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AN EXAMINATION OF GREEN SPACE EXPOSURE FOR WELL-BEING: A CASE STUDY OF COLOMBO CITY

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ABSTRACT

The rapid increase in population density has led to a scarcity of green spaces and limited access to green space for urban dwellers. Green spaces play an important role in promoting human well-being; both socially and psychologically. Ensuring equal access to green spaces is essential for creating equitable cities. When everyone has the opportunity to enjoy parks, gardens, and natural areas, it contributes to a healthier and more inclusive urban environment. However, Colombo, Sri Lanka's bustling city faces challenges in providing habitable and accessible green areas for its residents. This paper aims to assess green space exposure in the city of Colombo. The study examines the provisions, distribution, and accessibility of green areas across CMC's administrative areas, including North Colombo, Central Colombo 1, Central Colombo 2, Colombo East, Colombo West, and Borella. By using a multidimensional approach that combines ArcGIS mapping, spatial tools, population statistics, and remote sensing (via NDVI mapping), the research explores green space availability and proximity-based accessibility for the diverse urban population. This investigation is crucial for informed urban planning and enhancing the quality of life for Colombo's residents.

Keywords: *Green Space; Green Infrastructure; GIS; Green Space Exposure; Remote Sensing; Urban; Wellbeing.*

1. INTRODUCTION

Urbanisation is a worldwide phenomenon that refers to the increasing concentration of populations in urban areas, resulting in the growth and expansion of cities. It encompasses various social, economic, and environmental changes, leading to transformations in landscapes and lifestyles (Teleaga, 2020). The United Nations predicts that by 2050, there will be 6.252 billion people living in urban areas around the world, with an anticipated urbanisation rate of 67.2%. Rapid urbanisation has resulted in an increase in built areas and reduction and loss of urban green spaces and natural environments. The provisions and access to green spaces in cities is a United Nations Sustainable Development Goal (Goal No. 11.7), which aims to provide universal access to safe, inclusive, and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities by the year 2030 (WHO Regional Office for Europe, 2016). The benefits and contributions of green spaces are many. They contribute to improving physical and

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mental health, social interaction, and opportunity for active lifestyle and relaxation. They provide physical comfort by improving air quality, providing shade, mitigating urban heat island effects and enhancing the overall environmental quality of cities.

The loss of green spaces in cities contributes to decrease in physical activity, increased stress, and decreased social cohesion. International organisations and institutions have expressed the minimum limits for per capita green space, for overall wellbeing. UN expressed that the per capita green space should be more than $30m^2$, European Union (EU) says it has to be over $26m^2$, while the World Health Organisation (WHO) recommends it should be more than $9m^2$. (Lin & Pussella, 2016). However, the per capita green space in Colombo District has been significantly decreasing from $18.047m^2$ in 2008 to $13.582m^2$ in 2015, with a reduction of 4.46%. Hence, the predicted per capita green space in 2025 is $7.21m^2$ (Lin & Pussella, 2016). There is a concern that there is inequality in the provisions and access to green space within Colombo's administrative area. Although Urban Regeneration Projects have been implemented to house significant numbers of urban poor in the North and North-Eastern parts of Colombo, there is a concern over the provision and access to green space, in the form of parks, urban pockets, green walkways, playgrounds, and urban landscapes. Thus, raising concerns on equality across neighbourhoods when considering the provisions and access to urban green space. The study examines the provisions, access and green space exposure across administrative areas within the Colombo Municipal Council.

2. GREEN INFRASTRUCTURE

2.1 INTRODUCTION TO GREEN INFRASTRUCTURE

Many researchers have traditionally defined green infrastructure based on its thematic relevance, use, and real-world applications, as well as terms relating to larger connections between nature and humans in evolutionary biology, psychological evolution, social economics, and conservation (WHO, 2016). Green infrastructure is a collection of natural materials that generates a life support system while also benefiting humans and other animals. Green infrastructure, as described by Benedict and McMahon (2006), is "An interconnected system of natural areas and other open areas that conserves biological ecosystem values and function, maintains clean air and water, and provides a wide range of benefits to people and wildlife".

2.1.1 Typologies of Green Infrastructure

Green infrastructure plays a vital role in providing Eco-System Services (ESS) across different scales. At micro and small scales, elements of green infrastructure contribute to supporting and regulating services, such as improving air quality and modifying microclimates. On a larger scale, green infrastructure extends its functions to provisioning services, including urban agriculture, and cultural services that connect people with nature and enhance well-being (Hansen et al., 2017; Nieuwenhuijsen, 2020).

The concept of green space has garnered significant interest and research, particularly regarding its impact on health and well-being. Despite decades of studies in both urban and rural contexts, a universally agreed-upon definition of green space remains elusive (Nieuwenhuijsen,2020).

