TEMPORAL DYNAMICS AND RELATIONSHIP OF LAND USE LAND COVER AND LAND SURFACE TEMPERATURE IN DHAKA, BANGLADESH

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ABSTRACT

Analysis of change in LULC and LST helps to understand the UHI effect, as rapid urbanization and industrialization often take place without any coherent planning and control policies in cities of developing countries. This study aims to detect the pattern of LULC change in Dhaka City, the capital of Bangladesh, from the Landsat images of the year 1988, 2002 and 2016, considering four major LULC types named Built Up Area, Bare Lands, Vegetation and Wetlands/Lowlands. Along with the LULC, LST of those years have also been computed from the thermal band of the satellite images using the calibration of spectral radiance and emissivity correction of remote sensing, to investigate the changing nature of the climate. The change detection study has revealed that Dhaka can be characterized by increased Built Up Area and decreased Vegetation and Wetlands within these 28 years. Due to excess population pressure and rapid urbanization, Built Up Area has increased and encroached the Bare Lands and the Wetlands/Lowlands. Regression analysis has been used to characterize the relationship between LULC types and LST, which has revealed a very strong positive correlation (r^2=0.9281) between Built Up Area and LST and a very strong negative correlation (r^2=0.9556) between Wetlands/Lowlands and LST. This study will facilitate the land use managers and policy makers to monitor how the land is used and understand the development and directions of various kinds of land use, in particular, urban land use in the past, present, and future and to promote substantial and sustainable development accordingly.

Keywords: *Landsat; LST; LULC; correlation*

1. INTRODUCTION

Analysis of Land Use Land Cover (LULC) change is important to evaluate the global changes at various spatial-temporal scales and it has become one of the key issues in sustainable development and global environmental changes (Guan et al., 2011; Halmy et al., 2015; Zheng et al., 2015). For understanding the urban heat island (UHI) effect, exploration of the change in LULC is very essential. In developing countries, urbanization and industrialization often take place rapidly without any sustainable planning and guiding policies. Study of LULC to understand UHI effect has been proved to be very valuable for these countries (Tran et al., 2017). Change of LULC should be monitored regularly as it causes irreversible impacts on the environment, especially causing urban micro-climate warming (Ahmed et al., 2013; Dewan, 2015; Hahs et al., 2009; Heinl et al., 2015; Nagendra et al., 2012; Niyogi et al., 2010). These environmental impacts are most prominent and severe in rapidly growing developing nations of Asia, which have agricultural based economies (Chaudhuri & Mishra, 2016).

Like other developing countries, Bangladesh experienced a fast increase of urban population in the recent decades. This rapid urban growth results in encroachment of other land use types by Built Up Area to accommodate the huge population pressure (Dewan & Yamaguchi, 2008). This land use transformation results in more impervious surface and increases the heat storage capacity which is the main cause of UHI. UHI is considered as one of the main causes of urban micro-climate warming and defined as an environmental phenomenon where air and land surface temperatures (LST) of urban areas are higher than those of its surrounding areas (He et al., 2007; Trenberth, 2004). Growth of UHI has adverse effect on the urban climate change such as abrupt temperature rise, erratic rainfall, degrading air quality, causing calamities like flood, water logging, health outbreak, and water scarcity (Alam & Rabbani, 2007; Dewan & Yamaguchi, 2009; Hossain, 2008; Ifatimehin et al., 2010; Rizwan et al., 2008). Urbanization, the main driver of LULC change is one of the most significant factors of generation of UHI and changing LST (Chen et al., 2006; Kalnay & Cai, 2003). High spatial variability of LST has been shown in most of the urban areas, influenced by proportion of impermeable surface and vegetation mix associated with socio-economic variables such as, road and population density (Adams & Smith, 2014; Feizizadeha et al., 2013; Li et al., 2012; Zhang et al., 2013). The changing nature of LULC may influence the change in land surface temperature and urban micro-climate. So the trend of LULC should be an important topic to explore the trend of LST.

