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Estimation of Land Use Change to Identify Urban Heat Island Effect on Climate change: A Remote Sensing Based Approach.

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ABSTRACT

Climate change leads to higher temperatures and longer, more severe, and more frequent heat waves. Urban areas already suffering from the heat island effect will bear the brunt of these harsher heat events. The estimation of Land Use Change (LUC) is an important measurement to identify the Urban Heat Island (UHI) effect which dramatically impacts local and global climate change. In the last few decades, the land use of Rajshahi City has been changed constantly by physical, economic and social factors. LUC will increase the temperature of the city space and those impact of clime change in city atmosphere will also rise. The main objective of this study is to determine the urban heat island (UHI) effect with the establishment of relationship between land surface temperature (LST) and LUC in Rajshahi City Corporation (RCC) area. The decadal LUC maps and LST of the study area for the year 1995, 2005 and 2015 have been prepared using the Landsat TM/OLI satellite images. The LUC maps, LUC detection technique, and retrieval of LST has been prepared by using ArcGIS and ERDAS Imagine software. The result shows that vegetation and agricultural lands (VAL) has been reducing almost 25% in space of 20 years and maximum VAL have been shifted into built-up land dramatically. The study also finds that VAL represent an inverse relationship with surface temperatures and as a result, urban heat island (UHI) intensity have been increased in RCC area. This indicates that increasing the amount of built-up area increase the urban heat island (UHI) intensity. The study describes a national problem named urbanization which increases rapidly and increases the temperature in urban areas. The findings will help the concerned authority for further planning and strategy making policy about the most favourable actions taken to reduce the urban heat island (UHI) effect.

Key Words: Land use change, urban heat island, Climate change, Land surface temperature.

1. INTRODUCTION

Bangladesh faces rapid urban growth and sprawl which significantly affect the biophysical environment and causes serious damage to the urban environment. Since urbanization is increasing day by day the temperature of the environment is also increasing gradually (Kumar, Bhaskar, & Padmakumari, 2012). Because of these factors like latitude, altitude, distance from the sea, humidity etc. urban heat island is occurring, which badly affects the climate. It modifies the air temperature of the atmospheric boundary layer and is a key component in the surface energy balance. Due to increasing of the urbanization various buildings, roads, parking lots, and other paved surfaces are taking places instead of trees which reduce the capacity of absorbing solar radiation (Kalnay & Cai, 2003). As a result, the thermal heat of the solar radiation is spreading over the environment which creates urban heat island (Voogt & Oke, 2003).

Using image classification algorithm, Remote Sensing and GIS environment, changes of urban land, vegetation can be measured (Kafy, Ferdous, Faisal, Khan, & Sheel, 2018). Satellite images have been widely used to analyze temporal changes in land use/land cover (LULC) in Bangladesh (Tan, San Lim, MatJafri, & Abdullah, 2010). Remote Sensing (RS) and GIS environment has been used for classifying land cover where classification techniques can help to detect the specific land cover (Ozesmi & Bauer, 2002).

Land cover and vegetation density are observed by Landsat data because they are accessible in multi-spectral, multi-resolution, and multi-temporal forms and provide important information for analysis (Weng, 2001). The purpose of the study is to incorporate RS imageries and GIS Application to determine the urban heat island (UHI) effect with the establishment of relationship between land surface temperature (LST) and LUC in Rajshahi City Corporation (RCC) area..

2. EXPERIMENTAL

2.1 Study Area Profile

Rajshahi is the fourth largest metropolitan city of Bangladesh. It lies between 24°07′ to 24°43′ north latitudes and between 88°17′ to 88°58′ east longitudes (Kafy et al., 2018). It was one of the first Municipalities in Bangladesh, established in 1876. In 1987 was declared as a City Corporation (Clemett, Amin, Ara, & Akan, 2005). The region consists of Barind tract, Diara and Char lands. Rajshahi town (City Corporation) stands on the bank of the river Padma. The total area covered by the Rajshahi City Corporation is 96.72 sq. km (Kafy et al., 2018). The location of RCC location area shown in fig.1.

