IS COLOMBO CITY, SRI LANKA SECURED FOR URBAN GREEN SPACE STANDARDS?

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Abstract. Per capita green space is a quantitative measurement which is used to evaluate environmental sustainability of a city. Current high rate of urbanization and its impacts reduce green spaces gradually and remarkably. The main objective of the current study is to evaluate the present situation of Colombo city and its sustainability using per capita green space standards which have been defined by UN, WHO and EU. This study further compares Colombo with other major cities in the South Asian region. A time-series of Landsat images from 1980 to 2015, with the NDVI differencing technique, were used to prepare relevant green space maps in a GIS environment. Results of the study show a decrease (from 31.0km^2 in 1980 to 5.02km^2 in 2015) of green space in the city area and the per capita value recorded in 2015 (7.16m^2) is below WHO standard of 8m^2. Thus, it can be concluded that Colombo is not in a secure position in maintaining its green spaces. However, when comparing with 06 other cities in the region, it is observed that the situation in Colombo is more sustainable than the selected cities. This study recommends to analyze the problem at smaller sized administration units, the necessity of attention of policy makers and planners, and a comprehensive city plan.
Keywords: *urbanization, sustainability, per capita, urban planning, GIS, NDVI*

Introduction

Urban green spaces play a remarkable role to reduce bad consequences of the rapid rate of urbanization. The population in urban areas has been increased from 13% to 34% of the world's population between 1940 and 1980 (World Commission on Environment and Development, 1987; Kong and Nakagoshi, 2005). It reached 50% in 2008 according to the world urbanization prospects: the 2007 revision, which was published by the population division of the Department of Economics and Social Affairs, United Nations (UN), and Cui and Shi (2012). Urban population is expected to increase up to about 65% of the world's population in 2025 (Schell and Ulijaszek, 1999; Kong and Nakagoshi, 2005) and further it has been predicted that 70% of the world's population would live in urban areas in 2050 (Cui and Shi, 2012). The present rate of growth of urban population with the expansion of industrialization in cities and suburbs expands

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the urban areas in a massive manner everywhere around the world. It has changed the natural environment and its ecological systems severely. Its negative impact on urban green space is especially considerable (Kong and Nakagoshi, 2005), and requests immediate attention. Consequences and impacts are remarkable in the case of main cities in both the developing and under developed countries. Due to more infra-structure facilities and opportunities in cities when compared with rural areas of those countries, there is a tendency of the general public to settle down in urban areas or suburbs. Therefore, the maintenance of sufficient green space in the city or its closed vicinity has always been a challenge.

Though the definition of green space has long been argued, a universally accepted definition is still lacking (Byomkesh et al., 2012). European Commission (2013) defined green spaces as a strategically planned network of high quality natural and semi natural areas with other environmental features, which is designed and managed to deliver a wide range of ecosystem services and protect biodiversity in both rural and urban settings. Jim and Chen (2003) defined urban green spaces as vegetated areas which can be found in urban environments and named as semi natural areas in a city including parks, forest patches, open spaces, residential gardens of narrow strips of trees along streets. These areas can be covered with natural or man-made vegetation but are present in built-up areas (Kong and Nakagoshi, 2005; Phan and Nakagoshi, 2007; Byomkesh et al., 2012). Arabi et al. (2014) grouped urban green spaces into four categories: 1. Public green spaces, usually called parks, which have been allocated for general public to engage in their activities leisurely; 2. Semi public green spaces such as open spaces in hospitals, government or private departments etc.; 3. Private green spaces which are the residential garden units maintained by urban residents; 4. Street green spaces which are the tree layouts along roadways.

Green spaces perform a number of functions and services ecologically, socially and culturally. They provide key ecological functions such as carbon storage, soil conservation, noise buffering, maintenance of air quality, reduction of air temperature etc. to protect and maintain bio diversity of the city (Bao et al., 2016). They contribute in a positive manner to maintain public health by facilitating appropriate space for physical exercise to improve physical and psychological well-being (Cohen et al., 2007; Zhao et al., 2013). Additionally, green spaces perform an important role in increasing the quality of life of urban dwellers by offering esthetic enjoyment and recreational opportunities (Jo, 2002; Chen and Jim, 2008; Zhao et al., 2013). Csete and Horvath (2012) emphasized the importance of urban greening programs to mitigate the impacts of climate changes and to make sustainable cities. Furthermore, urban green spaces provide a good platform for local residents as a meeting place for their different social interactions (Kamierczak, 2013).