Several researchers have studied the LULC and LST change pattern for different areas and some have tried to establish the relationship between these two components, considering both linear and nonlinear relations (Ahmed et al., 2013; Chaudhuri & Mishra, 2016; Tran et al., 2017). Ahmed et al. (2013) studied the patterns of LULC changes and investigated their impacts on LST in Dhaka Metropolitan (DMP) area, using the satellite images of the year 1989, 1999 and 2009 and simulated LULC and LST for 2019 and 2029. Simulation results show that if the current trend continues, 56% and 87% of the DMP area will likely to experience temperatures in the range of greater than or equal to 30 °C in 2019 and 2029, respectively (Ahmed et al., 2013). Study of Chaudhuri and Mishra (2016) examined the spatiotemporal variability of LULC change and its relationship with LST, focusing on the southern part of the lower Ganges Brahmaputra Delta region along the international border of India and Bangladesh, with a comparison between Indian and Bangladesh part, revealing that LST changes were predominantly driven by LULC changes on both sides of the border. Dewan and Yamaguchi (2008) illustrated that the LULC of Dhaka Metropolitan had been drastically changed from 1960 to 2005, using topographic maps and multi-temporal remotely sensed data. The analysis indicated that the urban expansion of Dhaka Metropolitan resulted in the considerable reduction of wetlands, cultivated land, vegetation and water bodies, which are controlling factors of LST. Another research had been carried out to assess the relationship between the LST and LULC changes both in quantitative and qualitative ways in Dhaka Metropolitan Area using Landsat TM/ETM+ data over the period 1989 to 2010, revealing the direct correlation between these two parameters (Raja, 2012).

The knowledge of the existing LULC trends is one of the key necessities to address the challenges associated with land management (Chaudhuri and Mishra, 2016). Up-to-date, adequate and reliable LUCCs information from the past to present together with the future reasonable changes is vital to understand and evaluate several social, economic and environmental consequences of these changes (Foley et al., 2005; Wilson & Chakraborty, 2013). Being the capital of Bangladesh, Dhaka could be the best example of rapid population increase and associated environmental change, which is projected to be the third largest megacity in the world by the year 2020 (The World Bank, 2007). In Dhaka city, there is lacking or shortage of valid and up-to-date information on the type and intensity of LULC changes, which is essential for sustainable land use planning and management. If an important climatic parameter like LST can be explored along with LULC change, the more fruitful result will be gained. So this study aims to analyse the LULC and LST change in Dhaka City from the year 1988 to 2016 using Landsat images and to investigate the relationship between change in LULC and LST.

2. MATERIALS AND METHODS

2.1 Study Area

For this study, a portion of Dhaka Metropolitan Area has been selected, which can be extracted from the Landsat image scene (WRS2: 137/43) (Figure 1). Dhaka is one of the fastest growing megacities of the world and the rapid urbanization has a great impact on its LULC and LST (Ahmed et al., 2013; Dewan and Yamaguchi, 2008). The population of this city has increased by approximately 11 million in the past two decades and this causes the vertical and horizontal expansion of this city including significant change in its land use (Ahmed et al., 2013).

