more severe urban sustainability issues. This includes potential declines in biodiversity, worsened air and water quality, and increased vulnerability to climate change impacts, such as heatwaves and flooding. To balance the economic benefits of urban growth with environmental and social sustainability, it is essential to adopt comprehensive urban planning strategies. Policies that emphasize the conservation of green spaces, integrate eco-friendly infrastructure, and promote sustainable land use practices can help mitigate the negative effects of rapid population growth. Initiatives to enhance public green spaces, support mixed-use developments, and encourage community participation in urban decision-making are vital for ensuring that economic development does not come at the expense of environmental health and social well-being.

Socio-Economic and Cultural Dimensions of Urban Green Space Access in the Study Area

The socio-economic and cultural dimensions of urban green space access in the Durban CBD are deeply intertwined with the patterns of urban growth, population dynamics, and social stratification observed in the study. As the population in the CBD surged from 2.57 million in 2004 to 4.85 million in 2024, and is projected to reach 5.32 million by 2034, the pressure on urban land intensified, leading to the rapid expansion of built environments at the expense of green spaces. This urban growth disproportionately affected lower-income communities, limiting their access to green spaces and exacerbating socio-environmental inequities. For many low-income residents, particularly those living in informal settlements and densely populated neighborhoods, green spaces are often perceived as distant and inaccessible, both physically and economically. The reduction in green spaces, from 1,104.4 km² in 2004 to 203.2 km² by 2024, has made it increasingly difficult for these communities to access the environmental and social benefits associated with parks and recreational areas. This limitation not only compromises their physical health due to reduced opportunities for outdoor activities but also has negative implications for mental well-being, which is often supported by access to nature. Culturally, green spaces in urban environments serve as vital communal areas where social cohesion can be fostered, offering opportunities for cultural expression, community events, and collective identity-building. However, the unequal distribution of green spaces often means that marginalized communities, particularly those in lower-income areas, are excluded from these social and cultural benefits. This exclusion further deepens social divisions, as wealthier neighborhoods tend to have greater access to well-maintained parks and open spaces, contributing to a growing urban divide. The findings highlight how cultural and social dynamics in urban areas are shaped by the availability and accessibility of green spaces. While wealthier communities may use green spaces for leisure, recreation, and social gatherings, those in disadvantaged areas are more likely to face barriers such as limited physical proximity, poor maintenance, and even a lack of cultural relevance in the design of available green spaces. In essence, addressing these disparities requires a comprehensive approach to urban planning that not only focuses on the equitable distribution of green spaces but also incorporates the social, cultural, and economic needs of all residents, fostering an environment where everyone can benefit from the full range of ecological and social advantages that green spaces offer.

Conclusion

The interplay between LULC dynamics and population growth in the Durban CBD offers a profound reflection of both the socio-environmental challenges and opportunities that come with urban expansion. Over the past two decades, rapid urbanization has reshaped the landscape, reflecting both positive economic growth and the strain on natural resources. From a cultural, social, and spatial humanities perspective, the LULC changes illustrate not only shifts in physical space but also the evolving human narratives tied to these spaces. These transformations—especially the reduction of green spaces and increase in urban density—highlight the need for urban planning policies that prioritize cultural, social, and environmental equity. The expansion of built-up areas and the increasing population density have fostered economic growth, creating new opportunities in real estate, retail, and manufacturing. However, as population growth outpaces infrastructure development, the increasing strain on public services, housing, and natural resources cannot be ignored. This dynamic exacerbates social inequality, particularly in lower-income neighbourhoods that often face limited access to green spaces and essential services. From a cultural standpoint, green spaces are not just environmental assets but cultural and social hubs that define community identity and cohesion. It is crucial that green space development integrates the cultural histories and lived experiences of Durban's diverse communities, ensuring that these spaces reflect the city's rich heritage and provide equitable access for all residents.

In terms of social implications, the loss of natural vegetation and the shift towards agricultural expansion speak to a broader challenge of balancing economic development with environmental sustainability. While the agricultural growth supports food security and employment, it also places immense pressure on the land, threatening ecological resilience and biodiversity. A sustainable approach to agriculture, one that incorporates local knowledge and cultural practices, can mitigate some of these environmental challenges while ensuring that the livelihoods of vulnerable populations are protected. Thus, the urbanization of Durban presents a dual challenge: the need to foster economic growth and social equity while preserving the ecological balance. From a spatial humanities perspective, the transformations in land use also reflect shifting power dynamics and cultural narratives. The reduction of green spaces, once places of community gathering, not only reduces access to essential environmental services but also impacts the social cohesion of neighbourhoods. It is essential to reframe green space development not merely as a landscape intervention but as a cultural and social project that addresses inequities in access, representation, and community well-being. For future planning, policy must integrate cultural, social, and environmental considerations at every stage. Sustainable urban policies should prioritize the creation of culturally sensitive, socially inclusive, and environmentally resilient green spaces. These spaces should serve as centres for cultural exchange, social interaction, and environmental education, bridging the gap between diverse communities while enhancing overall urban livability. Furthermore, policy must encourage the sustainable management of agricultural lands and the restoration of degraded areas, aligning land use with both environmental and social justice goals. Ultimately, the changes observed in the LULC from 2004 to 2024 underscore the critical need for comprehensive urban planning that embraces the interconnectedness of space, culture, and society. Only through an integrated approach that balances economic growth with cultural and environmental sustainability can Durban navigate its urban future while ensuring a thriving, equitable, and socially cohesive metropolis. The challenge lies in creating a city where growth benefits all, where green spaces are accessible and meaningful to every community, and where urban development enhances rather than detracts from the city's cultural and ecological richness.

