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Assessment of Green Space Requirement and Site Analysis in Colombo, Sri Lanka – A Remote Sensing and GIS Approach

I.P. Senanayake*[1], W.D.D.P. Welivitiya[1], P.M. Nadeeka[1]

ABSTRACT - Green space distribution plays a vital role in urban planning since they contribute significantly in enhancing environmental quality of metropolitan areas by improving air quality, urban health, conserving biodiversity, reducing noise, etc. Migration of rural population into urban areas and widespread industrialization lead to the rapid growth of urban population, consequently expanding urban sprawls. Removal of vegetation cover can be identified as one of the most adverse effects of urbanization. Proper distribution of green spaces in urban environments is therefore a necessity for the sustainable development and healthy living. Hence, it is essential to identify the green space requirement quantitatively and spatially. In this endeavour, integration of remote sensing and GIS techniques can provide a time and cost effective methodology.Colombo city of Sri Lanka has been identified as one of the most polluted cities in South Asian region. Rapid urbanization and the population growth are the main causes for the degradation of environmental quality in Colombo. Unplanned constructions and settlements in Colombo have contributed to significant reduction of green spaces. Therefore, special consideration has to be made for the proper distribution of green spaces in future development and planning projects in Colombo.

In this study, available green spaces in Colombo are extracted through NDVI method using THEOS satellite imagery. Subsequently, green spaces required to be created are calculated with respect to WHO standards of green spaces per capita for healthy living (9.5 m2/ person) and a methodology is developed to spatially define appropriate areas to establish them.

Keywords: Environmental quality, green spaces, NDVI, sustainable development, urban planning

1.0 Introduction:

Rapid industrialization and migration of rural population to urban areas expand the areas of urban sprawls while rapidly increasing the urban population density. 50.5% of the world's population resided in urban areas as per year 2010. In 2050, the population residing in urban areas is expected to be doubled in developing countries (United Nations, 2012). Since the rapid growth of population and industrialization leads to rapid constructions such as buildings, roads, parking lots, bridges, etc. Removal of vegetation cover can be seen as one of the significant adverse effects of urbanization. Further, environmental pollution can be seen as a major problem of urbanization, due to fumes and gases emitted from factories, emissions from vehicles, removal of vegetation cover, disposal of industrial waste into waterways, large amount of solid waste produced in industries, human behaviour, etc.

Green spaces play an important role in enhancing the urban air quality while providing suitable areas for recreational activities for inhabitants. Hence, amount of available green space can be identified as an important parameter for healthy living. Enhancing air quality, conserving biodiversity, reducing urban heat island effect, reducing noise pollution and soil erosion are few of the noteworthy positive ecological impacts of green spaces. Consequently, the availability of green spaces can be considered as an indicator for ecological sustainability of an urban community. In addition, green spaces have many social benefits such as providing space for social gatherings, recreational opportunities and reducing mental stress.

Arthur C Clarke Institute for Modern Technologies, Moratuwa, Sri Lanka
Corresponding Author : **1indishe@gmail.com*

World Health Organization (WHO) has set minimum standard for urban green spaces per capita for healthy living, i.e. 9.5m²/person (Kuchelmeister, 1998). Hence, green spaces must be properly distributed in urban areas through strategic planning and positioning. Therefore, assessment of existing vegetation cover and site analysis for the establishment of new green spaces play an important role in environmentally sustainable urban development.

Integration of remote sensing and GIS techniques provide a time and cost effective methodology for assessing and planning urban green spaces due to their ability in gathering, storing, analysing and displaying spatial data with attribute information (Rusli and Ludin, 2009).

Colombo city, the commercial capital of Sri Lanka was well-known among Greek, Persian, Roman, Arabian and Chinese traders 2000 years back due to the strategic position of its harbour in the East-west trade route. Colombo city is located between latitudes 6^0 55′N to 6^0 59′N and longitudes 79^0 50′E to 79^0 53′E. Colombo Municipal Council (CMC) is the largest local administrative authority in Sri Lanka with an area extended over 37 km² (Colombo Municipal Council, 2012). CMC area consists of 55 Grama Niladhari (GN) divisions, which are the smallest administrative divisions in the country. According to the census carried out by the Department of Census and Statistics in 2001, CMC area has the highest population density with a resident population of 637,865 and nearly 100,000 floating population (estimated). With rapid urbanization and population growth, vegetation cover of Colombo city is diminishing significantly with unplanned constructions. Further, air quality of the city is degrading drastically due to emissions from vehicles and industrial activities. Therefore, Colombo has been identified as the most polluted city in the island (Liyanage, 2003).