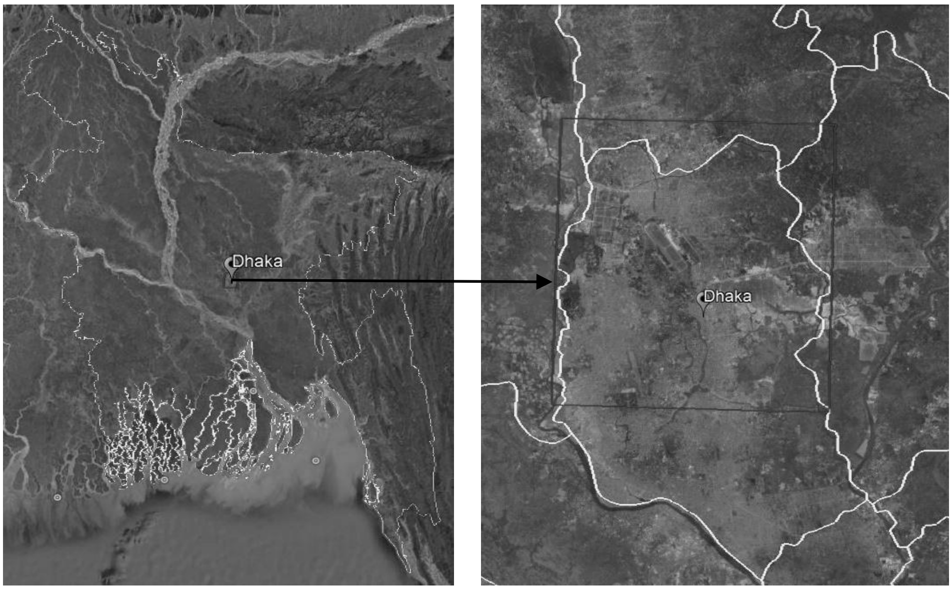


Figure 1. Location of Study area (Dhaka City)

2.2 Methodology

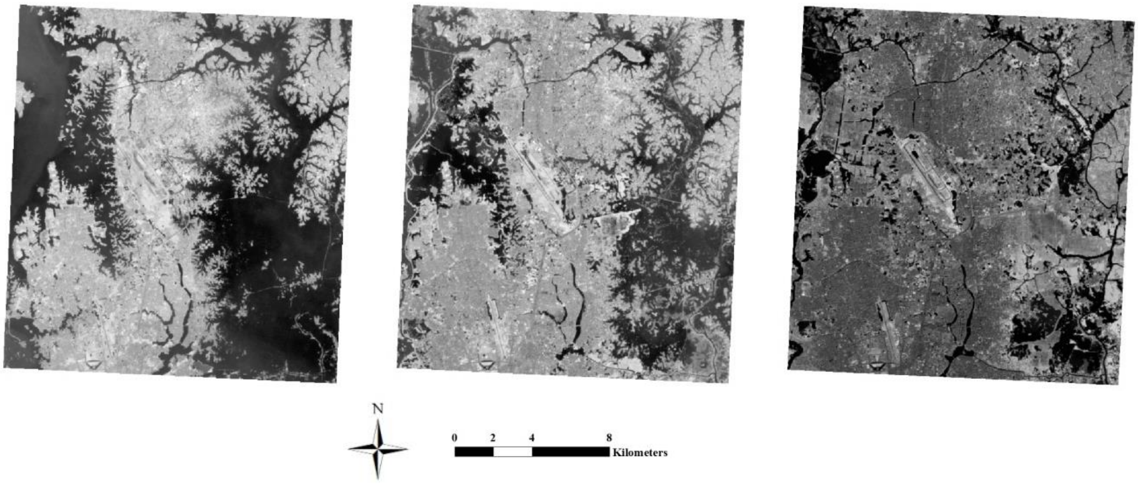
2.2.1 Acquisition and Processing of Satellite Images

To study the temporal dynamics of land use land cover (LULC) and land surface temperature (LST) in Dhaka City, Landsat Images of Dhaka city (WRS2: 137/43) for the year 1988, 2002 and 2016 have been collected from the United States Geological Survey (USGS) website (Table 1).

Table 1. Information regarding satellite images

Sensor	Path/Row	Acquisition Date
Landsat 5 Thematic Mapper (TM)	137/43	16 October 1988
Landsat 7 Enhanced Thematic Mapper (ETM+)		31 October 2002
Landsat 8 Operational Land Imager (OLI)		14 November 2016

All the spatial data layers will be registered to the same Universal Transverse Mercator (UTM) coordinate system and resampled to the same pixel resolution of 30 meter. In order to use satellite images of different periods, it is essential to acquire images of same dates, which has been followed in this study (Parsa and Salehi, 2016). Then necessary atmospheric and geometric corrections have been performed. Figure 2 shows the raw satellite images in false natural colour composite (in Grayscale).



a. b. c.

Figure 2. Thematic images of Dhaka City in False Natural Colour Composite (R(SWIR), G(NIR), B(Red)) a. in 1988, b. in 2002 and c. in 2016

2.2.2 Classification of Satellite Images

Maximum Likelihood Classification Technique of Supervised Classification has been used to identify the dominant LULC classes. Training samples have been prepared from observing false colour tone and connecting the window of ERDAS IMAGINE 2014 with Google Earth window. Researchers' prior knowledge about the LULC of the study area gained by field visits was proved very useful for this classification process (Rahman et al. 2017). Four LULC types have been classified named 'Vegetation', 'Built Up Area', 'Bare Lands' and 'Wetlands/Lowlands'. Table 2 describes the detail about LULC classes.