Recommendations

Creating a more sustainable, inclusive, and socially cohesive Durban CBD requires a comprehensive approach to urban planning, one that integrates cultural, social, and spatial humanities considerations. By applying these principles to green space policies and development strategies, we can address socio-environmental inequities while fostering a vibrant and equitable urban landscape. Below are actionable recommendations, each designed to resonate deeply with diverse communities and urban planners, and to create green spaces that are not only ecologically beneficial but also culturally enriching and socially empowering.

Transform Green Spaces into Cultural Hubs

Urban green spaces should not only serve as recreational areas but as cultural landmarks that reflect and celebrate the diverse communities of Durban CBD. The design and programming of green spaces should integrate local cultural values, creating environments that resonate with the city's social fabric. By incorporating elements of Durban's rich heritage—such as indigenous plants, historical markers, and art installations reflecting local traditions, parks and open spaces can become dynamic cultural spaces. These green areas could host community-driven events like traditional music performances, cultural festivals, and educational workshops that celebrate the city's history and identity. This approach ensures that every resident, regardless of their background, feels a sense of ownership and pride in the spaces they inhabit. By making green spaces cultural centres, we enhance social cohesion, foster a deeper sense of belonging, and create environments where cultural diversity is not just tolerated but celebrated.

Foster Social Cohesion and Equity in Green Space Policies

Green spaces are pivotal in fostering social cohesion, and their design should intentionally cater to the needs of all urban residents, especially those from underserved communities. Accessible, well-maintained parks should be strategically distributed across the city, ensuring that no neighbourhood is left behind. Geo-spatial analysis can pinpoint areas with significant green space deficits, enabling planners to prioritize development and improvement efforts where they are needed most. In addition to physical access, green spaces should serve as platforms for social interaction, offering multi-functional areas where people of all ages and cultural backgrounds can connect. Interactive spaces, such as playgrounds, communal gardens, or spaces for sports and outdoor gatherings, encourage diverse groups to engage with each other, breaking down social barriers. Furthermore, programs such as community-led gardening initiatives or environmental education workshops not only engage residents in sustainable practices but also strengthen social ties. By ensuring that green spaces are accessible, functional, and inclusive, we can create places where people from all walks of life feel equally valued and connected.

Integrate Spatial Humanities to Reflect Human Narratives in Urban Planning

Spatial humanities, which blends spatial analysis with cultural and social contexts, provides a powerful framework for understanding how urban environments can shape and reflect human experiences. Green space planning in Durban should not only be about improving physical access but also about respecting and amplifying the lived experiences of residents. This can be achieved by mapping and preserving sites of historical, cultural, and social significance within urban green spaces. These areas could tell the story of Durban's diverse communities, with educational materials and storytelling features that reflect local histories. For example, interpretive signage and digital platforms could highlight the rich cultural heritage and historical events tied to specific green spaces, allowing visitors to engage with the narratives that make these areas meaningful. Such initiatives would turn green spaces into living classrooms, encouraging deeper engagement with the city's spatial history and fostering a collective sense of ownership and pride among residents.

Prioritize Sustainability through Nature-Based Solutions

The environmental sustainability of Durban's green spaces is as important as their social and cultural value. Incorporating nature-based solutions into urban green spaces not only enhances biodiversity but also makes the city more resilient to the impacts of climate change. From green roofs and urban forests to rain gardens and bioswales, these interventions can help manage stormwater, reduce the urban heat island effect, and improve air quality. The use of native plants in parks can also provide habitats for local wildlife, promoting biodiversity in urban areas. These sustainable practices not only enhance the aesthetic and ecological value of green spaces but also contribute to the overall health and well-being of the city. By integrating these nature-based solutions into urban planning, we can create green spaces that serve as environmental assets, supporting both the city's ecosystem and the quality of life for its residents.

Strengthen Community Engagement and Ownership

The active involvement of local communities in green space planning and management is essential for the long-term success of any green space initiative. A participatory approach to urban planning empowers residents by allowing them to shape the spaces they use. Community workshops, focus groups, and public forums can be organized to gather input and ensure that the needs and aspirations of residents are reflected in the design of green spaces. Furthermore, fostering a sense of ownership among community members can lead to more sustainable outcomes. Programs like "Green Ambassadors" or volunteer-led clean-up initiatives can encourage residents to take responsibility for maintaining their local parks and green spaces, strengthening their investment in these spaces. Education and awareness campaigns can also help residents better understand the environmental, health, and social benefits of green spaces, promoting a culture of care and collective responsibility.

Continuously Monitor and Adapt Policies Based on Data

Green space policies must be flexible and responsive to the evolving needs of the community. Regular monitoring and evaluation of green space accessibility, usage, and social impact are essential for ensuring that policies remain relevant and effective. GIS tools and spatial analysis should be used to assess the ongoing distribution and quality of green spaces across Durban, with periodic surveys to capture community feedback. This data can inform adaptive management practices, enabling city planners to make timely adjustments to policies and designs as demographic shifts and urban trends evolve. Regular assessments and community consultations ensure that green spaces remain vibrant and relevant, addressing new challenges and opportunities as they arise.

By integrating cultural, social, and spatial humanities considerations into green space planning, Durban can create an urban environment that is not only more sustainable but also more socially inclusive and culturally rich. These recommendations lay the foundation for a future where green spaces serve as hubs of social interaction, cultural expression, and environmental stewardship, addressing both the ecological and socio-economic challenges faced by the city. In doing so, Durban can emerge as a global model of urban resilience and social equity, creating a cityscape where every resident feels connected, valued, and empowered.

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