WHO has recognised the lack of consensus regarding the definition of green space, especially in urban contexts. Across different academic disciplines, the definition of

urban greens pace exhibits substantial variability (Taylor & Hochuli, 2017). Despite the lack of consensus, a few definitions of greens pace have gained traction in various fields. One widely accepted definition, derived from The European Urban Atlas, characterises green space as "public green areas used predominantly for recreation" (WHO, 2016). This definition primarily emphasises vegetated land accessible to the public, including spaces including public parks, gardens, forests, and natural areas.

2.2 GREEN SPACE EXPOSURE

Green space exposure refers to the extent and quality of individuals' interaction with natural environments, including parks, gardens, playgrounds, forests, and other vegetated areas. However, there have been limited studies on measuring green exposure, particularly in terms of proximity, availability, and quality of green space (Quid et al., 2023).

Green space is a broad term that encompasses both recreational and natural components. It includes everything from small urban parks and rivers to vast wilderness areas. Within this context, green spaces are often categorised into two groups: i.e., (i) unstructured green spaces, and (ii) structured green spaces (Markevych et al., 2017; Zhang et al., 2020). Vegetative cover, which encompasses elements such as street trees, residential greenery, and urban agriculture, falls under the category of unstructured green space. Moreover, structured green spaces refer to park-based areas with recreational amenities, such as playgrounds, sports fields, water parks, pocket parks, and squares (Quid et al, 2023).

2.2.1 Importance of Green Space Exposure for Human Health and Wellbeing

Numerous studies worldwide, especially in China, have explored the impact of green spaces on human health and well-being. These studies often focus on the psychological well-being of people in rapidly urbanised cities. Across environmental, social, and health sciences, there is consensus on the positive effects of nature encounters on mental health. As urbanisation continues and global contact with nature decreases, safeguarding and enhancing opportunities for nature experiences become crucial. Green areas hold significant potential for improving public health.

2.2.2 Impact of Green Space Exposure on the Environment

Green spaces in cities improves the overall environmental sustainability. Green spaces help to reduce the impact of the urban heat island effect by providing shade, lowering temperatures, and improving air quality by absorbing pollutants and producing Oxygen.

According to Chiesura (2004; as referenced in Assali, 2015), trees help to purify the air by absorbing Carbon Dioxide and creating Oxygen, as well as boosting quality of life. Green spaces, helps in maintaining biodiversity and promotes ecological balance in urban ecosystems by providing habitat for a variety of plant and animal species. They help manage storm water runoff, reduce flood risk, and improve water quality through natural filtration systems.

2.2.3 Impact of Green Space Exposure on Physical and Mental Wellbeing

Green areas offer valuable opportunities for physical activity, including walking, running, and leisure pursuits. Engaging in these activities contributes to improved physical health and fitness, benefiting both the body and mind. Exposure to green spaces and natural environments has been linked to reduced stress, enhanced mood, and better mental health.

Access to green areas has also been associated with lower rates of obesity, cardiovascular disease, and mental health challenges. Researchers, such as Ward et al. (2016), have found that physical activity and exposure to green spaces are independently connected to various aspects of child development, including emotional well-being and cognitive abilities. Nature also provides specific environmental stimuli necessary for recovering from attention fatigue a state that occurs during sustained cognitive tasks requiring directed attention (Kaplan,1995). Nature facilitates psychophysiological stress recovery through innate, adaptive responses to natural settings. Characteristics such as spatial openness, patterns or structures, and water features trigger positive emotional reactions related to security and survival (Ulrich,1983). Given the global trend of urbanisation and reduced human contact with nature, it is crucial to protect and enhance opportunities for nature experiences. Green areas hold significant potential for improving public health in diverse ways.

2.2.4 Impact of Green Space Exposure on Social Wellbeing

Parks and green spaces play a vital role in fostering social interaction and community building. They serve as meeting places, providing spaces for social gatherings, leisure activities, and get-togethers that promote social cohesion. By reducing social isolation and strengthening community bonds, green spaces contribute to a sense of belonging.

Beyond their social impact, green spaces enhance the aesthetics of urban areas. Amid the built environment, well-designed parks, gardens, and landscapes offer visual respite, evoking feelings of beauty, calm, and relaxation. These aesthetically pleasing settings improve both the surroundings and residents' quality of life. Moreover, green spaces contribute to sustainable urban design. They enhance climate resilience and are critical components of sound design principles.

2.3 ASSESSMENT OF GREEN SPACE

2.3.1 Green Space Availability

Structured Green Spaces

Structured green spaces are planned and managed green spaces within urban environments that serve multiple purposes. These are spaces designed to enhance the quality of life for residents. They contribute to the environmental quality of cities. Typical structured green spaces as parks play areas, grounds, greenways, and conservation areas. In this study the mapping of structured green spaces was done using Google Earth in ArcGIS using data files and digital maps from CMC and Google Earth (refer to Figure 2).