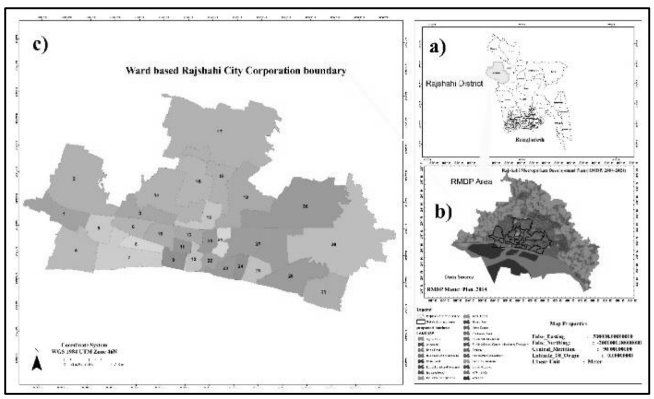

Figure 1 Location of Rajshahi City Corporation (RCC) area (a) in Bangladesh and in Rajshahi District b) in RMDP area and c) RCC ward boundary

2.2 Methodology:

For the present study the following methodology is implemented which involves satellite data assortment, classification of the imagery, estimation of land use/cover maps, preparation of NDVI maps, retrieval of Land Surface Temperature maps and correlation studies. Cloud Free Landsat satellite data of 1995, 2005 and 2015 for the study area has been downloaded from USGS Earth Explorer website. All the data are pre-processed and projected to the WGS 1984 UTM-45N projection system. The details of the satellite data collected are shown in the Table.1.

Table 1 Collection of Satellite Images

Respective Year	**Date Acquired**	**Sensor**	Path/row	Cloud cover
1995	24th April, 1995	Landsat 4–5 Thematic Mapper (TM)		
2005	19th June , 2005	Landsat 4–5 Thematic Mapper (TM)	138/43	Less than 10%
2015	9th May 2015	Landsat-8 OLI		

Using bands from Landsat 4-5 TM and Landsat-8 OLI images the land use / cover pattern was mapped by supervised classification with the maximum likelihood classification algorithm in ERDAS imagine 15 software. The Four classes considered for the study area are Built-up area, bare land, Agriculture and vegetation fields and Water (figure-2). The supervised classification involves pixel categorization by (i) Training, (ii) Classification and (iii) Output (Kumar, Bhaskar, et al., 2012). Classification Accuracy assessments were done with field knowledge and referring the Google Earth. The classification accuracy was also calculated for the Land use/cover map. The classification accuracy assessment was performed and the results are shown in Table.2. The Normalized Difference Vegetation Index (NDVI) is a measure of the amount and health of vegetation at the surface. The NDVI value is normalized and varies to -1<=NDVI<=1 (Kumar, Udayabhaskar, & Padmakumari, 2012). The index is defined by equation 1.

$$NDVI = \frac{NIR\ (Band\ 5) - R\ (Band\ 4)}{NIR\ (Band\ 5) + R\ (Band\ 4)} \qquad (1)$$

The digital number (DN) of thermal infrared band is converted in to spectral radiance (Lλ) using the equation supplied by the Landsat user's hand book and Jimenez et al research for Landsat 4-5 Tm and Landsat OLI images (Jiménez-Muñoz, Sobrino, Skoković, Mattar, & Cristóbal, 2014; Kumar, Udayabhaskar, et al., 2012). The retrieval equation for Landsat 4-5 Tm (eq.2-3) and Landsat-8 OLI (eq.4-5) is discussed below

$$T_k = \frac{K_1}{Ln\ (\frac{K_2}{R_{TM6}/_b} + 1)} \qquad (2)$$

Where, K_1 = 1260.56 K and K_2 = 607.66 (mW × cm^{-2} × sr^{-1} μm^{-1}), which are pre-launch calibration constants under an assumption of unity emissivity; b represents an effective spectral range when the sensor's response is much more than 50%, b = 1.239(μm) *(*Landsat 7 Science Data Users Handbook, 2010). After deriving the Land Surface Temperature in Kelvin unit it is converted to degree Celsius from the following equation:

$$T_{0_C} = T_k - 273 \qquad (3)$$

Estimation of Top of Atmospheric Spectral Radiance of TIRS Band 10 and 11 and OLI sensor of Band 2-5 individually using the algorithm given below.

$$L_\lambda = \left(\frac{L_{max} - L_{min}}{DN_{max}}\right) \times Band + L_{min} \qquad (4)$$

L = Top of Atmospheric Spectral Radiance in watts/ (m2 × srad × μm), L_{max} = Maximum Spectral Radiance of respective Band, L_{min} = Minimum Spectral Radiance of respective Band , DN_{max} = Qcal max – Qcal min = Difference of maximum and minimum calibration of the sensor.LST has calculated both for band 10 and band 11 using the following formula (Avdan & Jovanovska, 2015).

$$LST = \frac{BT}{\{1 + [\lambda BT/\rho]\ln(\varepsilon)\}} \qquad (5)$$

3. RESULT AND DISCUSSION

The land use land cover map of the study area developed for the year 2001 using supervised classification method is given in Fig.2 below. Changes of urban land use can be easily determined by the image. Noticeable change happens in buildup area which increase from 22% to 36% in space of 20 years. The rapid urbanization increases the sir temperature which occur the urban heat island effect in RCC area. The field knowledge and Google Earth were served as basis for estimation of classification accuracy. The classification accuracy assessment was performed and the results are shown in Table.2 below.

