IMPACT OF URBAN GROWTH ON VEGETATION COVER IN WORLD HERITAGE CITY OF KANDY, SRI LANKA: AN ASSESSMENT USING GIS AND RS TECHNIQUES

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Abstract: The rapid urban growth occurring in developing countries today is mostly spontaneous and causes to create many environmental problems that demand urgent attention. The paper attempts to examine the impact of urban growth on vegetation cover in Kandy city, Sri Lanka with GIS and RS techniques. Measuring the built up area expansion, detecting changes of natural vegetation cover, and identifying how the correlation between urban growth and vegetation cover has changed over time are the objectives of this paper. The paper uses Urban Index (UI), Normalized Difference Vegetation Index (NDVI) and linear regression technique to achieve the above objectives. Depending on the data availability Landsat satellite images in 1980, 1994, 2003, 2007 and 2015 with moderate resolution were obtained from USGS server. Image processing and related mapping were done with Arc GIS 10.2 software. Microsoft Excel 2007 was used to perform regression analysis.

As results reveal, during the corresponding period built up area of the city has expanded significantly while vegetation cover in the city has adversely been impacted. Only the very high vegetation category remains unchanged since its recognition as reserved forest while all the other categories of forest in the city under the threat of reduction. Correlation analysis which was performed to seek what extent these two phenomena are correlated shows that a crucial negative correlation is present between UI-NDVI. Correlation between UI and NDVI has gradually increased and it was much strong in 2015 indicating the problem of losing forested areas. This indicates that the city is losing its greenness due to modification of land surfaces. If necessary actions are not implemented in this connection many environmental problems will arise in near future and city will be uncomfortable place for living and working for the city uses. Therefore, this study strongly recommends to take necessary actions to control the problem of decrease the greener areas in the city.

Keywords: Kandy City, Landsat Images, UI, NDVI, Linear Regression Model

I. INTRODUCTION

Many urban areas especially in developing countries are experiencing a fast growth from recent decades due to variety of reasons. This fast growth is mostly spontaneous and causes to create many environmental problems that demand urgent attention.

The increasing spatial concentration of people as well as productive activities also has environmental spillover effects outside the urban area itself, many leading to problem of a global nature [1]. Therefore, it has become necessary to evaluate urban growth trend and its relation with its natural environmental condition quantitatively. Monitoring and mapping of urban growth trend are more effective for development of unplanned areas.

One of the major problems in relation to this is high cost for traditional data collection methods for planning authorities in these countries. In this regard, application of geo-spatial techniques based on remotely sensed imageries is very effective method to evaluate the changing conditions of rapidly growing urban areas.

Urban growth is indicative of physical expansion of urban areas. Occurrence of urban growth severely alters the biophysical environment in urban areas. In terms of ecological impact, urban expansion has been identified as one of the most significant and long-lasting forms of land use and land cover change and its extent of increase is linked to population growth and economic development [2]. Urban growth, both in population and in areal extent, transforms the landscape from natural cover types to increasingly impervious urban land. The removal of natural cover types and subsequent introduction of urban impervious materials brings many adverse impacts to city environment.

This study focuses on the change of vegetation of Kandy city, Sri Lanka which is one of world heritage cities in response to its expansion over time based on temporal basis Landsat data. Kandy city has the great national important since it is being the major cultural, commercial, administrative and transport center of the hill country during the last 600 years history since its establishment as the capital of the Kandyan Kingdom in the 15th Century. The most significant cultural character of the Kandy city is the location of the Sacred Tooth Relic Temple. Due to its historic value which was shaped by different ruling periods of local and colonial it has been inscribed as a World heritage city by UNESCO in 1986.

The city is situated in a valley bottom surrounded by green hill slopes and bounded by the river Mahawali on the North East and West and South by the Hantane

range. However, the economic boom in the later part of 1980, and 1990 associated with introduction of open economic policy into the country had created rapid constructions within the area of commercial, administrative and other uses without proper planning. This has caused to expand the built up area in the city on one hand and to remove the natural landscape of the city. In this context, this study attempt to examine the impact of urban growth with the objectives of measuring the built up area expansion, detecting changes of natural vegetation cover, and indentifying the degree of correlation between urban growth and natural vegetation cover.

II. MATERIALS AND METHODS

This study uses Urban Index (UI), Normalized Difference Vegetation Index (NDVI) and linear regression technique to achieve the above objectives. Depending on the data availability Landsat satellite data with moderate resolution were obtained from USGS server [3]. Image processing and related mapping were done with Arc GIS (Geographical Information Systems) 10.2 software.