Greenness: measured by Normalised Difference Vegetation Index (NDVI)

The NDVI is a measure of how much live, green vegetation is present in an area; an indicator of an area's 'greenness'(WHO Regional Office for Europe, 2016). NDVI is calculated from the light reflected by vegetation, considering that healthy plants contain more chlorophyll, which increases the absorption of visible light (and thus decreases its reflection) and increases the reflection of near-infrared light, yielding higher NDVI values. Less healthy or densely distributed vegetation, on the other hand, reflects more visible light and less near-infrared radiation, resulting in a lower NDVI rating. This index considers every element of vegetation from satellite imagery, thus measuring far more than just urban green spaces. It is based on vegetation health, which may be affected by the season in which the images were captured as well as the plants' life cycle (Martinez

& Labib, 2023). For the NDVI analysis, satellite imagery was downloaded from land sat data using Earth Explorer website (downloaded data in time 2022-2023) and applied in ArcGIS with the equation of NDVI analysis in the field calculation option. The reclassify tool was used to analyse the high and low areas of the NDVI output map (refer to Figure 5).

2.3.2 Proximity-Based Accessibility

The buffer and network analysis approaches are the most commonly used methods for computing green space accessibility. Nicholls (2001) examined the two methods and determined that the latter is the most accurate. The buffer analysis is a Euclidean distance-based method that assumes people can move in straight lines within urban tissue, which is not typical of reality and may result in overestimation. Proximity-based accessibility is another parameter that green exposure studies used, when measuring accessibility within a 15-minute walking time distance, the alternative of using green areas' centroids as starting points of service areas is shown to have no significant impact compared to using public green spaces' access points (Giuliani et al., 2021).

Buffer Analysis

A buffer formed around a green area from a centroid method merely provides an estimate of how accessible a green space is to a group of people or a community (Nicholls, 2001). Kabisch et al. (2016) uses the buffer approach only estimate the amount of green space available to inhabitants by getting an idea of proximity to green spaces. Kabisch et al. (2016) built a boundary of 500m and 300m around the UGS examined for the study using data from Urban Atlas and municipal land-use data, and then intersected grid cells containing population data with these buffers, aggregating the result per city. WHO suggests that the consistent service distance of green space is 300 m hence this study uses a buffer range of 100m-300m. For the purpose of this study buffer analysis maps was created by using multiple buffer analysis, giving a 100m-300m radius from green space centroid (refer to Figure 4). Euclidean distance of 100m-300m was applied to identify how green spaces covered the buffer area of each district.

Network Service Analysis

The network analysis (Nicholls, 2001) is a more appropriate alternative considering space accessibility because it uses actual travel distances (in time and distance) and can be measured from starting points to urban green areas in a much more realistic way by using accurate road networks. Furthermore, it evaluates the green area's periphery rather than its centre, considering its shape, Both Nicholls (2001) and Gupta et al. (2016) compared both methods in previous papers, with the exception that the latter used remote sensing data; however, both concluded that the straight-line method and network measures have distinct differences in the level of accessibility (Nicholls, 2011). For this study, a pedestrian network was constructed using road network data (refer to Figure 4). Centroids were created for each green space and mapped the ranges of 100m-500m considering the WHO recommended human comfortable walking distance which is 400m-500m. Due to the absence of data on the location access points, centroids were constructed for each urban green space, as these provided a proxy for green space access point.

3. RESEARCH METHODOLOGY

The case study of Colombo administrative area was selected and six divisions i.e. (i) Colombo-North, (ii) Colombo-Central 1, (iii) Colombo-Central 2, (iv) Borella, (v) Colombo-West, and (vi) Colombo-East was explored for their open spaces and accessibility. This study was conducted by mapping the relevant data using the Arc GIS (version 10.8) tool. Parameters of green space availability and proximity is assessed. Using Arc GIS and remote sensing data, structured green space i.e. parks, playgrounds, communal gardens, and cemeteries were mapped through NDVI calculations and structured green space locations to explore green space exposure and availability. Proximity-based accessibility and network service analysis was done through the analysis of multiple buffer rings using Arc GIS spatial analysis tools. The spatial data (from 2010-2020) was obtained from the Urban Development Authority and Survey Department and Colombo Municipal Council. Census data of the year 2010 was obtained from Census and Static Department and remote sensing methods were used to obtain shape files (https://extract.bbbike.org/, Landsat imagery).

