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Spatio Temporal Changes of Land Surface Features: Study on Ward-9 of Khulna City Corporation Area

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Abstract

This research aims to determine the effect of land use land cover (LULC) on terrestrial surface temperature in ward level of Khulna City Corporation area. This study also explores the relationship of LULC change and Land Surface Temperature (LST) from 2007-2017. To fulfill the aims, this study followed three steps. Cloud free satellite images Landsat 7 ETM+ and Landsat 8 were collected from USGS (United States Geological Survey), followed by supervised classification of images. LULC indices such as 1) NDVI (Normalized Difference Vegetation Index) 2) NDBI (Normalized Difference Built Up Index) 3) MNDWI (Modified Normalized Difference Water Index) were analyzed by using Arc GIS 10.5 to explore the relationship between LULC and LST. The NDVI value indicates that agricultural land, vegetation and waterbodies have been decreased rapidly due to urban growth for residential, commercial and other developments. LST was positively correlated with NDBI and negatively correlated with NDVI and MNDWI over the time, where the R2 value is significant.This paper suggests to take appropriate planning measures to reduce the rising temperature in urban areas.

Keyword:LST, LULC, MNDWI, NDBI, NDVI, Spatio-change.

Introduction

Urban Heat Island is one of the urban climate problems that are evolving within the region. As a result, surface and atmospheric heat is exceeding due to reduction of vegetation cover and expanded built up surfaces with solid, black-top, and so on (Islam & Islam, 2013).The accelerated urbanization tends to focus on urban climate change causing extensive increase of global earth surface temperature due to change of vegetated surfaces to impenetrable surfaces, change of vegetated and wetland into agrarian land or exposed waste land.(Pal,et. al., 2009). Such alterations affect the level of retention of sun based radiation, albedo, surface temperature, dissipation rates, heat transfer to soil, stockpiling of warmth, wind turbulence. These factors can definitely alter the near-

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surface atmosphere condition of cities, energy modification and transmission and water balance (Efe & Eyefia, 2014) furthermore assume crucial role in numerous ecological and environment process (Weng, et. al., 2004).

Many researchers had studied to evaluate the impact of LULC change on LST as LST is connected with built up area, vegetated area and water bodies. Rinner & Hussain, 2011 showed a correlation between NDBI and LST i.e. the commercial and industrial area of Toronto had higher LST. Again Chen, et al., 2002 showed that LST had increased those area of China such as Guangdong Province, southern China where rapid urabnization was occurred. Xiao, et. al., 2007 showed that unperceptive surface had positive correlation with LST in the case of Beijing, china and for the sake of to acquire correlation they used Landsat image and Quick bird images. Islam & Islam (2013) showed that due to economic development, Khulna city has been urbanized rapidly, that's why the LST was higher for the built up area but the opposite scenario was also observed for the water bodies and vegetated areas. Ahmed, et. al., 2013 reported that for Dhaka metropolitan area, the built up area became doubled within twenty years, mainly due to rapid urbanization.

In Bangladesh, the scholars conducted few studies, primarily for some metropolitan cities like Dhaka, Khulna, Chattogram, Sylhet. As most of the research paper focused on regional scale or large scale that's why for the small towns or nuclear region, no such work has been carried relating to the impact of land use or land cover changes. Considering this issue, present study is based on one of the largest and populated part of Khulna City Corporation, ward no. 9, which is basically a residential area, having mix land uses causing substantial variations in land use cover change in the recent periods. Again 'Ward' is a compositional unit of a city corporation and though the impact of LST and LULC is little to be seen for local scale but this is helpful to improve polices to reduce the environmental hazard for the Khulna city corporation.The timeline selection is based on author's research design and the availability of satellite images with association of other essential data. In this research,built up area formula was used in the NDBI to get accurate result as dehydrated vegetation has higher reflectance in short wave. Again MNDWI has been used instead of NDWI because the information of water features sometimes mixed up with the built up areas and further the study area is a mixed area with built up areas and water bodies.

This study aims to evaluate the relationship between Land use / Land cover (LULC) change with Land surface temperature (LST).The main Objective of this research is to detect land cover change with respect to spatio-temporal land surface temperature distribution for 5 years' interval at 2007, 2012 and 2017. Besides it aims to evaluate the impact of LULC on environment and to identify the relation between LST and other land use indices as well. Remote sensing data and satellite image data have been used in this study for acquiring the spatial and temporal analysis.