In this study, urban growth is represented by UI [1] which is used to estimate the built up area in the Kandy city in 1994, 2003, 2007 and 2015. Since urban areas are mainly dominated by built-up lands with impervious surfaces, in this study, urban built-up area is used to represent the area directly occupied by a particular physical structure, including buildings, streets and all man-made structures. Information of images used for UI retrieval is mentioned in Table 1. Equation 1 is used to extract the UI. UI values are represented as a ratio ranging from -1 to +1. Positive values from 0 represent the built up area while negative values represent none built up areas.

$$UI = \frac{(SWIR-NIR)}{(SWIR+NIR)} \text{..... Equation 1}$$

This study uses the NDVI for the purpose of detecting spatio-temporal change of vegetation cover in the Kandy city during the last 35 years. The analysis of spatio-temporal change in vegetation cover and its density has a greater significance in understanding the changing nature of vegetation cover in the city with response to increasing urban expansion.

NDVI values are represented as a ratio ranging in value from -1 to +1 but in practice extreme negative values represent water, values around zero represent bare soil and values over 6 represent dense green vegetation. Equation 2 gives the formula used for the NDVI while Table 2 provides information of LANDSAT images used to retrieval of NDVI in the Kandy city.

Table 1: Information of Landsat Data for UI

Acquisition date	Satellite/ Sensor	Wave Band		Spatial (pixel) Resolution
		SWIR	NIR	
1994.09.11	Landsat 5 TM L1T	7	4	30 Meter
2003.01.31	Landsat 7 ETM+LIT	7	4	30 Meter
2007.03.23	Landsat 5 TM LIT	7	4	30 Meter
2015.03.29	Landsat 8 OLI TIRS	7	5	30 Meter

Table 2: Information of Landsat Data for NDVI

Acquisition date	Satellite/ Sensor	Wave Band		Spatial (pixel) Resolution
		SWIR	NIR	
1980.02.26	Landsat 3 MSS L1T	7	5	60 Meter
1994.09.11	Landsat 5 TM L1T	4	3	30 Meter
2003.01.31	Landsat 7 ETM+LIT	4	3	30 Meter
2007.03.23	Landsat 5 TM LIT	4	3	30 Meter
2015.03.29	Landsat 8 OLI TIRS	5	4	30 Meter

$$NDVI = \frac{(NIR-Red)}{(NIR+Red)} \text{.....Equation 2}$$

Objective three was achieved through a simple regression analysis which is based on the relationship between the cell values of UI and NDVI. Linear regression model helps to examine whether there are correlations between above variables and how the magnitude of correlation changes over time. This was performed by using regression analysis available in Excel 2007. Following is the equation of the simple regression.

$$y = a+bx+e \text{.....Equation 3}$$

y=Dependent variable
x=Independent variable
e=an "error" term
Constant a and b represent the intercept and slop, respectively of the regression line.

Table 3.Information of Simple Regression

Independent variable (x)	Dependant variable(y)	Year	No of Cells
UI	NDVI	1994 2003 2007 2015	29210 29210 29210 29210

III. RESULTS AND DISCUSSION

3.1. Built Up Area Expansion

Colour images of UI with five categories are shown in Figure 1. Illustrations drawn by using their statistics are shown in Figure 2. Above 0 value (pixel) represents "intensity of built up lands" and minus pixel values represent mix of built up, vegetation, water and bare lands.

As Figure 2 indicates all categories of UI have undergone a change positively and negatively during the last two decades. Expansion of built up area is an essential result of urban growth and Kandy city also has expanded its built up area over the time. "Very high" category of UI which is the area of dense built up has a remarkable continuous increase from 4.73 percent to 10.94 percent from the year 1994 to 2015 (Figure 2 and Figure 3). "High" and "medium" categories of UI also have increased by a higher rate from 1994 to 2015. "Low and "none built up" categories which represent the vegetation have declined in corresponding time period. The most affected category observable in this connection is the "None built up category which represents the dense vegetation in the city. It has declined by 10 percent within a very short period from 2003 (28 percentage) to 2007 (18 percentage). It is evident that built up area of the city has expanded considerably within the last two decades and as a result city has lost its dense vegetation cover by a substantial amount.