Therefore, proper distribution of green spaces play a vital role in future urban planning projects in Colombo for the sustainable development. In this endeavour, it is essential to identify the required amount of green spaces and site analysis to establish new green spaces according to international standards.

Objective of this study is to calculate the required amount of new green spaces in Colombo city quantitatively with respect to WHO standards (i.e. 9.5m²/person) and to develop a methodology to spatially identify the suitable areas to establish them using remote sensing and GIS techniques.

2.0 Methodology:

Visible Red (0.62-0.69 µm) and Near Infrared (0.77-0.90 µm) bands of Thailand Earth Observation System (THEOS) satellite imagery covering Colombo district was used to extract green spaces in Colombo city area by using "Normalized Difference Vegetation Index" (NDVI) method (Equation 1). Resolution of the red, green, blue and near infrared bands have been enhanced up to 2m by using typical pan-sharpening operation.

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)} \qquad (1)$$

NDVI generates pixel values range from -1 to +1. Green vegetation gives positive NDVI values, while values close to +1 indicates (0.8-0.9) highest possible vegetation density (NASA-Earth Observatory, 2012) The generated NDVI layer was classified using appropriate value ranges to extract green spaces and the obtained results were spatially verified using natural colour composite image (Fig. 1-a and Fig. 1-b). The extracted green space areas were then converted to polygonal feature class and intersected with the 'GN divisions' layer (Fig. 1-c). Subsequently, total land area of each GN division and existing green space area in each GN division were calculated on a GIS platform.

The current population of GN divisions of CMC area were calculated using a statistical projection, considering 2011 Colombo district preliminary population data and population growth trend data (Ariyawansa and Udayanthika, 2012).

Once the existing green spaces have been identified and extracted in each GN division, GN divisions were identified where green space area per capita is less than the standard value recommended by WHO (i.e. 9.5 m²/person). Also, it is essential to identify regions where vegetation can be established in order to improve the living conditions of inhabitants in each GN division. As the first step, area of green spaces required for healthy living in a GN division was calculated according to the number of inhabitants in each GN division (by assuming equal distribution of population within a GN division) using the number of inhabitants and the standard value recommended by WHO (Equation 2).

$$TGS_{(GN)} = N_{(GN)} \times StGS \qquad (2)$$

where;
$TGS_{(GN)}$: Total green space area required for healthy living according to WHO standards in the GN Division
$N_{(GN)}$: Number of inhabitants of the GN Division
StGS : Standard minimal green space area per capita, recommended by
WHO (i.e. 9.5m²/person)

By subtracting the existing green space area from the required area of green spaces in each GN division, amount of green spaces which is needed to be created in order to raise the green space per capita to minimum standard level recommended by WHO was determined (Equation 3).

$$RGS_{(GN)} = TGS_{(GN)} - EGS_{(GN} \qquad (3)$$

where;
$RGS_{(GN)}$: Required green space area to be established in the GN Division
$EGS_{(GN)}$: Existing green space area of the GN Division
Equation (4) was derived by substituting Equation (2) to Equation (3).

$$RGS_{(GN)} = (N_{(GN)} \times StGS) - EGS_{(GN} \qquad (4)$$

If $RGS_{(GN)} \leq 0$, existing green spaces in the GN division are adequate to fulfil the WHO standards.

When the green space requirement for each GN division is calculated, it is essential to identify where these new green spaces should be created. In order to do this, a methodology has been developed taking the population density, standard minimum green space area per capita recommended by the WHO and the area of each green space.

Once the amount of green space area required to be established in each GN division is identified, it is beneficial to determine where they should be created. In this endeavour, spreading the green spaces effectively over each GN division is essential. To achieve this goal, areas where new green spaces should be created were determined by using GIS based buffering technique. The standard minimal green space area per capita value recommended by WHO and population densities of each GN division were used in the calculation of required buffer radius using the following method. Since GN divisions are the smallest administrative areas in the country, population within a GN division has been assumed to be equally distributed in this analysis (land area of Kurunduwatta, the largest GN division in Colombo city is 3.57 km² only).

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Equation (5) was derived to calculate the buffer area needed to be established around each existing green space in a single GN division.

Required green space area per capita for healthy living as recommended by WHO is assumed as s m^2. Therefore, according to WHO standards for healthy living, g/s number of persons can live healthily in and around the existing green space area (g m^2) in a GN division.

By assuming equal distribution of population (p persons/m^2) within a GN division, land area requirement for g/s persons were calculated by $g/(p\times s)$ m^2. In other words, the existing green spaces in a GN division are adequate for the people living in $g/(p\times s)$ m^2 area within and around the green spaces. Hence, the suitable area with healthy living conditions based on existing green space can be demarcated by area covered with green spaces and a surrounding buffer region.