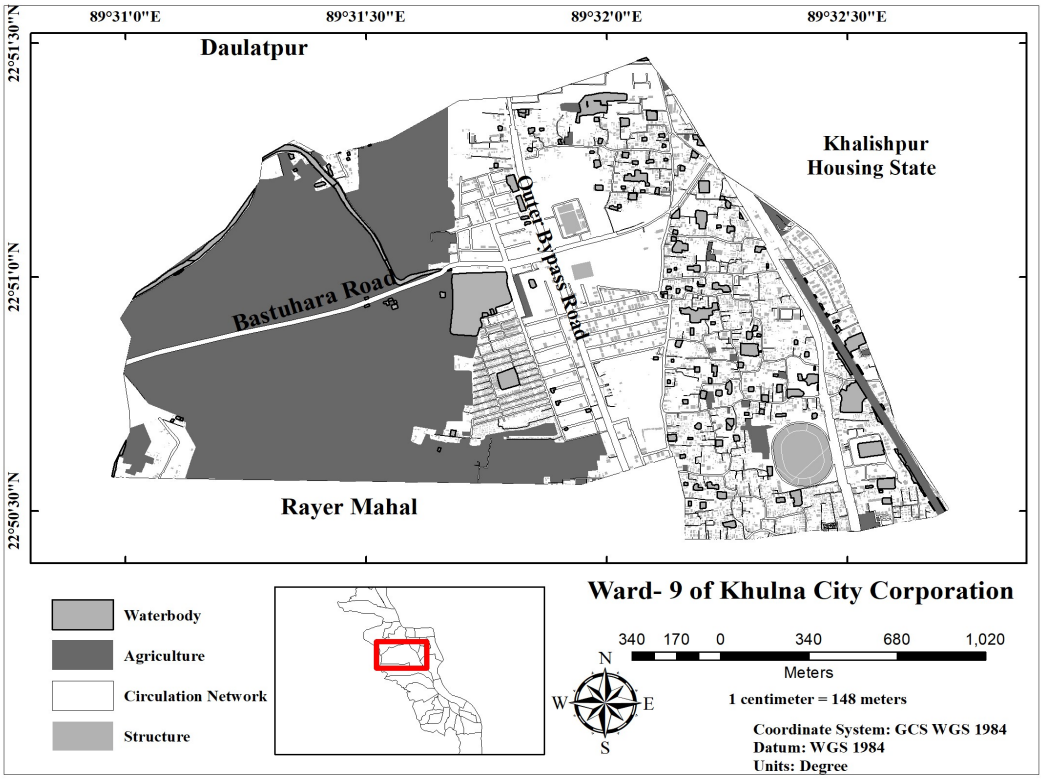
Study Area

Khulna is the 3rd largest city in the Bangladesh. Most of the coastal people is migrated to Khulna city due to get employment. As a result, the environmental condition is deteriorated day by day because the population in the city is increasing (Haque, et al., 2019). Study area belongs to Ward no 9 of Khulna City Corporation.

Table 1: Study Area profile

Area size	3.540127 sq.km
Population	48430(2015)
Distance from Shibbari	3.5km
Number of Slums	3

Source: KCC 2019



Source: Author, 2020

Figure 1: Study area and land use

Methodology

In this research, year 2007, 2012 and 2017 have been selected for time series and satellite image such as Landsat-8 OLI-TIRS, Landsat 5were acquired from USGS. The path and row of Landsat Image 8 and Landsat 5 is 138/44 and the spatial resolution of those

imageis 30 m.The images were selected on the basis of some criteria such as 1) cloud free images 2) Shade free images as those decreases the accuracy of the analysis. In this study, Arc GIS 10.5 and ERDAS Imagine 15 were used in the whole study and statistical tool like Excel was also used for statistical analysis.

Table 2: Details of Satellite Image

Image	Path/Row	Acquisition date	Source
Landsat 7	138/44	26 October 2012 21 October 2007	USGS
Landsat 8	138/44	23 October 2017	USGS

Land Use Change Detection

Land use change is a vital concern nowadays as 18% greenhouse gas emission is occurred due to land use change instigating deforestation (Bhuiyan,et al., 2019). For this paper, supervised classification was done as well as the land cover of the area was classified into 4 classes such as 1) Built up area 2) vacant land, 3) waterbody and 4) vegetation. Maximum likelihood approach was used to examine the land use. To assess percentage of change and annual rate of change, the following equations have been used (Hossen, et al., 2019).

Land use change= Magnitude of the new year- magnitude of previous year(1)

Percentage of change= Land use change*100/ Base year (2)

Annual rate of change= Final year- Initial year/ No. of years. (3)

Calculation of NDVI

The NDVI is used to define the greenness of an area through a numerical way. Actually NDVI is a mathematical index in which two types of bands from electromagnetic spectrum are being used such as red and near infrared bands. Chlorophyll ofplants leaves absorb visible part of red bands as well as at the same time the cell of leaves reflects the near infrared. The NDVI is generally used to assess where live green vegetation exists. It is considered as ratio where the range of NDVI values is -1 to 1 and following equation was followed to obtain such values.