4. CASE STUDY AND ANALYSIS

4.1 CASE STUDY

Colombo city is located in the West coast of Sri Lanka between Northern latitudes 6◦55 to 6◦59 and Eastern longitudes 79◦50 to 79◦53 (refer to Figure 1). CMC administrative area is the region that encompasses the entire Colombo metropolitan area. It is the most significant local administrative authority in the country with an area over 37 km^2. The city is one of the oldest in South Asia (Senanayake at el., 2013). CMC area consists of 55 GN administrative divisions, the minor administrative units in the country. The study focuses on the Colombo municipal wards district, which encompasses various urban and densely populated areas. The selection of this study area is based on its significance as a central urban region in Sri Lanka, where green space exposure is of particular importance due to high population densities and urbanisation.

4.2 DATA ANALYSIS

The distribution of residential areas are shown in Figure 01 indicating a diverse distribution of residential clusters across Colombo-North, Central 1, Central 2, Borella, Colombo-East, and Colombo-West. However, Figure 02: the structured green space map shows that the green spaces are not equally distributed in the residential areas. It shows that Borella and Colombo-East has more provisions of green space as opposed to the other areas, where there are predominant residential clusters. The distribution of residential population, and amount of structured green spaces shows that there is a significant lack of green space availability in Colombo-North, Colombo Central-1 and Colombo-West. However, Colombo-West being in close proximity to the coast has the benefits of blue infrastructure as an alternative to green infrastructure. Colombo-North and Colombo-Central 1 are most deprived from green infrstarcture although observed as areas with high density of vulnerable low-income residents living in informal settlements and multistorey housing.

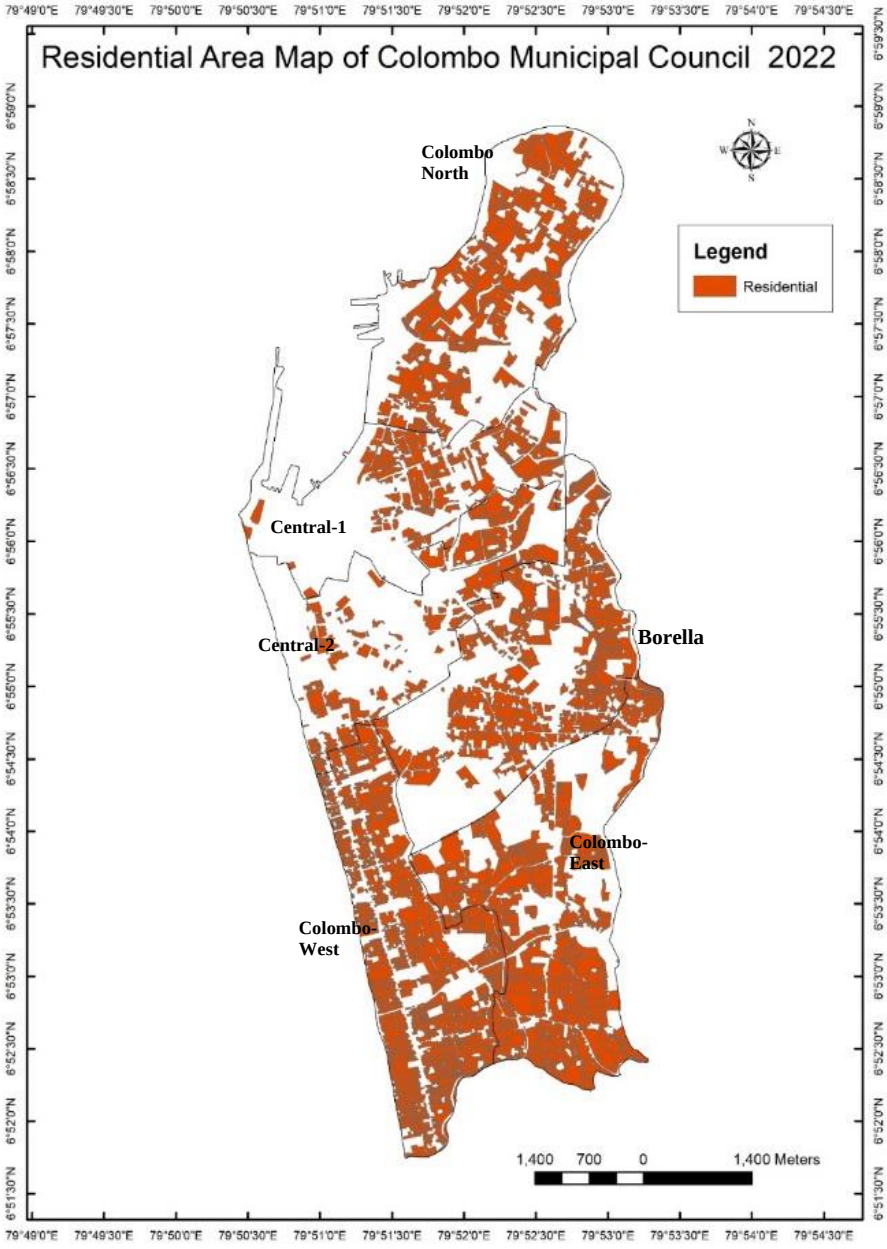

Figure 1: Residential distribution map in CMC area
Source: by author using GIS data