Therefore, the buffer area can be calculated by subtracting the area of existing green spaces by the area where people can live healthily based on green spaces (i.e. g/ps m^2).

This can be simplified in to Equation (5)

$$b = g\left(\frac{1}{p\times s} - 1\right) \qquad (5)$$

where, b: Buffer area around an existing green space

g: Area of the existing green space

s: Standard minimal green space area per capita, recommended by WHO (i.e. 9.5m^2/person)

p: Population density of GN division

In this context, buffer area represents the areas which people could live outside an existing green space, given that the green space per capita is equal to WHO standard.

When the buffer region area is calculated the approximate buffer radius (r m) can be determined by dividing the buffer area (b m^2) by the perimeter (k m) of the green space within the buffer. Calculation of the buffer radius is given by Equation (6).

$$r = \frac{g}{k}\left(\frac{1}{p\times s} - 1\right) \qquad (6)$$

where, k: Perimeter of the existing green space

Utilizing Equation (3) approximate buffer radii of all the green space polygons were calculated and the buffer map was generated. This particular map shows the area where green spaces are sufficient for the people residing in that area, which implies that, during a future urban redevelopment project, creation of green spaces should be done outside these areas.

Further, this methodology can be utilized in other urban centres to demarcate suitable areas to create green spaces, in order to uplift the environmental quality.

3.0 Results and discussion:

Analysis of the estimated green space requirement map (Fig. 2) revealed, 34 out of 55 GN divisions lack the minimum "green space per capita requirement" recommended by WHO. Kochchikade-North ($6^0$56'34''N, $79^0$5'10''E), Jinthupitiya ($6^0$56'37''N, $79^0$51'29''E) and Kochchikade-South ($6^0$56'17''N, $79^0$51'19''E) are the most crucial GN divisions on the basis of existing green spaces. In these GN divisions, green space per capita values are lower than 1m^2/person. Highest green space availability in Colombo city is present in the Gothamipura GN division (61.79 m^2/person). The average green space per capita for the whole CMC region is approximately 9.53m^2 which is slightly above the WHO recommended standard value. Comparing with other South-Asian cities such as Mumbai and Chennai where the green space per capita is less than1m^2/person, the green spaces availability in the Colombo city is much better (Kuchelmeister, 1998).

Taking the population density and the existing green spaces in each GN division into account, GN divisions where new green spaces are required to be created were identified and their extents were calculated (Fig. 2).

Using the minimum standard value of green space per capita recommended by WHO and the population density of each GN division, green space buffer map was created which shows the habitable areas on the basis of existing green spaces (Fig. 3). In this map, green polygons represent the area where there are adequate green spaces for the inhabitants living in that particular area with respect to the population density. Un-buffered areas (i.e. areas uncovered by green polygons) represent areas where creation of new green spaces is required in order to increase the green space area per capita value to WHO standard value. Inspecting this map revealed that, buffer radii around green spaces, where the green space area per capita value is near the standard level, were much larger (Fig. 4-a) compared to other regions (Fig. 4-b) with low per capita values of green space area. Also, the buffer area of a large green space polygon is larger than that of a polygon with a smaller area (Fig. 4-c pointed with arrows), which implies that new green spaces should be created away from larger existing green spaces. Since the areas outside the buffer region represent areas lacking the proper amount of green spaces for healthy living, a future re-development project can make use of this map to identify suitable areas for establishment of new green spaces.

Since Colombo city consists of buildings, roads and other constructions, it is hard to change the land use to upraise the green spaces according to the site map (Fig. 3). Though, major changes in land use, such as removal of buildings, roads is impossible, strategic planting of trees can be employed by city planners to enhance the environmental quality with the aid of the site map.

4.0 Conclusion:

This study was carried out to assess the existing green spaces in Colombo city of Sri Lanka quantitatively and to identify sites to create new green spaces in order to upraise the green spaces for the minimum required value recommended by WHO (i.e. 9.5 m^2/ person). Green spaces in Colombo city were extracted from THEOS satellite images using NDVI method and analysed for each GN division, to calculate the required amount of green spaces to be created. Subsequently, a site analysis was carried out using GIS based buffer technique to spatially identify the areas to create new green spaces. The methodology adopted in this study can be utilized effectively in other urban centres to calculate the required amount of green spaces and to identify the sites to create green spaces, in order to enhance the environmental quality of the city based on WHO standards.