In designing and maintaining sufficient extents for green spaces in an urban area, parameters of the city such as population, environmental conditions, climate conditions and different cultural behaviors of immediate residents have to be considered thoroughly (Arabi et al., 2014; Latifi et al., 2016). The percentage of space which has been allocated for green spaces from the total extent of the urban area can be used to assess the environmental sustainability of a city (Chiesura, 2004). There are some standards with the aim of assessing the ecological sustainability of cities, defined by various organizations. One such application is determining the per capita green space extent of a city (Laghai and Bahmanpour, 2012). This value represents the extent of green area in square meters (m^2) for a single citizen. UN has expressed that the per

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capita green space should be more than $30m^2$, and such cities are named as sustainable cities, while the European Union (EU) stated the minimum value as $26m^2$ (Khalil, 2014). Yet the World Health Organization (WHO) has defined that an area of $9m^2$ of green space should be maintained for each person in an urban area to provide a better quality life (Khalil, 2014). Sometimes, developed countries have their own per capita green space values, for example, $50m^2$ in USA, 30 to $60m^2$ in Germany and 50 to $60m^2$ in Switzerland (Hosseini et al., 2015). Major cities, too, in developed countries have defined individual values, for example, $154m^2$ by Los Angeles and $47m^2$ by New York (Hosseini et al., 2015).

Not only the per capita green space, but also factors such as the spatial distribution, physical condition of the space, and accessibility should be considered in determining the ecological sustainability of a city. As a method to assess the accessibility of the urban residents to green spaces, most authors have defined that the urban parks should be within 400m, it means 05 minutes walking distance, from residencies (Herzele and Wiedemann, 2003). Handley et al. (2003) concluded that urban green space should be managed by a hierarchical size and distance criteria using a model called "ANGSt". This model requires a number of different criteria which should be satisfied by the green spaces, such as residents should live in areas which are 300m away from natural green spaces of at least $0.02km^2$ in size, and should provide of at least $0.01km^2$ of natural space for 1000 residents (Handley et al., 2003). As one of the basic standard provisions of urban parks, the standard which was recommended by National Recreation and Park Association, USA can be considered (Nicholls, 2001). According to that, a space of $0.41km^2$ has to be kept as urban parks for 1000 residents (Nicholls, 2001). The Six Acre Standard of National Playing Fields Association of United Kingdom is another standard which recommends $0.24km^2$ as the open space for 1000 residents (Nicholls, 2001).

As urban expansion and urban population growth are contineous phenomenon, keeping green spaces in accordance with the above standards is a challenging task. It is a timely important task of urban planners and designers. In the planning and designing stage of urban green spaces, attention has to be given to the standards of optimization and development of them (Arabi et al., 2014). The main objective of the present study is to assess the vulnerability of Colombo city, Sri Lanka, for green space reduction. The vulnerability was determined using the rate of urban green space reduction, growth of built-up area, population growth, and urban expansion. Next, the current situation of the city was compared with adjoining main cities in the South Asian region. Only the UN, EU and WHO standards were used to determine the vulnerability of the cities for green space reduction.

Materials and Methods

Study area

As a result of the movement of economical growth from global North to global South in the late 20^{th} century, rapid urban growth can be seen in the South Asian region (Subasinghe et al., 2016). Colombo city, the former capital city of Sri Lanka, was nominated as one of the fastest growing urban cities in South Asia by the World Bank in 2013. Colombo metropolitan area is very important as the main economical hub of Sri Lanka, and is responsible for more than 80% of the country's industrial output, and 50% of the Gross Domestic Product (GDP) (Emmanuel, 2005; Subasinghe et al., 2016).