NDVI= NIR-RED/ NIR+RED*(4)*

Where NIR= Near Infrared wavelength band values, Red= The Red wavelength band values,

The larger values indicate high photosynthetic activity is occurred i.e. the difference between red bands and infrared bands is high and indicating tropical forest and on the other hand, the lower value of NDVI shows the difference between red and infrared bands is low, meaning photo synthetic activity is occurred vaguely and these values represent the barren land, sand etc. Moderate values show shrubs, grassland and negative values are considered as water bodies.

Calculation of NDBI

The 'Normalized Difference Built up Index'shows the urban built up lands of an areausing shortwave bands. Usually built up lands have high reflectance in the shortwave bands than near infrared bands (Zha, et al., 2003).To calculate the built up index the following formula is used.

$$NDBI = MIR - NIR / MIR + NIR \quad (5)$$

Where, MIR= Mid Infrared wavelength band values.,NIR= Near Infrared wavelength band values.

But the researchers showed that the reflectance value of certain vegetation is increased in the short wave length due to reduction in the water content in the leaf of trees i.e. dehydrated trees having high reflectance in the short wave bands as a result the positive NDBI value was observed (Gao, 1996).That's why to increase accuracy, the following formula was also used, where BU= Built up area (He, et al., 2010).

$$BU = NDBI - NDVI \quad (6)$$

Calculation of MNDWI

Green bands of the spectrum enhance the reflectance value of water as well as it is helpful for giving opportunity tohigh reflectance of NIR by vegetation and built up area while it reduces low reflectance of NIR by water features. As a result,water bodies consist with positive values and vegetation are stifled due to having negative values. That's why generally NDWI (Normalized Difference Water Index) is used to extract water bodies. But NDWI index is not suitable in that area where built up area and water bodies are mixed up. As built up features have positive values that's why the information of extricated water features is often mixed up with built up areas (XU, 2008). To overcome this problem, Modified Normalized Difference of Water Index was used in this paper and the following equation was also followed, where MIR denotes Mid Infrared band and Green represents green band.

$$MNDWI = Green - MIR / Green + MIR \quad (7)$$

Land Surface Temperature (LST)

Land Surface Temperature is a fundamental determinant of terrestrial thermal behavior, since it controls the Earths dynamic radiating temperature. To calculate the LST, 3 steps should be followed.

i) Conversion to radiance from Digital Number (L_c)

$$L_C = ((L_{MAX} - L_{MIN}) / (Q_{CALMAX} - Q_{CALMIN})) * (Q_{CAL} - Q_{CALMIN}) + L_{MIN} \quad (8)$$

Where,Q_{CAL}= The quantized calibrated pixel value in DN, L_{MIN}= 0.10033 for land sat 8and 3.2 for land sat 7,L_{MAX} = 22.00180 for land sat 8 and 12.650 for land sat 7, Q_{CALMIN}= 1 for both land sat 7 and 8, Q_{CALMIX}= 65535for land sat 8 and 255 for land sat 7.

ii) Spectral Radiance conversion to brightness of temperature and convert Kelvin to degree centigrade

$$T = K_2 / ln\ (K_1 / Lc+1) - 273.15 \quad (9)$$

Where, T= Effective at-satellite temperature in Kelvin, K_2= 1282.71 for land sat 7 and K_2= 1321.0789 for landsat 8; K_1=666.09 for land sat 7 and K_1= 774.8853 for land sat 8, Lc= Spectral radiance in watts/(meter squared * ster * μm).

iii) Land Surface Temperature

Spectral Emissivity correction was also done by using the NDVI values for each pixel. To get emissivity corrected LST the following formal was used.

$$LST = T / (1 + ((\lambda * T/\rho) * ln\ \varepsilon)) \quad (12)$$

Where, λ= wavelength of emitted radiance (λ=*11.5 was used),* $\varrho = h * c/\sigma$ ($1.438*10^{-2}$mK), σ= $1.38*10^{-23}$ J/K (Boltzmann constant), h=$6.626*10^{-34}$ Js (Planck's constant), c= $3*10^8$ (Velocity of light), ε= emissivity.

To get emissivity, following formula was used.

$$Emissivity(\varepsilon) = 0.004*Pv+0.986 \quad (13)$$

where, Pv= proportion of vegetation, calculated by following equation

$$Pv = (NDVI-NDVI_s / NDVI\ v - NDVIs)^2 \quad (14)$$

Where, NDVIv and NDVIs are the threshold value of vegetation and soil.