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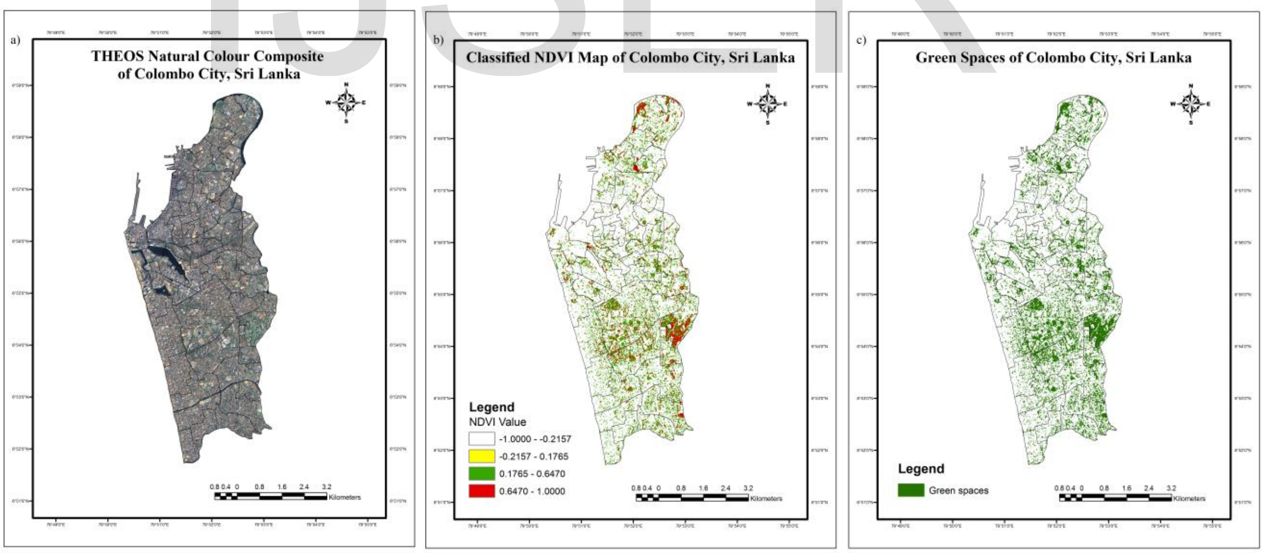

Fig. 1: a) THEOS natural colour composite of Colombo city, Sri Lanka. b) Classified NDVI map of Colombo city, Sri Lanka. c) Green spaces of Colombo city, Sri Lanka.

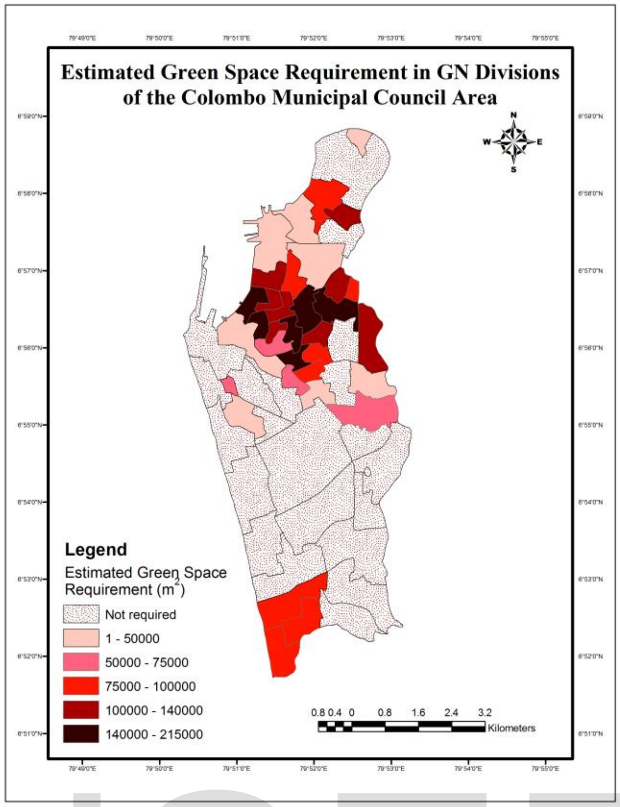

Fig. 2: Estimated green space requirement in GN divisions of Colombo city, Sri Lanka.