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As a country, Sri Lanka does not suffer much from urbanization, when the situation is compared with other major cities in the South Asian region. The population growth of the city is comparatively low, and it records the lowest rate (1.1%) in the South Asian region according to the world development indicators defined by World Bank in 2017. According to the Department of Census and Statistics, a high percentage (77.4%) of the total Sri Lankan population lived in rural areas of the country by 2015. However, when compared to other urban areas of the country, approximately 15% of the total urban population of the country lives in the city of Colombo. Consequently, the scenario for the city is not so good when it is compared with other urban areas. The city area of Colombo consists of two divisional secretariat divisions: Colombo and Thimbirigasyaya and covers of an areas of 37.29km^2 in extent (*Fig. 1*).

The cities for the comparison study were selected according to the economical strength and data availability. 06 main cities in the South Asian region: Dhaka in Bangladesh, and Bangalore, Chandigarh, Gandhinagar, Jaipur and Mumbai in India were selected to compare the environmental sustainability for the current rate and pattern of urbanization. Due to data unavailability, major cities in other South Asian cities were not selected.

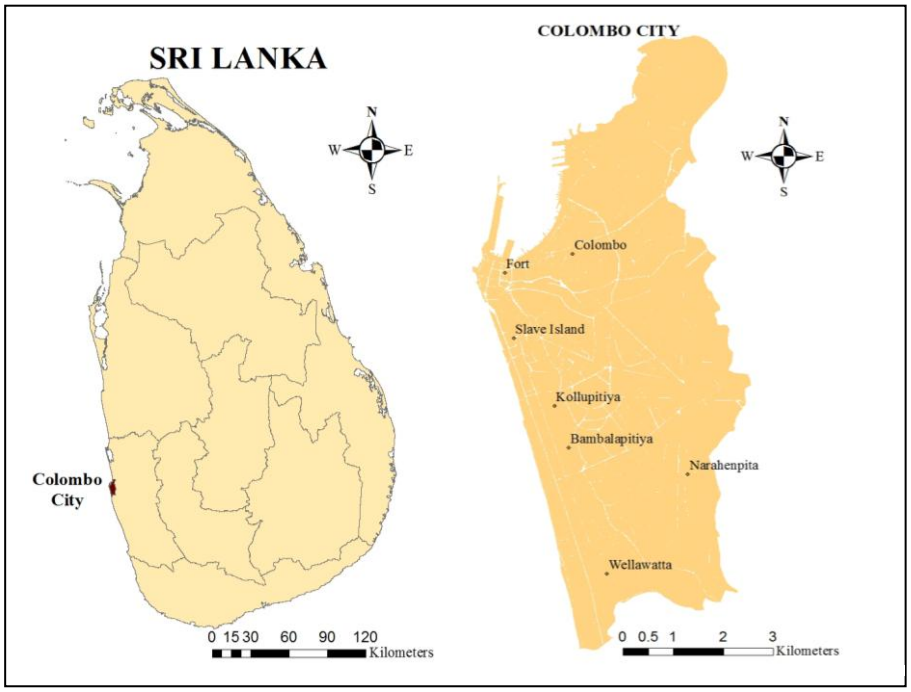

Figure 1. *Study area: Left – Sri Lanka map, Right – Colombo city map*

Data requirement

Two types of data were used in the study as: (i) land use and land cover data to determine the extent of the green space in the city, and (ii) the socio-economic data to understand the vulnerability of urban green space for urbanization and to calculate the per capita rates. Land use and land cover maps were prepared using data which were extracted from Landsat TM and ETM+ satellite images, downloaded in GeoTIFF file format from the United States Geological Survey

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(USGS) Earth explorer official website for the years of 1980, 1988, 1997, 2001, 2011 and 2015. The resolution of the image which was taken in 1980 was 60m, while the other images had a 30m ground resolution. These images were projected on to the Universal Transverse Mercator (UTM) coordinate system by using the reference datum as WGS1984. The population data were gathered from the official website of the Department of Census and Statistics, Sri Lanka, and their reports. The study also used the land use and land cover map prepared by the Survey Department of Sri Lanka, as the base map. Data on the scenarios of other cities were collected from the official web sites of government institutions in respective countries, and scholary articles in reputed journals.