Result and Discussion

Relative Changes of LULC

Considering the interest of the investigation and prevailing LULC, four classes have been created. Few other classes could be generated yet their extent is too little being reflected properly. That's why those unclear pixels have been consolidated inside neighboring classes inside the framework. The ultimate classified results in the Table-3 give an impression of the major LULC highlights of ward no- 9, KCC. Total area of interest is 354.54 ha [1 ha= 2.47 acre]. Figure-2 representsthe total temporal percentage tabulationof land proportion for three phases. Table-3shows the trends of LULC changes that represents increasing change of built up area implying positive change of 3.077% during 2007-2012 and 23.2133% during 2007-2017 due to increased urbanization. Furthermore, it can be explained that built up land area and vacant land cover both extended as vegetation and water body has been reduced. Built up land cover tends to spread due to residential and commercial development and slum formations as well.On the other hand, rest of two LULC classification - vegetation and water body - shows inverse change by decreasing its relative spatial pattern. Vegetative land use has been decreased gradually over the time and a total reduction of 32.481% from 2007-2017 (Table 3).Actually the urban growthhas been decentralized due to residential development and other initiatives.Spatial change of water body has been found to be reduced by 68.43% from 2007-2017.Gradual reduction in vegetation and water body land uses have been accelerating vacant and built up LULC.

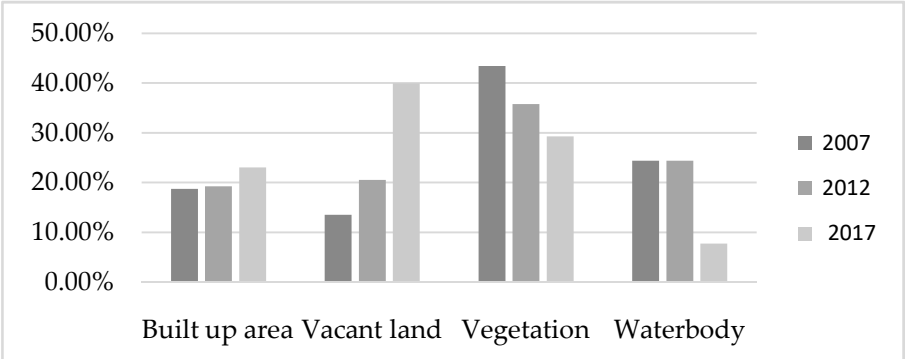


Figure 2: Relative changes of LULC for different years*(Source: Author, 2020*)

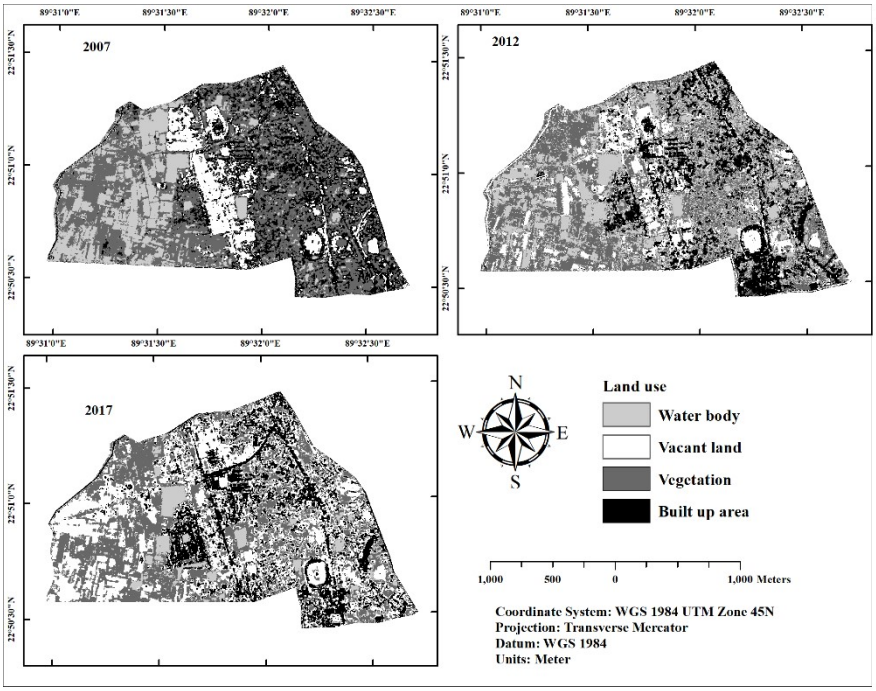


Figure 3: LULC change of ward-9, Khulna (*Source: Author, 2020)*

Decline of Vegetation coverage has been observed greater than water body in the study area. Actually the urban growthhas been decentralized due to residential development and other initiatives.Spatial change of water body has been found to be reduced by 68.43% from 2007-2017. Gradual reduction in vegetation and water body land uses have been accelerating vacant and built up LULC in the study area.