Table 2. Land use/land cover classification scheme

Land use/Land cover types	Description and color tone
Vegetation	Natural vegetation, parks, mixed forest, vegetated lands. Agricultural lands, crop fields etc. (green tone)
Built Up Area	All infrastructure – residential, commercial, settlements, road networks (purple tone)
Bare Lands	Unused empty lands, fallow lands, open space, earth/sand fillings, bare soil and others (tan/brown tone)
Wetlands/Lowlands	River, lakes, ponds, canals, low lying areas, marshy lands and swamps etc. (blue tone)

2.2.3 Calculation of Land Surface Temperature (LST)

Land surface temperature has been computed from the thermal band of the satellite image using the calibration of spectral radiance and emissivity correction of remote sensing. All the necessary data to calculate LST have been found in the header file (metadata) downloaded with the satellite images. At first, the Digital Number (DN) value of thermal bands of satellite images has been converted to radiance value (L_λ) and the radiance has been converted into At-Satellite Brightness Temperature. Thermal band data can be converted from spectral radiance to brightness temperature using the thermal constants provided in the metadata file (equation 1).

$$T = \frac{K_2}{ln\left(\frac{K_1}{L_\lambda} + 1\right)} \quad (1)$$

where,

T = At-Satellite Brightness Temperature (K) in Kelvin scale

L_λ = TOA spectral radiance

K_1 and K_2 = Band-specific thermal conversion constant from the metadata

After calculating the At-Satellite Temperature in Kelvin scale, it has been converted into degree Celsius scale. For Landsat 5 TM and 7 ETM+ thermal band (band 6) has been used to calculate land surface temperature. For Landsat 8 OLI, both thermal bands (band 10 and 11) have been used to calculate land surface temperature. Mean of cell values of these two bands has been used as final output.

2.2.4 Change Detection and Relationship of LULC and LST

Temporal changes in LULC has been analysed and change map between the period 1988 to 2016 has been prepared by the MOLUSCE Plugin of QGIS. Transition between different LULC types has also been calculated to present the transformation pattern (Rahman et al., 2017). Change in LST has been analysed by classifying the values in six groups and identifying the areas under these groups for the selected three years. Relationship between different LULC types and modal LST has been investigated by regression analysis.

3. RESULT AND DISCUSSION

3.1 Change in Land Use and Land Cover (LULC)

After performing the Supervised Classification technique in the raw images, they have been used to carry out the change detection study. Table 3 summarizes the change statistics between 1988 to 2016.

Table 3. Summary of Land Use/ Land Cover change statistics

LULC Types	**Area in percentage**			**Change in percentage**		
	1988	2002	2016	1988 - 2002	2002 - 2016	1988 - 2016
Vegetation	11.6	28.2	8.8	16.6	-19.4	-2.8
Built Up Area	34.4	41.4	50.7	7.1	9.3	16.3
Bare Lands	15	6.5	32.9	-8.6	26.4	17.8
Wetlands/Lowlands	39	23.9	7.6	-15.1	-16.2	-31.3

From the change analysis, it is clear that Dhaka is characterized by increasing ‘Built Up Area’ and ‘Bare Lands’. Though there is a little decrease in ‘Vegetation’ area, ‘Wetlands/Lowlands’ has experienced a significant reduction (31.3%) between 1988 to 2016. Figure 3 represents the classified images of Dhaka city for the year 1988, 2002 and 2016.

'Vegetation' areas had been increased during 1988 to 2002 by a significant portion. But it decreases in the recent period and becomes less in amount than 1988, which is an alarming threat for Dhaka city. Dhaka should conserve its natural vegetation and promote afforestation to maintain a healthy environment. Encroachment of vegetation area by other land use especially 'Built Up Area' should be prohibited.