Methodology

The Normalized Difference Vegetation Index (NDVI) values were used in the study to identify the changes of green cover in the study area for different years. This technique is extensively used for the purpose of vegetation change analysis (Gao, 1996) as a very simple and quick method. The NDVI values fall within the range of -1 to +1 which generally indicates non-vegetated areas with negative values and vegetated areas with positive values (Pettorelli et al., 2005). They can be calculated using the equation of (NIR – RED)/ (NIR + RED) where NIR – Near Infra Red band value of a cell and RED – Red band value for the cell (Gao, 1996). The images were classified into two categories as green space areas, and built up and other areas using NDVI threshold values which were determined by analyzing and comparing the NDVI image with Google Earth images and the land use map of the study area via using a number of sample points. The classification results were analyzed using the process of accuracy assessment through comparing the images with 120 random sampled ground truth points in the ArcGIS software environment. For this, Google Earth images, true and false color composite images, and prior knowledge about the study area were used as reference data. The error matrices were created using the pivot table tool in the ArcGIS software. The user's accuracy, producer's accuracy, and overall accuracy were calculated using the respective error matrices. The per capita green spaces of Colombo city limits for each year were calculated using the population data. Temporal changes of green space in the city were compared with adjoining major cities in the region using frequency distribution, temporal curves, and trend values. Since numerical values did not cover the overlapping years for different cities, this study used linear regression modeling to obtain the trend values.

Results and Discussion

The pixel values of the NDVI images were with a range of distribution (colomn 2 of *Table 1*). According to these values, the threshold values for green spaced areas were determined for different years (colomn 3 *of Table 1*), and were used in the process of image classification to extract the urban green space maps for the respective years. In this work, only the lower limit of the threshold value was determined, while the highest value of the NDVI of the images were considered as the upper limits for green space areas.

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Table 1. *Threshold values for green spaces*

Year	NDVI Value Range	Threshold Values for Green Space
1980	-0.351351 to 0.528455	0.06
1988	-0.513514 to 0.729032	0.12
1997	-0.692308 to 0.731544	0.12
2001	-0.662338 to 0.568862	0.17
2011	-0.25 to 0.629139	0.23
2015	-0.0865626 to 0.552974	0.26

Table 2. *Accuracy assessment of classification results*

Year	User's Accuracy	Producer's Accuracy	Overall Accuracy
1980	68.34%	71.45%	70.32%
1988	72.48%	74.21%	73.43%
1997	82.19%	81.28%	81.68%
2001	88.13%	90.40%	90.01%
2011	93.23%	92.35%	92.47%
2015	90.38%	89.10%	90.02%

Using the threshold values, the images were classified into two classes as green spaces, and built up and other areas. The land uses and land covers such as parks, grounds, cultivated areas, forest areas, home gardens, marshy lands, and scrub covers were classified under green spaces, while land uses and land covers such as water, sand, and buildings and roads were considered as built up and other areas (*Fig. 2*).

The green space covered extents were determined from classified maps using the calculate geometry tool in the ArcGIS software (*Table 3*). It can be clearly observed that there is a reduction of green space extents in the area with time, as a result of the rapid urbanization. Additionally, the results show that the total extent of Colombo city has not changed. As a consequence, according to the Department of census and statistics, Sri Lanka, this has lead to a higher rate of population density. The green space change is remarkable since 2001, with annual reduction rates of $0.46km^2$ (1980-1988), $0.39km^2$ (1988-1997), $0.37km^2$ (1997-2001), $1.37km^2$ (2001-2011) and $0.71km^2$ (2011-2015). With the economical development of the country, there has been a significant development of infra structures of the Colombo city. As such, the land use and land cover of the city has changed dramatically. Most of the vacant areas and forest areas in the city have been converted into urban settlements, administration buildings and industrialized parks. Therefore, it can be clearly observed that urbanization is the main factor responsible for the reduction of green space in Colombo city.