Table 3: Statistical figure of LULC change in ward-9, Khulna

Land use category	Changed area (2007-2012)	% of change	Annual rate of change	Changed area (2012-2017)	% of change	Annual rate of change	Changed area (2007-2017)	% of change	Annual rate of change
Built up area	2.0397	3.077	0.408	13.350	19.536	2.670	15.389	23.213	1.539
Vacant land	24.942	52.137	4.988	68.905	94.676	13.781	93.847	196.174	9.385
Vegetation	-26.977	-17.523	-5.395	-23.029	-18.136	-4.606	-50.006	-32.481	-5.0006
Waterbody	-0.021	0	-0.004	-59.208	-68.423	-11.842	-59.228	-68.43	-5.923

Source: Author, 2020

Spatio-Temporal Effects On Vegetation Health

NDVI was applied to classify the vegetation intensity of ward-9. From the figure-4(A, B, C), it was observed that the density of vegetation was higher earlier than the present scenario. Table 4 indicates that the highest range of NDVI value was 0.2118-0.4653in 2007 depicting evergreen forest, mixed forest and agriculture cover was significant but in 2012 and 2017, the value of NDVI has decreased as built up area and bare land cover increased over the time through deforestation as well as due to urban development.

Table 4: The statistic of NDVI value in the ward-9

2007		2012		2017	
NDVI values	Percentage of area (%)	NDVI values	Percentage of area (%)	NDVI values	Percentage of area (%)
-0.2692-0.0101	26.375	-0.2407-0.0724	23.301	-0.0411-0.0498	18.097
0.0101-0.2118	37.417	0.0724- 0.0447	43.578	0.0498-0.1134	41.851
0.2118-0.4653	36.774	0.0447-0.2413	33.122	0.1134-0.2767	40.058

Source: Author, 2020

Changing Phenomena of Built Up Area

To detect the built up land area change, NDBI is applied here forward-9. Figure-4 (D, E, F) shows that built up land area density is higher in recent times than earlier periods. From Table-5, it can be said that built up area for higher range of -0.093 - 0.603 was 31.579% in 2007, which became 33.229% of higher range -0.204 - 0.0064 in 2017.Hence the built up land area increased by 1.65% due to the factors such as 1) Fast growing integrated accessibility of communication, 2) Comparative lower land value having services and facilities than other residential zones. For the sake of providing land for residential and commercial purposes, existing water bodies have been converted to

builtup areas. 4) It is noticed that a particular naval community is living in the Navy colony which is the initial establishment of this area leading to the development of more buildings, thereby reducing the open space in this particular boundary.

Table 5: The statistics of NDBI value in the ward-9

2007		2012		2017	
NDBI value	Percentage of area(%)	NDBI value	Percentage of area(%)	NDBI value	Percentage of area(%)
-0.509- -0.078	29.649	-0.653- -0.222	28.634	-0.639- -0.309	21.806
-0.078- -0.093	38.682	-0.222- -0.086	41.885	-0.309- -0.204	44.965
-0.093-0.603	31.579	-0.086-0.233	29.593	-0.204- 0.0064	33.229

Source: Author, 2020

Spatio-Temporal MNDWI Image Results

In the figure-4(G, H, I) darker black tone highlights higher percentage of water body existence and the whitish tone highlights less amount of water bodies which illustrates that water bodies in three maps has been decreased during recent years than earlier scenario. Table-6 shows MNDWI values are classified into four ranges for three years – low, moderate, high and very high respectively. For all of the four ranges, water body land cover has been reduced from 2007 to 2012 to 2017 with an exception of substantial land cover increase in 2017 for moderate ranges of MNDWI values. In the moderate range, land cover percentage is quite same which means water body is rarely changed here in thisperiod. Rest of the two ranges, low and very high percentage ranges indicate drastical decrease of water body in the area. For low range, it has been decreased by 2.64% in 2012 and 15.6% in 2017 because the wetlands are being filled and turned into developed land and later these lands are being used for various purposes.