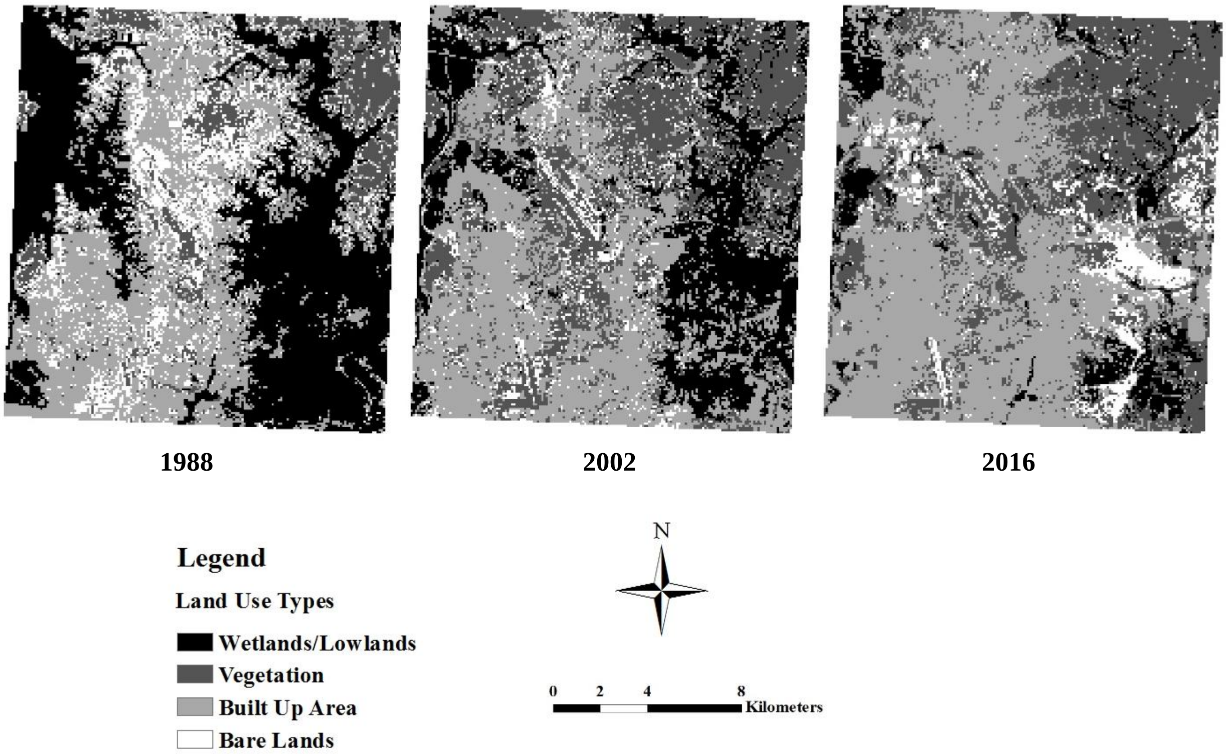


Figure 3. Classified images of Dhaka City showing four dominant LULC types

'Built Up Area' has showed an increasing trend during these 28 years. From this analysis, it has been found that half (50.7%) of the city is under 'Built Up Area' category. There was 7.1% increase during 1988 to 2002, which has increased to 9.3% during 2002 to 2016. Due to the huge population pressure, increasing 'Built Up Area' is justified. Dhaka is growing day by day not only for natural growth but also for the huge number of migratory people from the rural areas and other small urban areas. On the other hand, being the capital, Dhaka will grow to accommodate all the civil facilities. But it should not encroach other essential land uses like 'Wetlands' and 'Vegetation'.

'Wetlands' play a significant role in the environment. It influences the temperature of the atmosphere a lot. Moreover, for better circulation of waterbodies, connectivity among them is must, which can be affected through the reduction of 'Wetlands'. From the change analysis of LULC, it has been found that 'Wetlands' are decreasing day by day. In 1988 39% area was covered by 'Wetlands' which decreases to 7.6% in 2016. This huge change has substantial impact on the environment and local warming issue.