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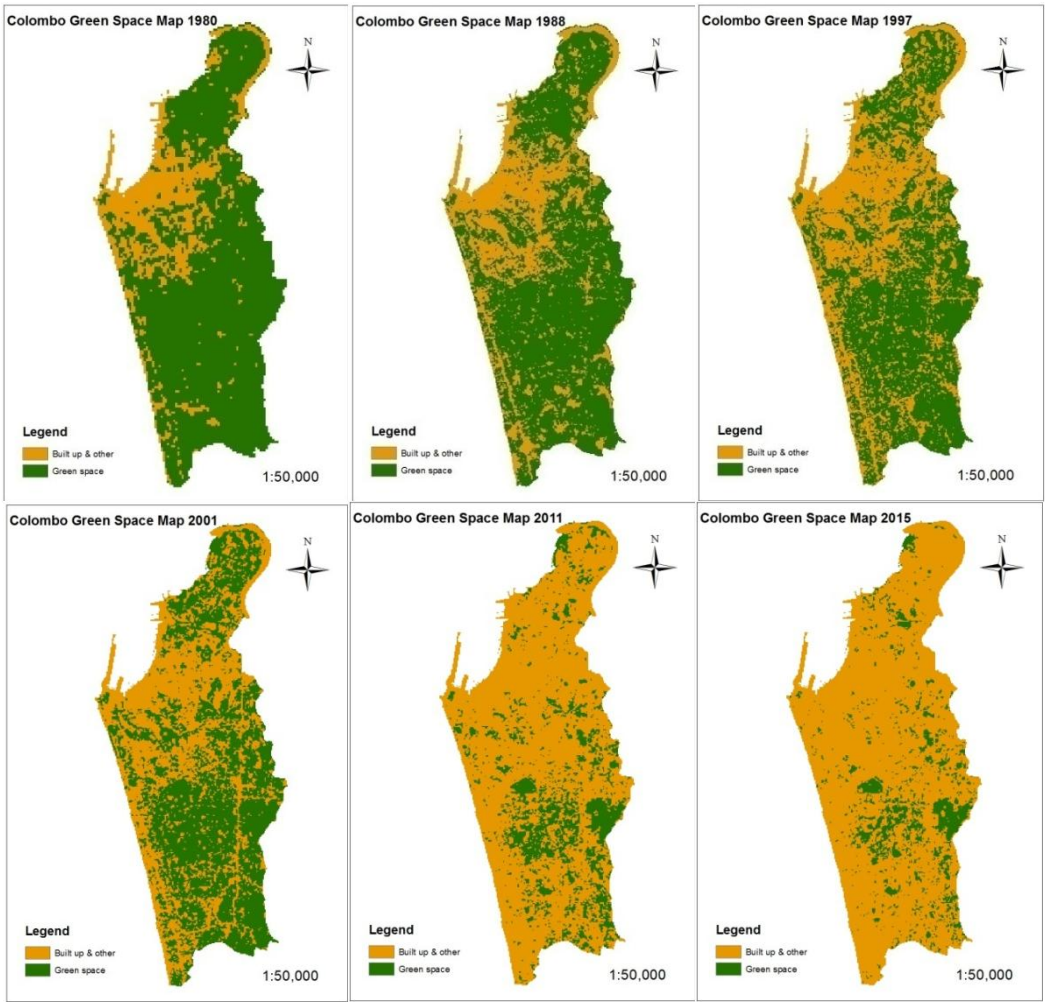

Figure 2. *Green space maps for 1980, 1988, 1997, 2001, 2011 and 2015*

Table 3. *Extents of the green space of Colombo and per capita green space*

Year	Total Area (km^2)	Green Space (km^2)	Percentage reduction (%)	Recorded Population	Per capita green space (m^2)
1980	37.29	31.00	83.14	581245	53.34
1988	37.29	27.32	73.26	No Data	-
1997	37.29	23.01	61.70	No Data	-
2001	37.29	21.53	57.75	637865	33.76
2011	37.29	7.88	21.14	561314	14.04
2015	37.29	5.02	13.47	701348	7.16

Using the population data of Colombo city, the per capita green space was calculated (*Table 3*). However, the per capita rates were not calculated for the years of 1988 and 1997 since there were no official population data records. The findings of this study imply that the present situation is vulnerable since the city does not fulfill any standards defined by UN, WHO or EU. In addition to that, the current rate of change of green

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space would lead to a severe problem in the near future, if the policy makers do not pay their attention on this matter efficiently and effectively (*Fig. 3*).