Table 6: The statistic of MNDWI value in the ward-9

2007		2012		2017	
MNDWI values	Percentage	MNDWI values	Percentage	MNDWI values	Percentage
-0.471- -0.0.282	32.264	0.393- 0.012	29.624	-0.252- -0.048	14.038
-0.282- -0.049	34.143	0.012-0.175	34.777	-0.048-0.029	46.226
-0.049- 0.238	13.657	0.175-0.375	14.952	0.029- 0.129	14.673
0.238- 0.625	20.130	0375- 0.627	20.841	0.129- 0.235	14.038

Source: Author, 2020

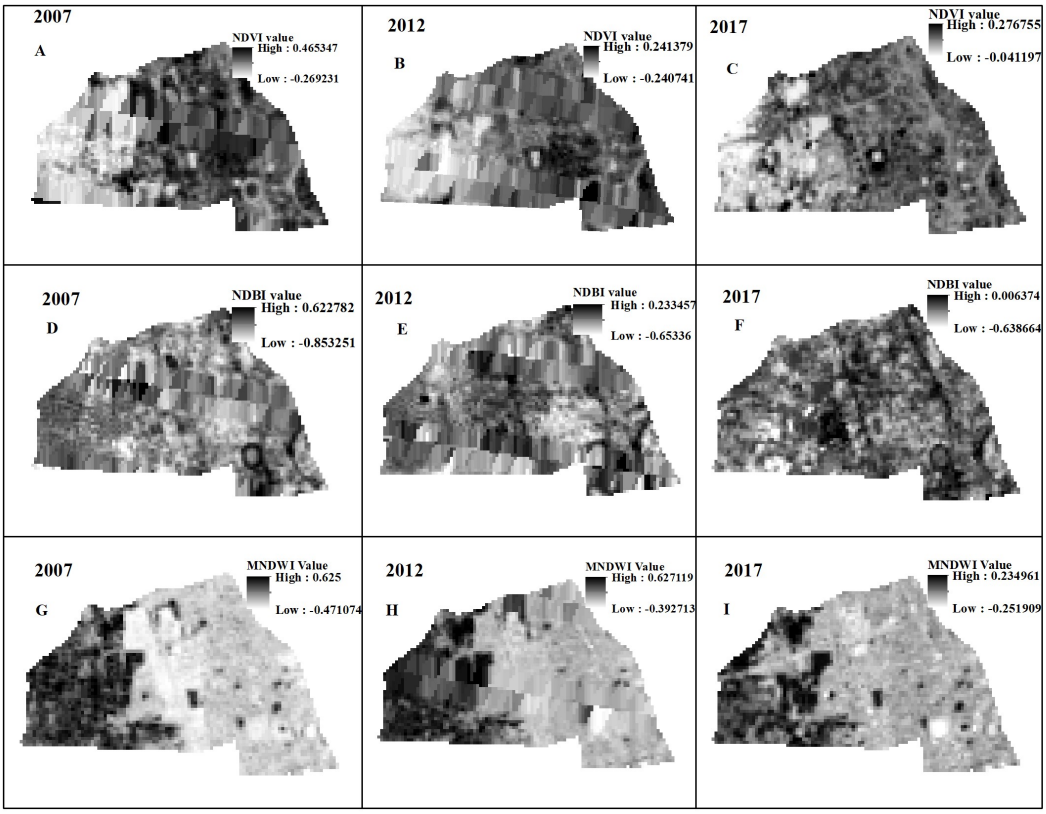
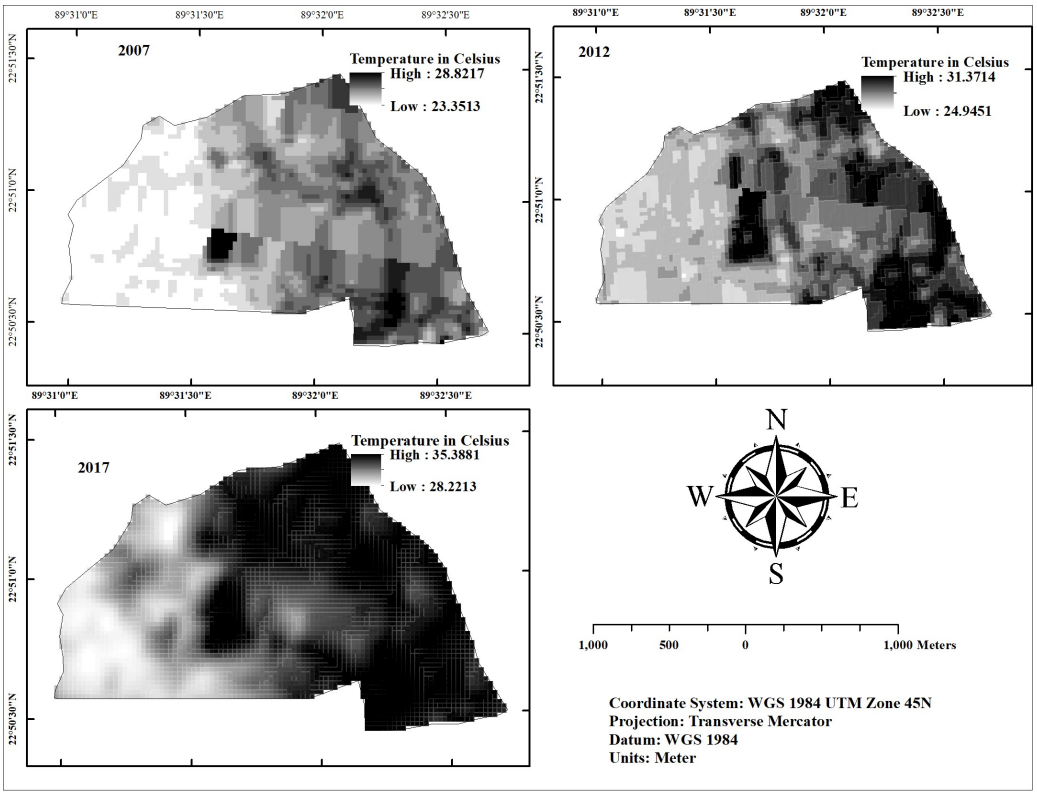