WHO recommended a minimum of $9m^2$ of green space per capita with an ideal UGS value of $50m^2$ per capita. As per Table 1, when comparing the green space per capita values across the Wards in CMC area it shows that only Borella is fulfilling the minimum green space standard set by the WHO while all other wards green space per capita is below the expected standards. As per Table 1 and Figures 1 and 2, it shows that high population sizes are in Colombo-North, Colombo-Central 1 and Colombo-Central 2 and they also have the lowest Green Space per capita.

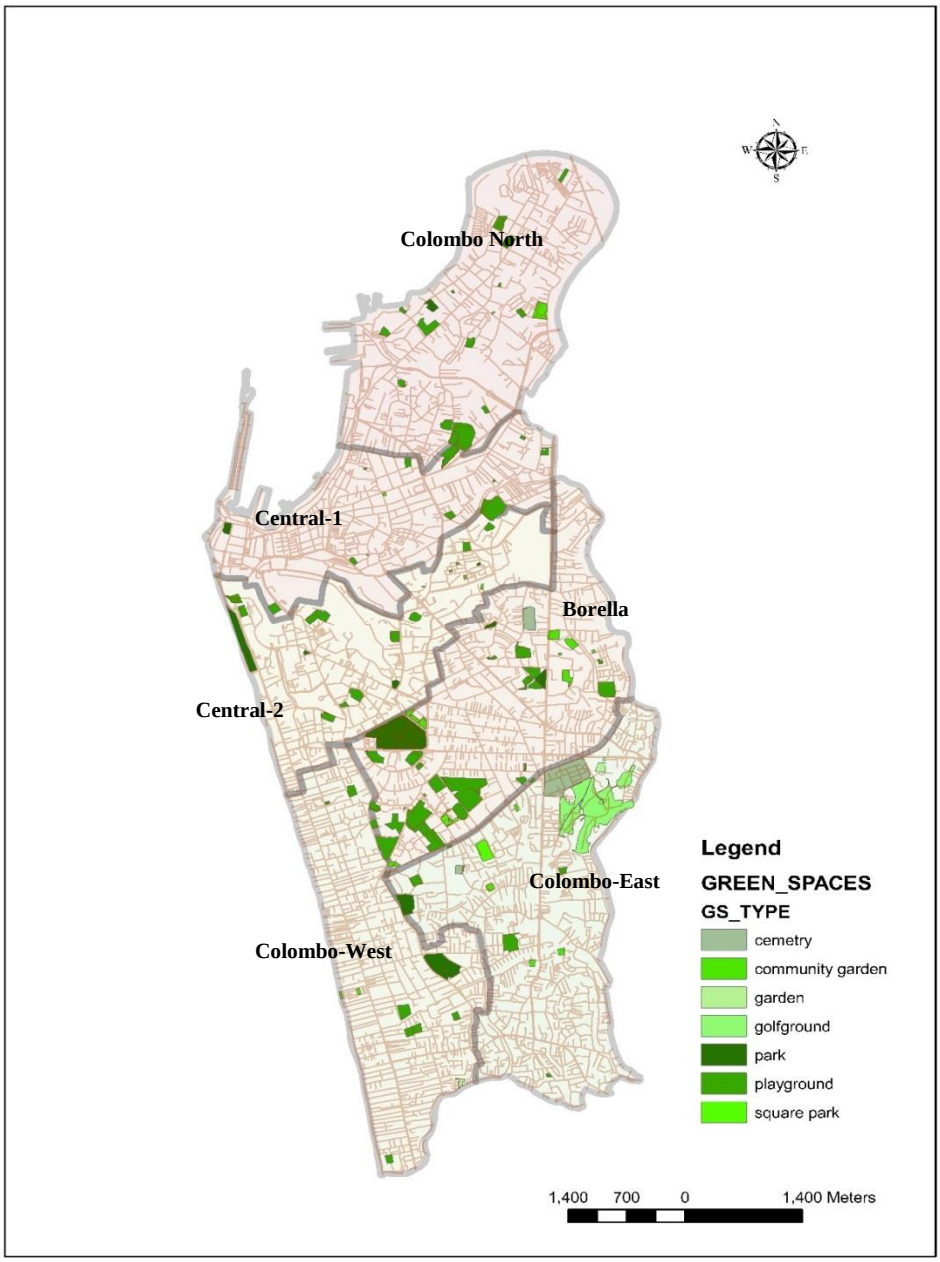

Figure 2: Structured green space distribution map in CMC area
Source: by author using GIS data