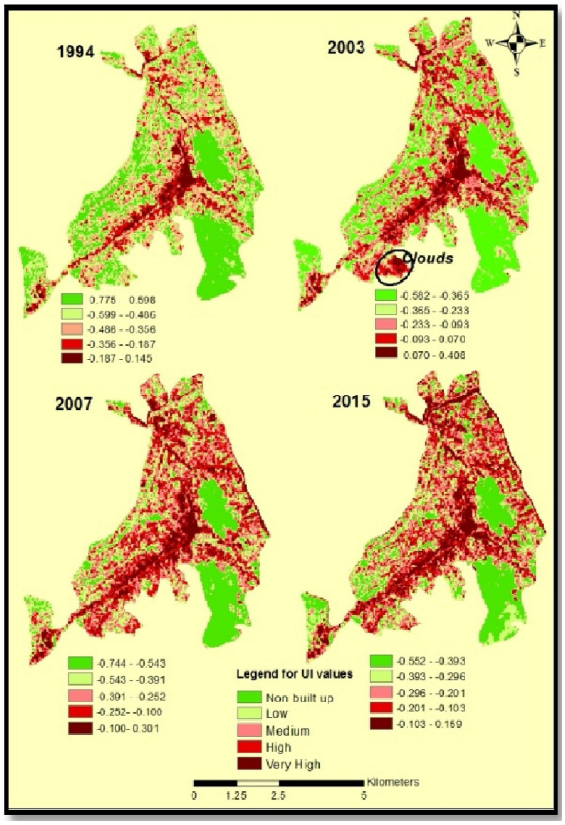

Fig.1. UI Categories in Corresponding Years in the Kandy City

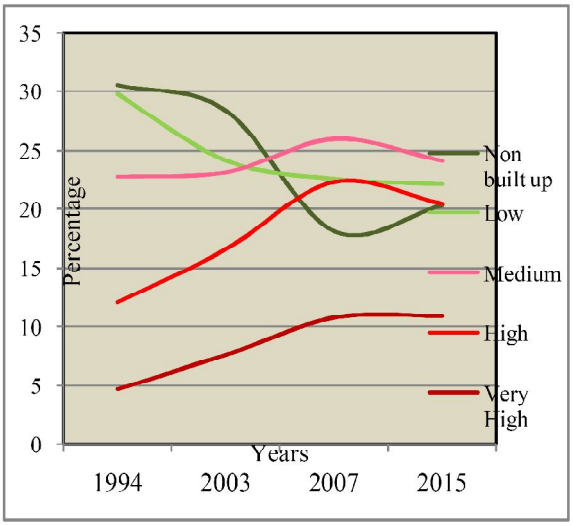

Fig.2. Trend of UI Categories in Corresponding Time Period in the Kandy City

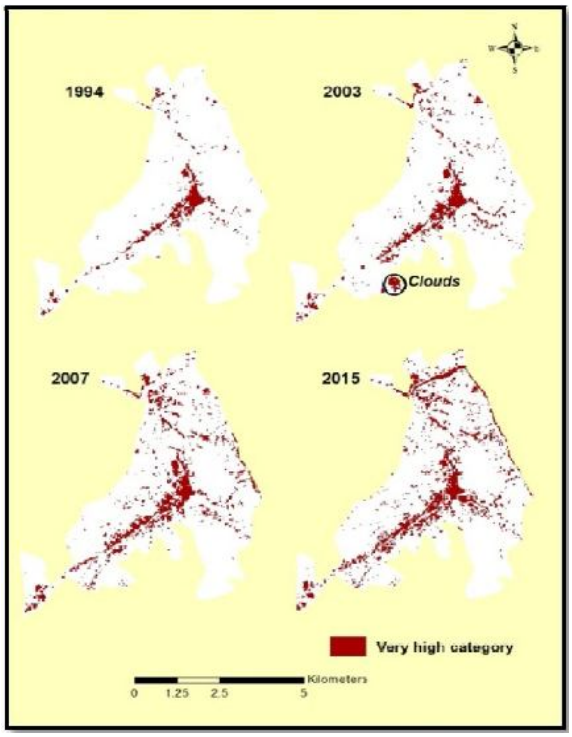

Fig.3. Change of Very High Category of UI in Corresponding Years in the Kandy City

3.2 Changes in Normalized Difference Vegetation Index (NDVI)

Result of the NDVI extraction from landsat images in five different years within the period of 1980 to 2015 in Kandy city is illustrated by Figure 4 and Figure 5. According to theses illustrations all categories in NDVI have changed significantly with both positive and negative values in response to the city growth.