Figure 4: A, B, C represents the temporal change of NDVI; D, E, F represents the temporal NDBI classification and G, H, I represents the temporal MNDWI classification of ward-9, Khulna. (*Source: Author, 2020)*

Spatial Change of Land Surface Temperature

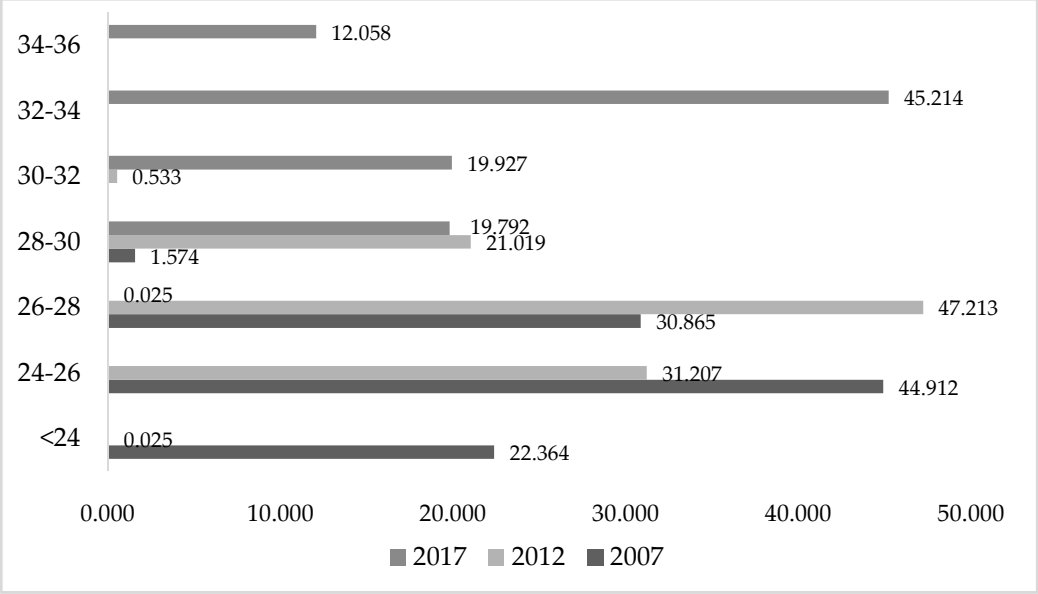
Figure-5 illustrates spatial pattern of land surface temperature in the area of interest in three phases. This analysis is conducted for the month of October in all three years. In all three maps, darker black tone highlights higher temperature and whitish tone illustrates gradual low temperature in degree Celsius. Table -7 depicts minimum, maximum and average level of temperature for different types of land use and land cover. Results show that about 6.66^0C temperature has been increased in the case of built up areas. The main reason of increased temperature is the reduction of vegetated area i.e. low evaporation is occurred as well as this green space is replaced by those materials which have high heat capacity and non- evaporative materials.



Source: Author, 2020

Figure 5: Temporal Land surface temperature classification of ward-9,Khulna

Figure 6 represents that22.36% area was under below 24^{0}c in 2007 while 0.03 % area has temperature around 26-28^{0}c in that period. But about 47.21% area of ward experienced temperature around 26-28^{0}cduring 2012. The figure shows that, there was no area which was below 24-26^{0}c in 2017 i.e. there was no part in the lower heat area but about 44.91% area was under this range in 2007. It means that greater proportion of area has been gaining enhanced temperature as built up land area has been considerably increased as revealed in thisanalysis.