Table 1: Population and green cover across CMC area
Source: Data obtained by author using GIS maps (2024)

Municipal Ward	Total cover area (m^2)	Population	Green Space Cover Area (m^2)	Green Space per Capita
Colombo-North	7,343,928.23	123,799	332,975.75	2.689648139
Colombo-Central 1	3,835,416.72	117,693	141,924.5	1.205887351
Colombo-Central 2	5,856,100.96	131,723	224,139.68	1.701598658
Borella	7,559,916.18	94,907	910,763.32	9.596376663
Colombo-West	6,366,193.09	57,999	190,282.3	3.280785876

Colombo East	7,816,323.36	98,535	744511.81	7.555810727

As show in Figure 3, the structured green space network service map shows a 100-500m walking distance to green spaces considering road networks. Colombo-Central 1, Colombo-West, and Colombo-East areas significantly lack green space within 300-500m walking distance. Since Colombo-West is in close proximity to the coastal belt residents have access to "blue infrastructure" as an alternative. Some of the residential areas with a lack of access to green space are Kotahena East, Kotahena West, north of Mattakkuliya, and Blumedhal in Colombo-North. Figure 4; Buffer Analysis map highlights the green space buffer zones that indicate a Euclidean distance of 300m from the green spaces. This shows the 300m radius from green space irrespective of the road network walking distance. Several residential clusters in Colombo-North, Colombo-Central 1, Colombo-East, and Colombo-West lack green space distribution within 300m from residential areas. Colombo Central-2 and Borella areas have a comparatively better distribution of green space as per Figures 3 and 4.

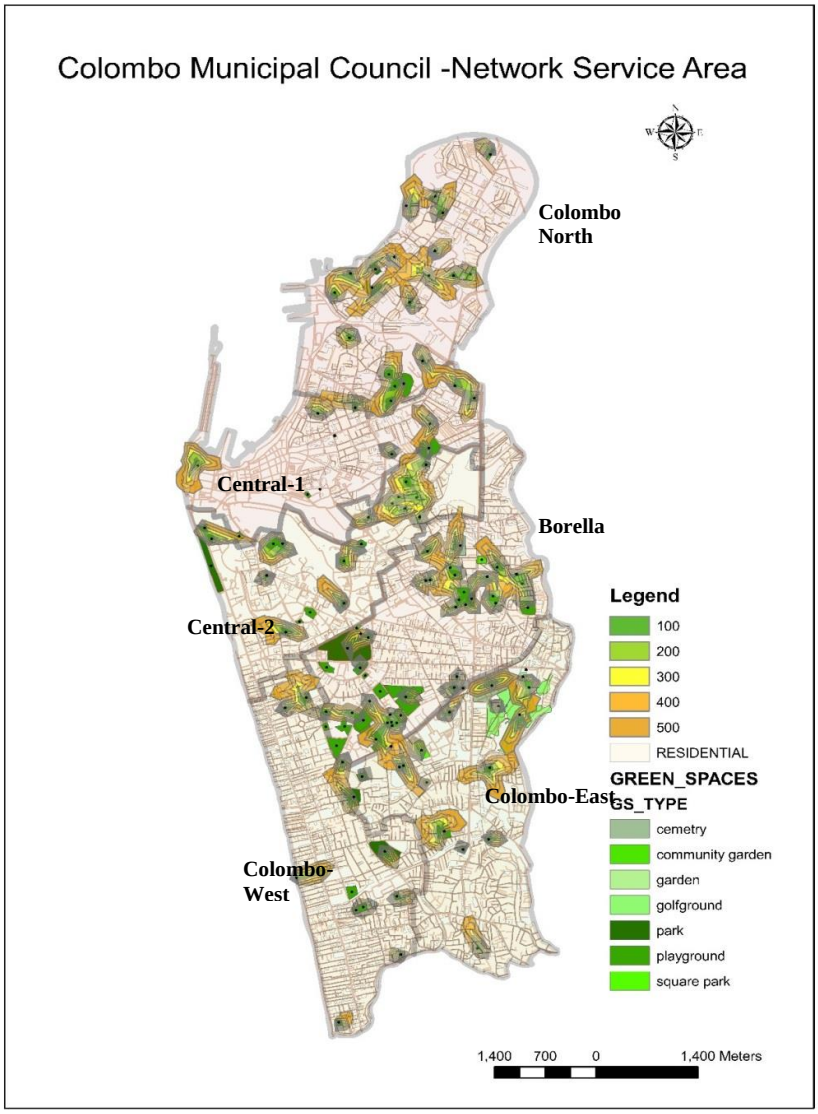

Figure 3: Network service from structured green space map in CMC area
Source: by author using GIS data