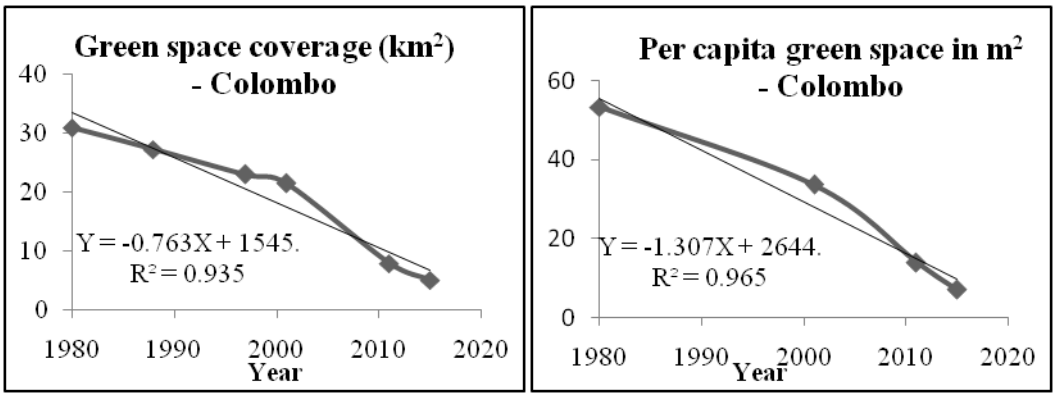

Figure 3. *Green space coverage and per capita green space of Colombo*

Furthermore, as another objective of the study, the city was compared with 06 major cities in the South Asian region. The incredible growth of population, 0.3 million in 1950, 2.2 million in 1975, 6.6 million in 1990, 10.3 million in 2000, 14.7 million in 2010 (Byomkesh et al., 2012) and 17.6 million in 2015, according to world population review in 2017, has severly hurt Dhaka, the capital of Bangladesh. The city was ranked as the 11th most heavily populated city in the world in 2000 (Lizin, 2002), and it controls the economy of Bangladesh extensively. According to the preliminary report of national population census published by the Bangladesh Bureau of Statistics, Ministry of Planning, Bangladesh, in 2001, the population density was remarkably high in Dhaka, recording 15333 persons/ km^2 in 1991 and 18055 persons/ km^2 in 2001. The rate of infra structure development aspects in the urban area has lead tremendous changes in the natural land use and land cover pattern. The extent of green space has decreased at an alarming rate, 186.26 km^2, 148.18 km^2, 129.66 km^2 and 100.09 km^2 in 1975, 1988, 1999 and 2005 respectively, while the built-up area has expanded from 55.5 km^2 in 1975 to 205.49 km^2 in 2005 (Byomkesh, 2012) (*Fig. 4*). According to Fatemi (2014), Dhaka possesses only 486m^2 for 1000 residents in 2014, meaning that 0.486m^2 as the per capita green space. Using these data, the per capita green space for the years were calculated (*Table 4*). The population was estimated for 1988 and 1999 using the growth rate between the adjacent years. According to these, it can be suggested that the present scenario is at the worst stage. However, when compared with Dhaka, Colombo is on the safer side.