Source: Author, 2020

Figure 6: Changing pattern of Temperature zone

Table 7: Land use wise land surface temperature

	2007			2017		
Land use	Minimum	Maximum	Average	Minimum	Maximum	Average
Built up area	27.85	28.34	28.09	33	35	34
Water bodies	24.36	25.38	24.87	28.22	30	29.11
vegetation	23.32	24.21	23.77	29	30.28	29.64

Source: Author, 2020

Correlation between Land Surface Temperature and Land use indices

Three types of land use indices have been used in this paper to establish relationship between LST and those index. After analyzing NDVI, it was observed that, NDVI has been decreased over time. Similarly, MNDWI i.e. water content in the vegetation was decreased but on the other hand, NDBI was increased gradually. Figure 7 shows the relationship between LST and other indices. The result of these multiple correlation indicates that, NDVI, MNDWI are negatively correlated with LST and NDBI is positively correlated with LST.

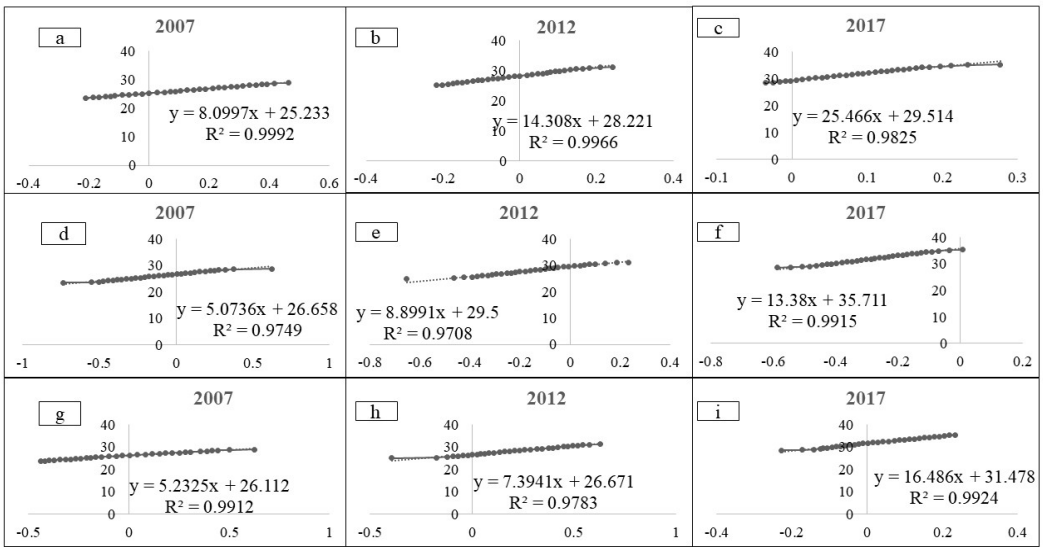


Figure 7: a(2007), b(2012), c (2017) represents the correlation between LST and NDVI, d(2007), e(2012), f(2017) represents the correlation between LST and NDBI and g(2007), h(2012), i(2017)represents the correlation between LST and MNDWI

Conclusion

This investigation is conducted to recognize the environmentally critical parts and their spatial pattern based on LST distribution in ward no-9,KCC . For this study, the LULC changes and related LST impact variations were observed for the study area, using three multi-temporal TM images from 2007, 2012 and 2017 on a smaller zonal scale. Results of this study reveal that, built up land area has been increased by 23.21% during 2007-2017, whereas vegetaed land cover and water body has been decreased by 32.481% and 68.43% but extreme reduction of vacant land has been observed by 196.17% during 2007-2017.Three types of land use indices NDBI,NDVI and MNDWI were correlated with LST and it showed positive correlation with NDBI (R^2=0.97 for 2007, 2012 and R^2= 0.99 for 2017) and negative correlation with NDVI(R^2= 0.99 for 2007, 2012 and R^2=0.98 for 2017) , MNDWI (R^2= 0.99 for 2007and R^2=0.9 for 2012 and 2017). It is observed that the land surface temperature has increased over the long time in the territory. A portion of the high-temperature zones are likewise observed at the North-Eastern and South-Eastern part of the landscape land use. Results of this study indicates that the water bodies and vegetation had generally lower surface temperatures and were productive in diminishing urban LST but both were negatively correlated with LST. In comparison, the built-up area was detected as the principal heat in the observed zone. This urges urban planners and relevant authorities to give more endeavors in securing urban lakes and vegetation. Further investigative studies are required to evaluate the impacts of LST in surrounding areas. The average LST of various LULC, extracted from the images, helps to get better interpretation of the thermal response of surface materials. The methodology, followedin

this paper for LST mapping,can help in environmental management for the meteorological or water department.Appropriate planning measures should be taken in urban areas to reduce the rising temperature and proper balance between built up areas, vegetation and waterbodies should be maintained for balanced urban development.

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