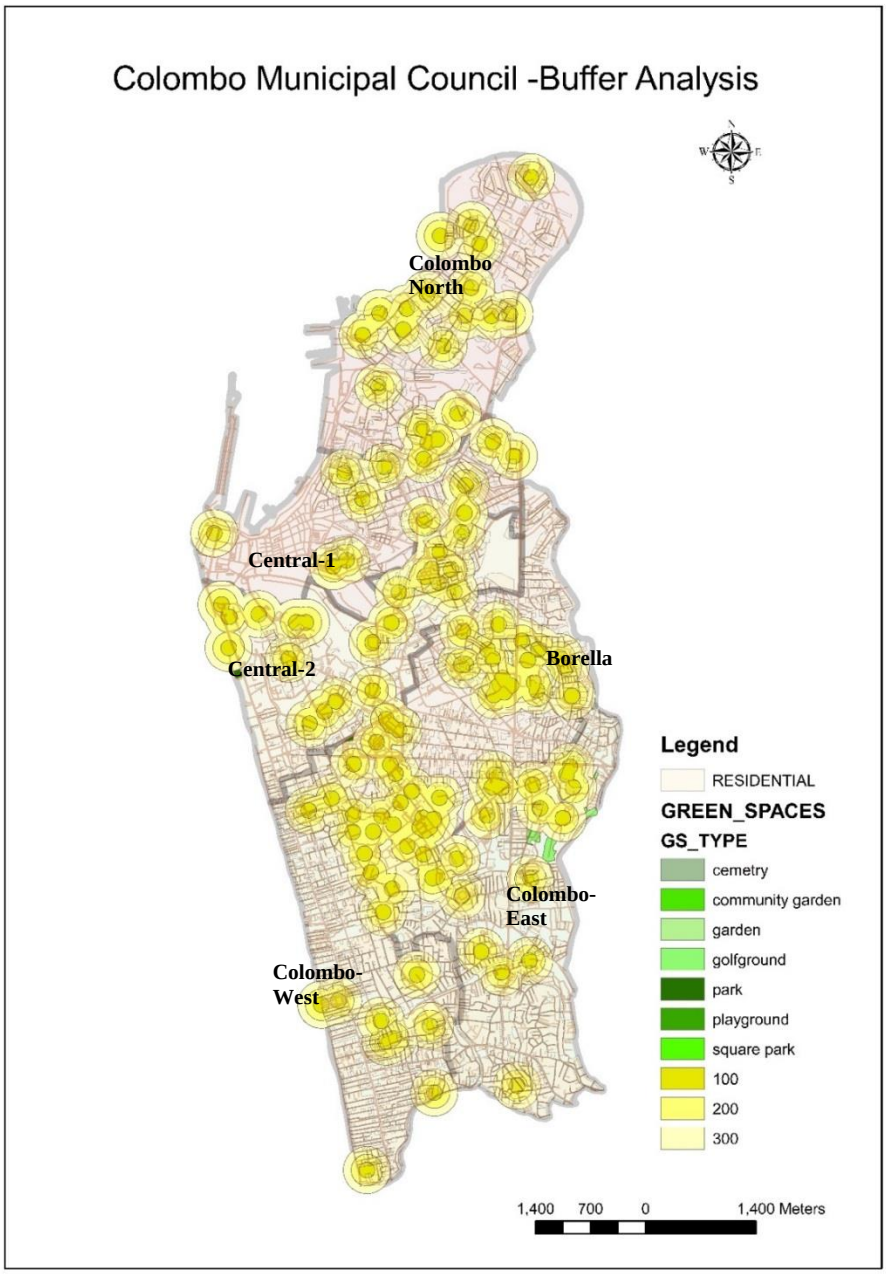

Figure 4: Euclidean radius distance buffer from structured green space map in CMC area
Source: by author using GIS data

NDVI map given in Figure 5 shows the exposure to both structured and unstructured green spaces. The high exposure is shown in green while lowest exposure is shown in red. The highest green space exposure is observed in Borella and Colombo-West. Colombo-North, Colombo-Central 1 and Colombo-West, has least exposure to green.