As historical records reveal, Kandy city and its surrounding area was covered with impermeable dense forest from its inception due to its physical manifestation and climatic condition. Topographical nature and its climatic situation were appropriate for

not only growth of tropical rain forest but plantation crops introduced by Europeans. Both these natural landscape and agricultural landscape kept the city and its surrounding more "green" for a long period. This situation existed up to recent history because of slow growth of the city. NDVI image even in 1980 provides significant evidences for this situation.

Other images from 2003 illustrate increase of "light green, yellow and red patches which are impervious surfaces with low vegetation. Built up area was very limited in 1980 and 1994 and basically concentrated in the city center and along the major roads in the city. Other images from 2003 to onward show gradual increase of non vegetated areas initially in the city center, along the major road lines as well as peripheral areas in the city. Figure 5 gives statistics taken from NDVI categories in each year for the realization of how vegetation cover in the city has been impacted with the increase of city growth. Table explains the areas in the category of medium and high vegetation has a remarkable negative change indicating a sharp drop in the vegetation cover in the city in the corresponding period. In 1980 areas with high vegetation has recorded as 28 percent and by the year 2015 it has declined up to 18 percent. Its loss is 10 percent and this category is the most affected NDVI category of vegetation in the city due to the urban expansion compared with the change of other NDVI categories. Together, areas with medium vegetation cover also have reported a 3 percent decline from 25 percent to 22 percent during the last 35 years.

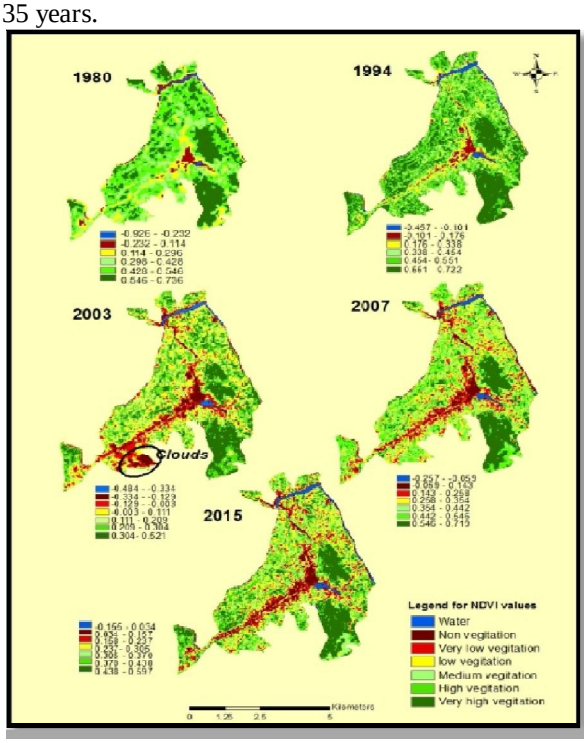

Fig.4. NDVI Categories in Corresponding Years in Kandy City

Vegetated areas in the category of very high vegetation seem to be remained constant. Its percentage in 1980 was 16 percent and no considerable change has undergone through the time. This category represents the dense forested areas in the city with NDVI value over 0.5 which is declared as reserved forests in the city. There are two major forest patches located on the Eastern and Northern part of the city and they are very close to the city center. Udawattakele forest which is located in the side of Eastern part is one of the major forested areas in the city. Udawattakele with 104 hectares is a historic forest reserve on a hill- ridge in the city of Kandy. During the days of the Kandyan kingdom, Udawattakele was known as "Uda Wasala Watta" in Sinhalese meaning, "the garden situated above the royal palace". This sanctuary is famous for its extensive avifauna and also contains a great variety of plant species. Udawattakele was designated as a forest reserve in 1856, and it became a sanctuary in 1938. Dunumadalawa forest located in Southern part is the other dense forest area in the city. It is situated on the edge of the Hantane range just south of the main town. It spans across 480 hectares comprising of secondary growth forest having once being the site of plantations. It supports diverse avifaunal stock which boasts a high level of endemicity. This forest also has become a sanctuary since its conservational importance.