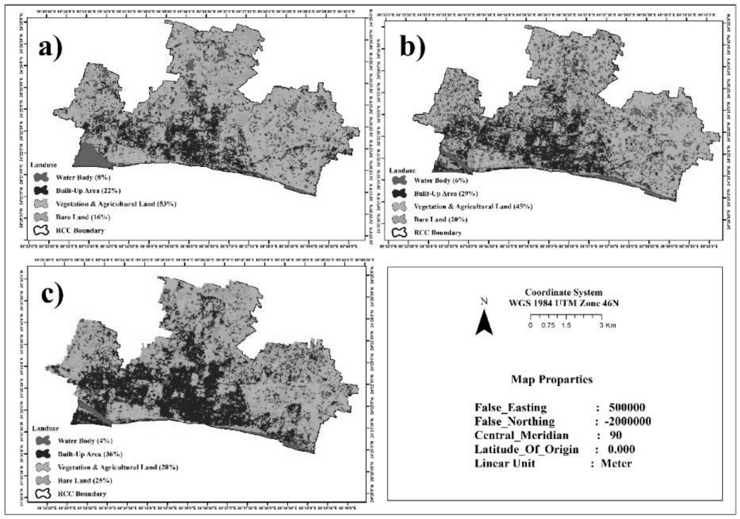

Figure 2 Land cover maps of the study area; a) 1995 b) 2005 and c) 2015

Table 2 Classification accuracy assessment report

User Accuracy (%)					**Producer Accuracy (%)**				**Overall Classification Accuracy**	**Overall Kappa Statistics**
Year	**Water body**	**Built-up area**	**Vegetation**	**Bare soil**	**Water body**	**Built-up area**	**Vegetation**	**Bare soil**		
1995	100	80	100	100	100	100	100	75	93.75%	0.9080
2005	100	85	85	100	100	100	100	63	87.50%	0.8095
2015	100	100	100	81	100	60	100	100	87.50%	0.7714

The NDVI value of the pixels varies between -1 and +1. Higher values of NDVI indicate the richer and healthier vegetation. Lower LST(except water bodies) is usually measured in areas with higher NDVI values (Kumar, Bhaskar, et al., 2012; Kumar, Udayabhaskar, et al., 2012). The Normalized Difference Vegetation Index (NDVI) image developed is shown in the Fig.3 below

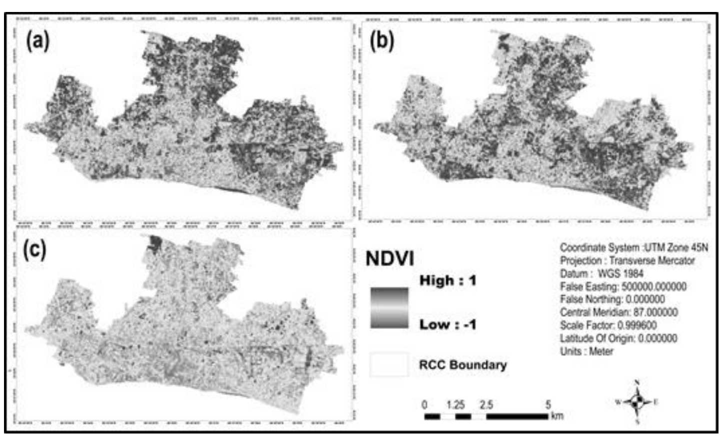

Figure 3 NDVI Map for RCC area in three different years a) 1995 b) 2005 and c) 2015

From brightness temperature (TB) and Emissivity images the final Land Surface Temperature image was obtained by developing a model in ERDAS Imagine 9.1. The Final LST image is shown in the Fig.4 below.

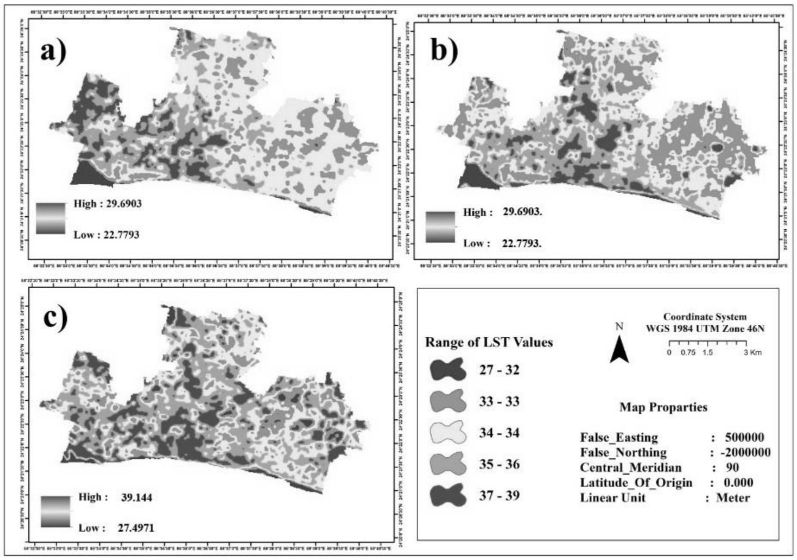

Figure 4 Spatial Pattern of Land Surface Temperature (LST); a) 1995 b) 2005 and c) 2015