3.2 Transformation Dynamics of LULC between 1988 to 2016

By comparing the classified image, transformation matrix among the LULC types has been produced using MOLUSCE Plugin of QGIS. Table 4 shows the transformed areas in hectares from one LULC type to another. Figure 4 shows the LULC change map between the period 1988 to 2016.

Table 4. Transition between different Land Use/Land Cover

Transition Period		LULC Types (Area in hectares)				
		To	Vegetation	Built Up Area	Bare Lands	Wetlands/ Lowlands
1988 to 2002	From	Vegetation	2418.3	389.8	165.76	22.71
		Built Up Area	2343.36	5427.73	702.4	421.59
		Bare Lands	2038.33	1132.32	668.34	65.85
		Wetlands/Lowlands	499.55	3770.88	153.65	5658.58
2002 to 2016		Vegetation	38.6	2659.75	4249.24	351.96
		Built Up Area	485.93	7673.45	2000.49	559.35
		Bare Lands	973.37	513.94	0	202.85
		Wetlands/Lowlands	1748.44	1808.23	1750.71	857.57
1988 to 2015		Vegetation	18.92	889.36	1923.28	165
		Built Up Area	48.44	6264.86	2251.02	330.77
		Bare Lands	21.95	2110.24	1557.7	214.96
		Wetlands/Lowlands	2183.66	3850.35	2781.36	1261

1923.28 ha and 2110.24 ha areas have been transformed into 'Built Up Area' from 'Vegetation' and 'Bare Lands' area respectively between 1988 to 2016. Transformation from 'Wetlands/Lowlands' to other LULC types was significant. 2183.66 ha, 3850.35 ha and 2781.36 ha 'Wetlands/Lowlands' have been transformed into 'Vegetation', 'Built Up Area' and 'Bare Lands' respectively between these 28 years.

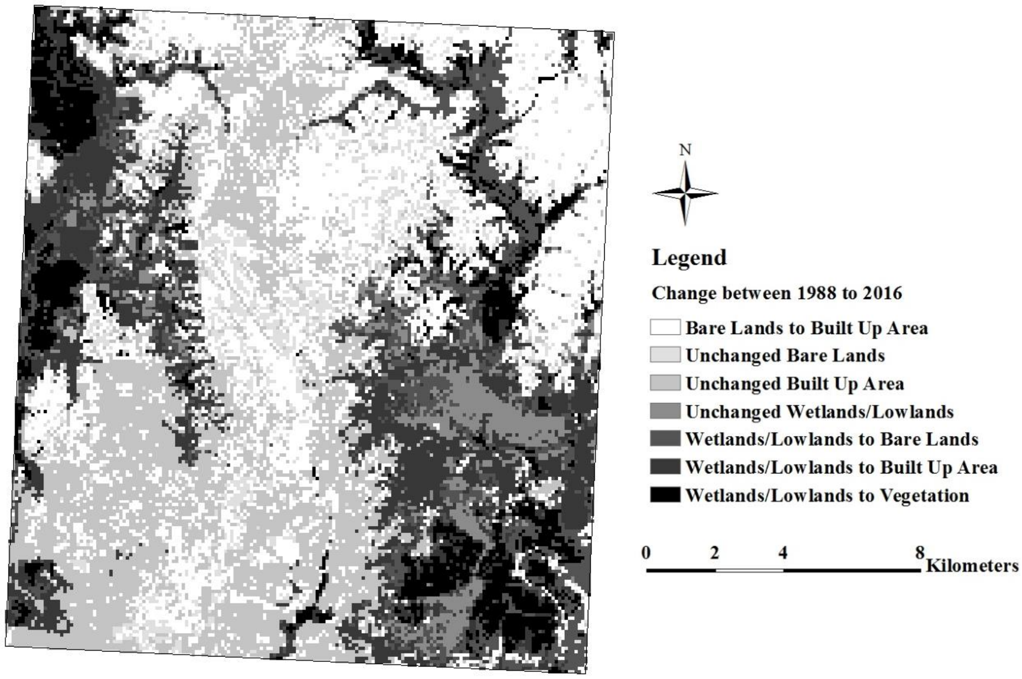


Figure 4. LULC Transformation map between 1988 to 2016

3.3 Change Pattern of Land Surface Temperature (LST)

Thermal bands of Landsat images show the spatial distribution of Land Surface Temperature (LST). Analysis of LST for Dhaka City has shown that LST is gradually increasing. LST has been divided into six groups to represent the spatial distribution visibly (Figure 5).