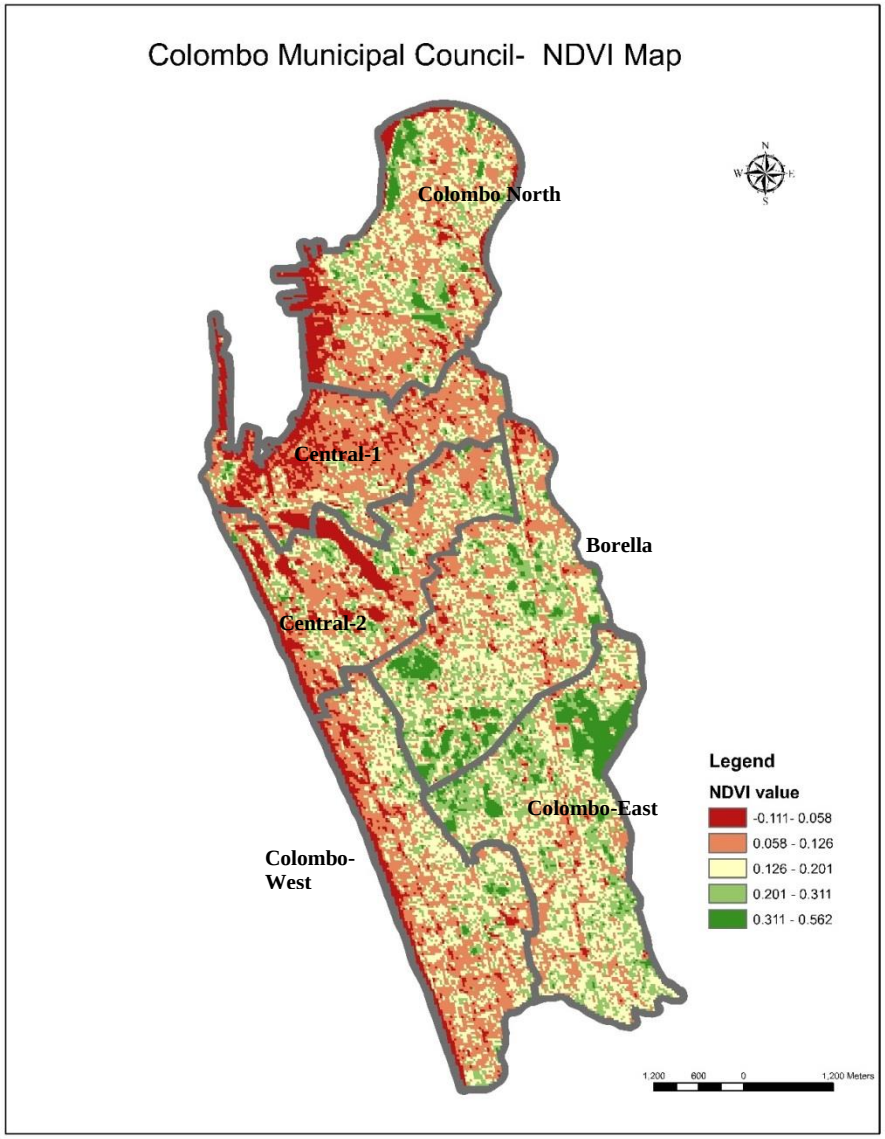

Figure 5: NDVI map in CMC area
Source: by author using GIS data

5. CONCLUSIONS

Green spaces are important components of urban infrastructure because they promote mental and physical health, social interaction, and provide a respite from the hustle and bustle of city life.

This study takes into account the green infrastructure within the CMC area and examines the buffer zones within a 300-meter radius and network analysis within a 500-meter radius. Notably, when compared to other CMC wards, North of Colombo, Colombo-West and Colombo-Central 1 has minimum green space coverage within the buffer zone, indicating these areas as possible focal locations for future green space development. Crow Island Park in North Colombo shows the possibility for green space development to satisfy the requirement for more exposure. Significantly, the results of network analysis strongly coincide with the findings of buffer zones, emphasising the necessity of permitting reasonable walking distances to green space. Borella and Colombo East

emerge as areas with significant green space coverage and green space exposure. However, due to the distinct locations and nature of green space the presence of urban green areas does not necessarily translate into fair accessibility for all inhabitants. The private or public nature and the functions of green space also play an important role in accessibility. The analysis, as shown in above maps, highlights the presence of parks inside each district, yet emphasises the need for strategic planning to improve citizens' access to these green havens. Despite the availability of green areas in Borella, it is clear that the distribution throughout other divisions is not consistent, necessitating a critical review of allocation practices. Special emphasis is required in the provisions and access to green space in Colombo-North, Colombo-Central 1 and Colombo-West. CMC administrative areas need to improve proximity-based accessibility to green space by constructing green spaces within walking distance to residential clusters and enhancing the accessibility to green spaces and creating "green space equity" for the diverse and vulnerable, such as the elderly, women, children and the urban poor.

The access to green space within walking distance can significantly enhance their exposure to green and promote overall wellbeing. This research highlights the need for provisions and access to green space in specific areas within the CMC boundaries and suggests the need for strategic planning to ensure fair access to these natural havens. Hence careful consideration of green space availability and accessibility in the development and formation of urban neighbourhoods can result in healthier, happier, and sustainable urban communities.

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