Table 4. *Extents of the green space of Dhaka, Bangladesh*

Year	Green Space (km^2)	Recorded Population (in milloins)	Per capita green space (m^2)
1975	186.26	2.221	83.86
1988	148.18	5.837	25.39
1999	129.66	9.894	13.10
2005	100.09	12.331	8.12
2014	No data	No data	0.49

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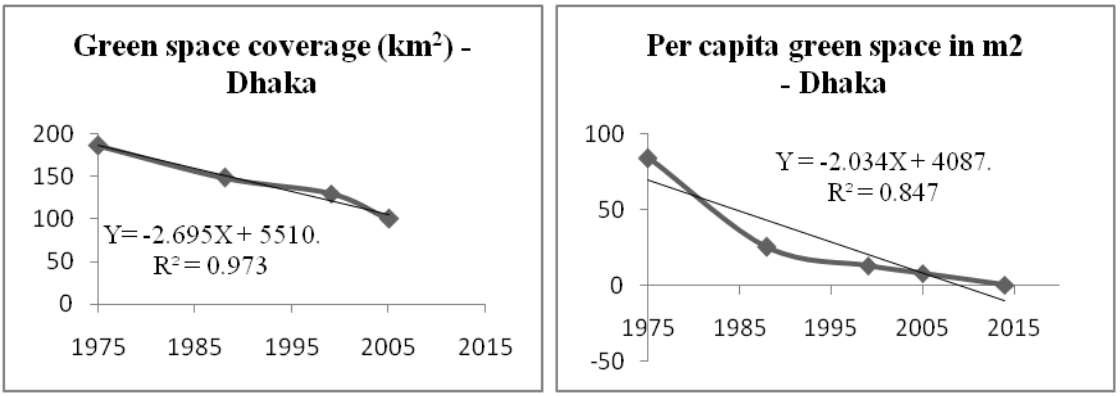

Figure 4. *Green space coverage and per capita green space of Dhaka*

In the study, 05 main Indian cities: Bangalore, Chandigarh, Gandhinagar, Jaipur and Mumbai were selected according to the data availability to compare the urban green space reduction with Colombo. Delhi city was not selected, since it has a good management plan in maintaining green spaces. The scenario of Indian cities can be considered as extremely bad due to the exceptional dynamic nature of the current rapid growth of population and economical advancements which create a number of urbanization related problems. Almost all the mega cities in India face significant changes in land use and land cover, with an alarming increase observed in the built-up areas and decrease in urban forests. The changes of per capita green space of cities are shown in *Table 5*. It can be clearly observed that the rate of change is high in these cities. Even though Chandigarh and Gandhinagar are maintaining a good per capita green space, if it continues with the present reduction rate, the problem would become severe in the near future. When comparing Colombo with the Indian cities, the situation of Colombo is at a higher level of satisfaction.

Table 5. *Per capita green space of Indian cities (Chaudhry et al., 2011)*

Year	Bangalore	Chandigarh	Gandhinagar	Jaipur	Mumbai
2001	17.32	54.45	162.8	2.3	1.95
2011	2.17	15.9	30.27	1.6	0.635

Conclusions

Colombo city and the metropolitan area are very important to the economical growth of the country. The location of the city is strategically very important as a harbor city connecting the eastern part of the world and the western part. Therefore, rapid urbanization which is currently faced by the city is not strange. This would be more serious in the future with the proposed developments such as the Colombo port city project. Even though the city had maintained a good rate of per capita green space which satisfied the UN, WHO and EU standards until 2011, it has now been converted into a serious issue. The urban area is rapidly expanding to the right side of the city, and there is a need to take necessary actions by the city planners and policy makers in a timely manner to mitigate this problem. As such, there is an urgent requirement for a

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comprehensive green space plan for the city and its suburbs to convert the city of Colombo to a green city with comfortable living standards.

The comparative study implies that the present situation of Colombo is still at a manageable state when compared with other big cities in South Asia. However, the rapid growth of population is the reason for the low per capita value of other cities which were considered in this study. Yet, Colombo generally has a, comparatively, low rate of population growth. Therefore, if the green space reduction rate would be considered, Colombo could be the worst city with the highest rate of reduction compared with other cities. Hence, this study suggests to analyze the problem at a micro level to provide a better and effective solution. The results would differ significantly if analyzed using smaller sized administrative units such as Grama Niladhari Divisions. It would lead to identify the exact areas which do not maintain sufficient green spaces for the residents. As a practical solution to solving this problem, a tax paying system can be introduced to get the attraction of the general public. This would be a better method to get the maximum support from the public, and encourage them to make their territories into greener areas.

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