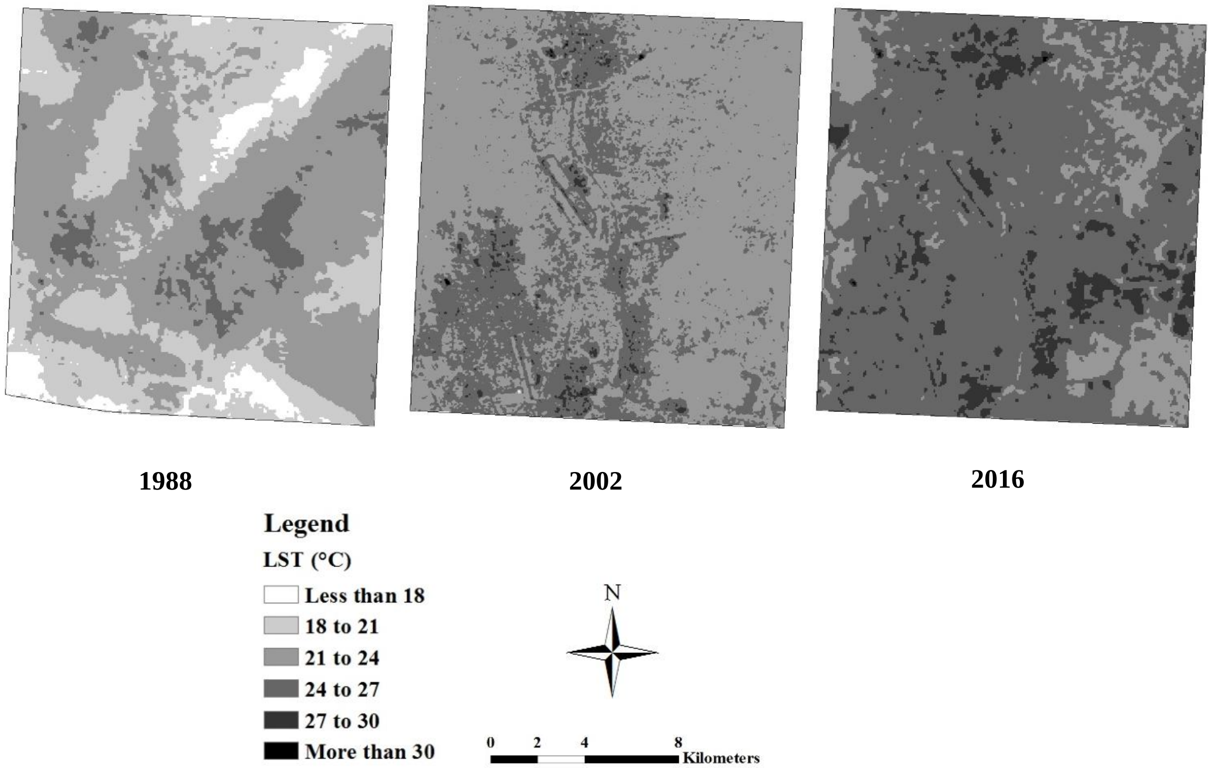


Figure 5. Spatial distribution of LST in Dhaka City

From the LST analysis, it is found that in 1988 there were some part of the City which had LST less than 18°C. In 2002, most of areas (around 70%) had LST within 18 to 21°C. But the LST distribution of 2016 has showed that around 75% areas have LST within 24 to 27°C (Figure 6).