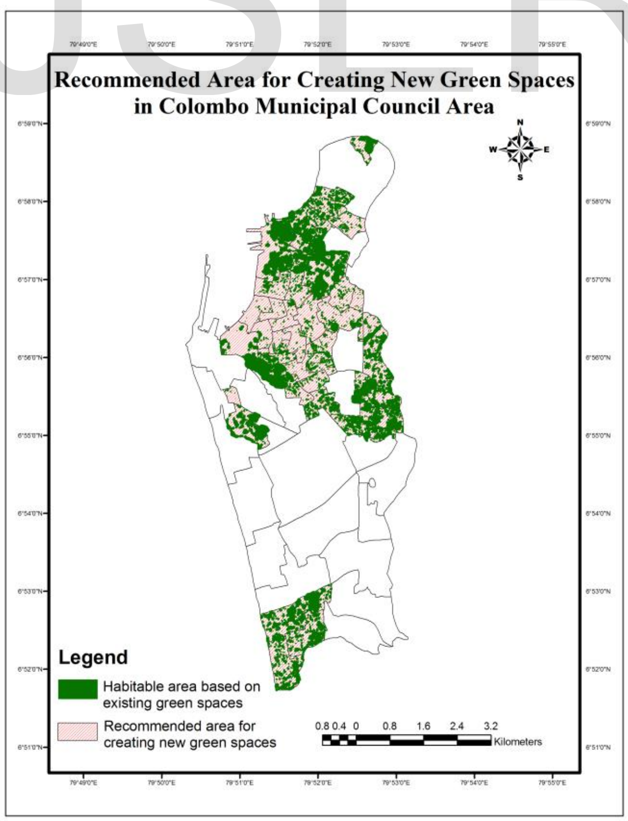

Fig. 3: Recommended area for creating new green spaces in Colombo city, Sri Lanka.

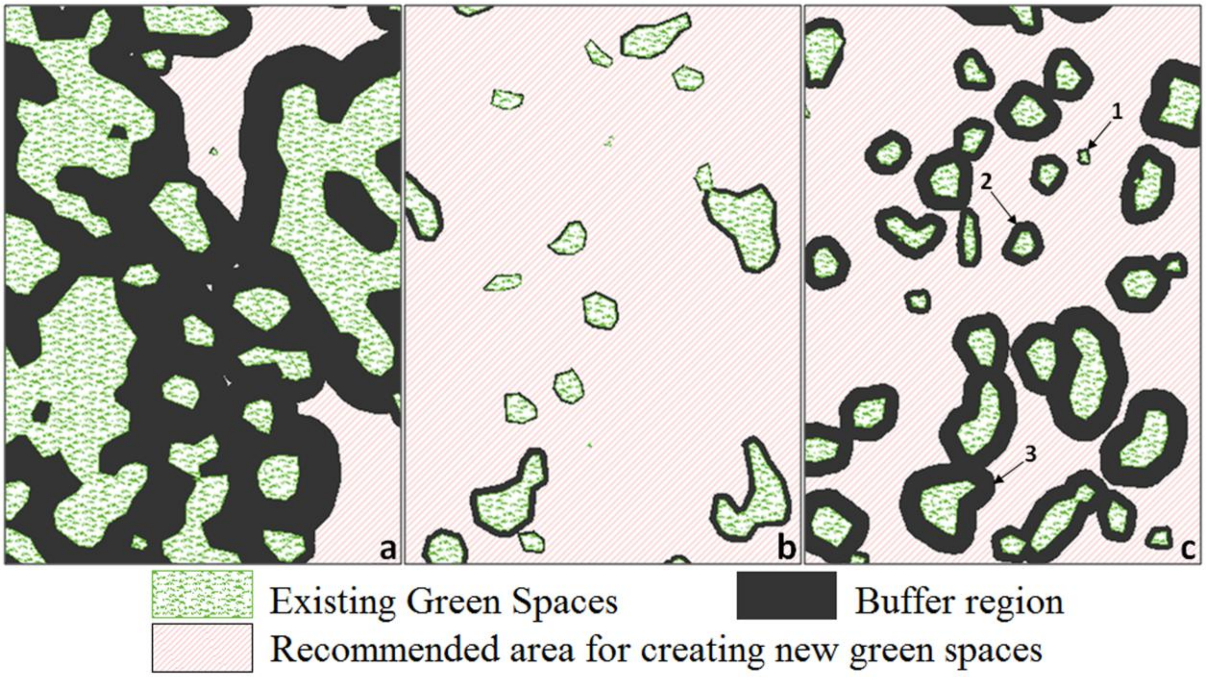

Fig. 4: Dichotomy of buffer regions (habitable areas) depending on the green space per capita of GN divisions and the size of enclosing green space. (a) Large buffer regions of GN divisions with high green space per capita. (b) Small buffer regions of GN divisions with low green space per capita. (c) Difference of buffers surrounding green spaces depending on the size of enclosing green spaces.

I.P. Senanayake,

W.D.D.P. Welivitiya

P.M. Nadeeka