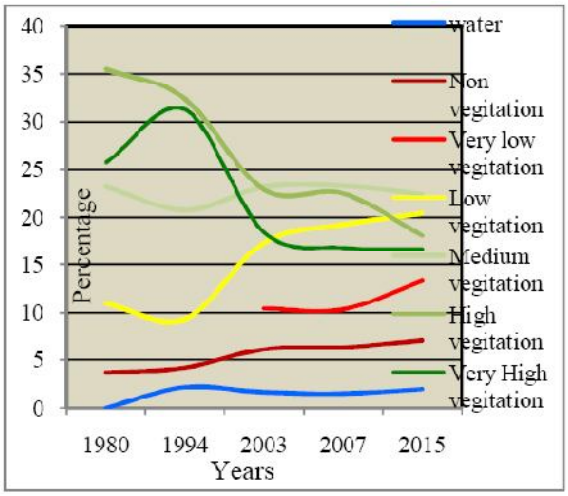

Fig.5. Trend in NDVI Categories in the Kandy City from 1980-2015

3.3. UI-NDVI Correlation

UI, in general is negatively correlated with NDVI. NDVI reduces with increasing UI. As explained in 3.1 and 3.2 UI in corresponding years in the city has increased while NDVI in corresponding years has decreased. According to the results it is found that in 1994 UI-NDVI in the city was moderately correlated (Coefficient of correlation=0.61) but from 2003 the relationship has become strong (Figure 6 and Table 4). Its correlation has gradually increased over time and presently it is much strong (Coefficient of correlation=0.91). As well R square (Coefficient of determination) which measures the percentage of explained variation from the total variation of dependent variable (NDVI) by the independent

variable (UI) has gradually increased with time. In 1994 UI was responsible only for 38 percent of total variation of NDVI and it is rather low compared with the other years. After 2003 percentage of explained variation of NDVI has become greater and presently 83 percent of variation of NDVI is due to UI. Therefore, this is clearly indicating that there is a strong correlation between reduction of NDVI and increase of UI.

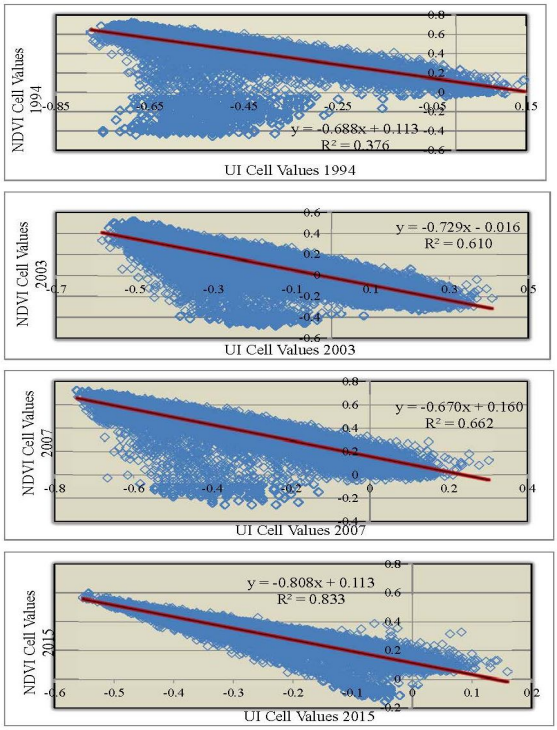

Fig. 6: Scatter plots of correlation between UI and NDVI

Table 4: Correlation information between UI and NDVI

Year	Multiple R Coefficient of correlation	R Squared coefficient of determination	P Value	Correction type/degree
1994	0.61	0.38=38%	0	Moderate negative correlation
2003	0.78	0.61=61%	0	Strong negative correlation
2007	0.81	0.66=66%	0	Strong negative correlation
2015	0.91	0.83=815	0	Strong negative correlation

CONCLUSION

This study initially attempted to examine impact of urban growth on vegetation cover of Kandy City, Sri Lanka with GIS and RS Techniques. As result shows during the time period from 1994 to 2015 built up area has expanded significantly and as a result of that its natural environment especially vegetation in the city area has adversely been impacted. Only the vegetated areas in the category of very high vegetation seem to be remained constant since its recognition as reserved forest area while all the other categories of forest under the threat of reduction.

Seeking up to what extent these geo-spatial phenomenon are correlated is much significant to understand the impact of urban growth on the city environment. Correlation analysis between UI-NDVI, by using linear regression technique has revealed that the most crucial correlation is present between the UI and NDVI. There is a strong negative correlation between UI and NDVI. Correlation between UI and NDVI is much strong in the 2015 indicating the problem of losing forested areas.

Vegetation loss in general brings a many interrelated environmental problems including climatic change. Urban heart islands, temperature increase, lack of evapotranspiration, lose of shade and cooling effect of trees [4] [5] are some of such possible problems with a decreased amount of vegetation. If mitigate measures are not implemented in the city, in near future city will be uncomfortable place for living and working and will increase the economic cost of living. Therefore, this study strongly recommends to take necessary steps to control the problem of decrease of greener areas in the city.

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