From the LST image it was observed that highest temperatures of about 39^0C in year 2015 which recorded in urban built up areas and other impervious areas and lowest temperatures of about 22^0C are existing at vegetative and water body areas in year 2005 and 1995 (Fig. 4).

To show the profile of the Land Surface Temperature in the study area, two transacts were taken, one from east end to the west end and the second from north end to south end which are passing through the city. The temperature profiles shown in the Fig. 5 clearly demonstrates the Urban Heat Island effect in various area

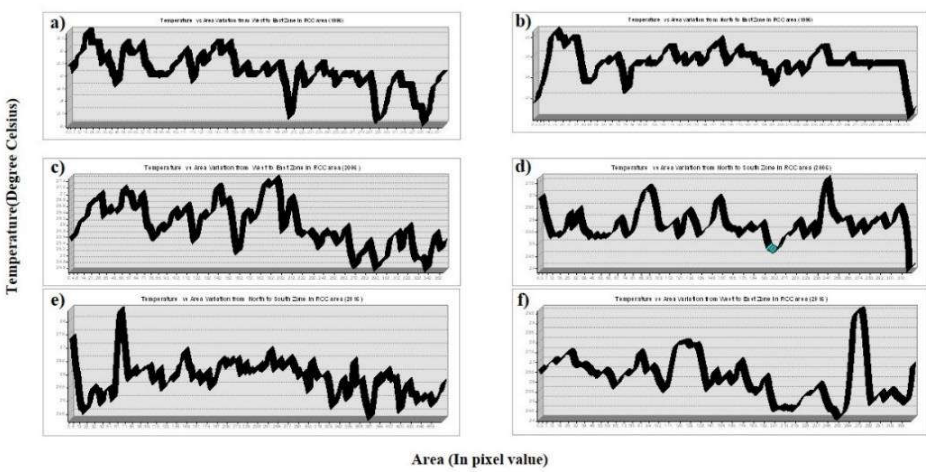

Figure 5 Land Surface Temperature profile from North end to South end and West end to the East end of the study area a,b)1995 ; c,d) 2005 and e,f) 2015

More than 150 points are selected randomly form the LST image and corresponding NDVI values are obtained to find the correlation between LST and NDVI. The correlation coefficient obtained between LST and NDVI is found as -0.83. This is clearly indicating that the LST is strongly and negatively correlated with NDVI. Hence areas with least vegetation are experiencing more land surface temperatures.

4. Conclusion

Rajshahi is the third largest city of Bangladesh and gradually became commercial capital for the country. In the last few years the city is experiencing rapid urbanization. With urbanization most of the land surface is covered with concrete, asphalt and other such impervious materials. This leads to a variety of urban environmental issues like an increase in runoff increase in land surface temperatures, etc. The cities in Bangladesh are experiencing additional heat than the surrounding rural areas mostly due to the decrease in water bodies and lack of vegetative cover. In this study an attempted is made to identify the relationship between and the land surface temperature and land cover changes in three different years. GIS and remote sensing has the capability of monitoring such changes, extracting the changing information from various satellite data. In this work Landsat 4-5 TM and Landsat-8 OLI images of Rajshahi City Corporation was collected from USGS earth explorer web site. The land cover maps of the study area are developed by supervised classification of the images. Four broad land use classes have been identified as Urban (Built-up), Waterbody, Agricultural, and Vegetation land and Bard Land. Overall classification accuracy for the three decades is more than 75%. Surface temperature is retrieved from two different satellite to understand the variation of temperature in three decades and which land use is contributing to the increase in UHI effect in the city. From the LST images, it is undoubtedly understood that surface temperature is more in the urban area and less in the vegetated area. Also, the correlation analysis shows that the LST is strongly and negatively correlated with NDVI. This information assists in monitoring the dynamics of land use change demands because of the increasing population and associated issues like Urban Heat Island. The spatial layout of the land cover in a city has a significant impact on the increase of heat islands. Therefore, urban planning can be applied to minimize the effect of urban heat islands in fast-growing cities all around the world.

5. ACKNOWLEDGMENT

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