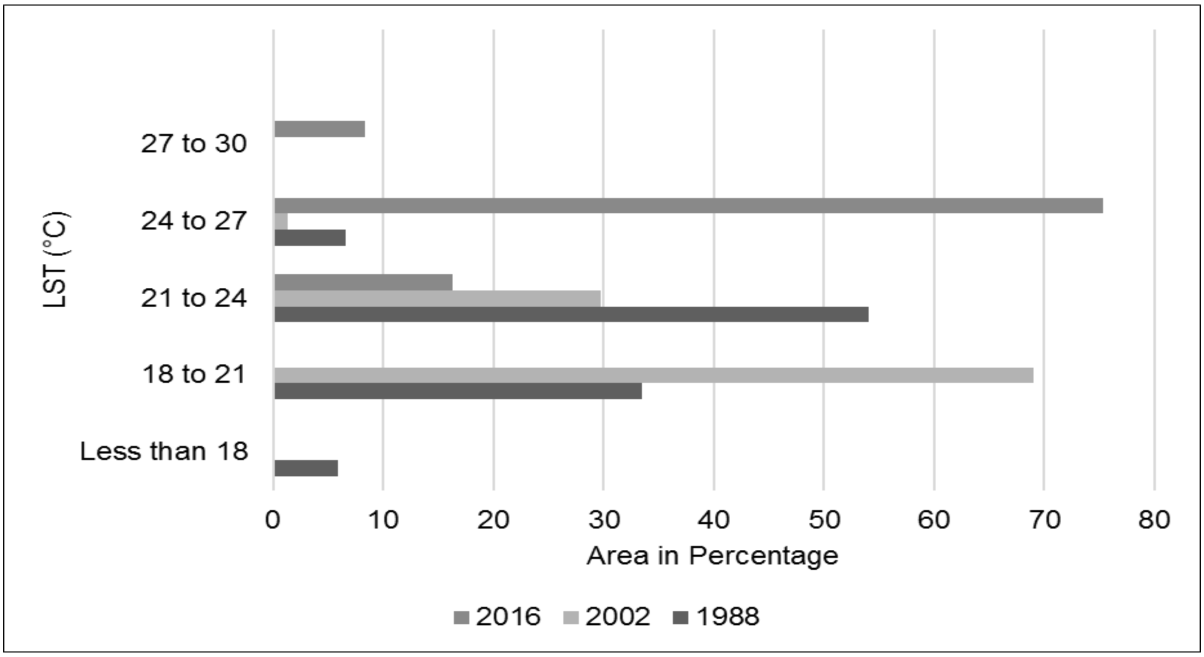


Figure 6. Changing pattern of LST (°C) in Dhaka City

3.4 Relationship between LULC types and LST

The images were during post monsoon season (October to November). Surface temperature should be less enough. But the analysis shows the increased surface temperature, which can be related to the land use distribution of Dhaka city. Impervious surface causes more heat trap and exacerbate the Urban Heat Island Effect. Half of the city is under 'Built Up Area' category, which explains the increasing trend of LST. This study tries to build up correlation among the LULC types and the LST. For the correlation study, areas under each LULC type and modal value of LST have been used. A strong positive correlation between 'Built Up Area' and modal LST has been found (r^2 = 0.9281). 'Wetlands/Lowlands' and modal LST share a strong negative correlation (r^2 = 0.9556). Ahmed et al. (2013) conducted study on Dhaka city and found similar results. This analysis shows that by controlling the amount of 'Built Up Area' and 'Wetlands/Lowlands', LST can be under control, so the UHI.

Several researchers have also studied the relationship among LULC types and LST. Spatial distribution of different types LULC has significant influence on the LST distribution (Bakar et al., 2016; Callejas et al., 2011; Sun et al., 2011; Tran et al., 2017). High land surface temperature would find in dense urban areas, followed by bare lands (Callejas et al., 2011). LST decreases with vegetation areas and wetland areas (Bakar et al., 2016; Sun et al., 2011; Tran et al., 2017).

4. CONCLUSIONS

This study focuses on the rapid land use change occurring in Dhaka City, resulting the increasing LST. If the present trend continues, Dhaka will no longer be sustainable and the environment will be severely affected due to the effect of local warming. Policy makers and the land use managers should focus on this issue. Future planning of this city should focus on ensuring more urban 'Vegetation', conservation of the existing 'Wetlands/Lowlands' and guided development of 'Built Up area'. Change of LULC should be always under monitoring and any haphazard development should be strictly prohibited. Moreover, the excessive pressure on the Capital city should be lessened through the sustainable and effective land management system like decentralization.

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