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Monitoring the Land Cover Change and Its Impact on the Land Surface Temperature of Rajshahi City, Bangladesh using GIS and Remote Sensing Techniques

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Authors' contributions

This work was carried out in collaboration among all authors. Author MM designed the study, performed the statistical analysis, Author MMK wrote the protocol, wrote the first draft of the manuscript and Author MKH managed the analyses of the study. Author MKH managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Urban growth possesses significant impact on land cover by replacing natural landscape into impervious surface. Substantial alteration of the green space into built-up areas have influential impact on the land surface temperature of a city. The aim of this study is to identify the land cover change on Rajshahi City Corporation (RCC) area for the last twenty years (1998-2018) and to assess the impact of land cover change on land surface temperature. During the last two decades, constant expansion of built-up area within Rajshahi city encroach the substantial amount of vegetation, open space, and waterbody areas, which results in large area of impervious surface. Therefore, two spatial analysis software namely Arc GIS and Erdas Imagine have been used to identify the amount of land cover change and variation in land surface temperature through supervised image classification and spectral radiance calculation methods on Landsat satellite images (1998. 2008 and 2018). The result shows that, the built-up area have been doubled during

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the last two decades by covering 10.98 and 22.82 square kilometers areas in 1998 and 2018 respectively. With a strong positive correlation between the land surface temperature and the land cover area, the maximum temperature rises from 23.25 to 27.08 degrees Celsius. This trend of Land Surface Temperature indicates, Urban Heat Island is building up within Rajshahi city.

Keywords: Urban Growth; land cover change; land surface temperature; remote sensing; GIS.

1. INTRODUCTION

Land cover is the physical cover spotted on the land surface, and land use defines its functions [1]. Land use and land cover are the vital elements of the global environment, which possess direct interaction with the Earth's climate [2]. In present times, worldwide land cover alteration has been executed by extensive urban growth and expansion [3]. Urban expansion results in a substantial reduction of urban green space over time [4,5]. Widespread removal of natural areas within the city, altered the evaporation and transpiration rates [6] thereby, modifies the local climate and local atmosphere significantly [7]. Each land cover area holds specific energy absorption and reflection capabilities. Impervious surfaces such as pavement, roofs, asphalt absorb a lot of the incoming solar radiation and generate more heat in the environment. Therefore, land cover changes from natural cover to the impervious surface is the prime reason of changing Land Surface Temperature (LST) [8]. As a result, the LST and the air temperature inside the city area usually warmer compared to their peripheries [9]. Several studies found that, Urban Heat Island (UHI) is associated with the spatial distribution of LST. In this regard, LST is recognized as a fundamental influencer of the UHI issue. Therefore, it is significant to calculate the LST as an initial measure to urban heat island identification [8].

The major land cover classes in Bangladesh are vegetation with forest and agricultural land, water bodies with wetlands, built-up areas, and bare land. Bangladesh is facing a speedy rate of urbanization with unplanned ways [10]. Rapid population growth with socio-economic development in Bangladesh leads to expansion of every cities and growth centers [11]. Extensive development of built-up areas across Bangladesh resulted considerable decline in the area of vegetable land, forested lands, wetlands and waterbody area. In this regard, such an urban growth and expansion alters the land cover from natural types to impervious land surface [12]. Thus, the urban growth in Bangladesh is growing at a dramatically way that needs to be monitored accurately for the betterment of the country. Like other areas of Bangladesh, Rajshahi City Corporation (RCC) area have faced rapid population growth throughout the decades. According to census [13], RCC area had 388811 populations. In 2011, the populations increased to 449756 persons respectively [14] and the city has an approximate population of 700133 within its 48 sq. km. area in 2018. The population growth of RCC area shows an increasing trend which have crucial impact on land cover change across the RCC area [15].

Integrated Geographic information system (GIS) and remote sensing (RS) techniques regards as the most useful and reliable technique for detecting land use and land cover change. In several studies, remotely sensed satellite images were used to detect urban land cover change throughout the decades and thermal bands of that satellite image ware also used to calculate the Land Surface Temperature (LST). Most of those studies established the interaction between the land surface temperature (LST) and land cover area types [12]. According to several studies, vegetation type land cover areas have the least temperature and the urban area always represent higher temperature [16-18]. Land cover change has become major issue for RCC; here continuous population growth altering the land cover area day by day and increasing the amount of impervious surface within the city. As, land cover change is interrelated with the change in the land surface temperature and urban heat island origination, it is necessary to formulate a comprehensive understanding about the land cover change in associated with change in LST across RCC area over the periods.

2. LITERATURE REVIEW

The land cover of any urban area is quite multidimensional. Different land covers have their different spectral reflectance at specific wavelengths [19]. All over the world, land use and land cover change is properly monitored by land use and land cover mapping through satellite imagery. Both geographic information systems (GIS) and remote sensing (RS) techniques have been integrated and considered as an effective tool in monitoring the spatiotemporal dynamic forces of land cover change across the world through several techniques namely supervised and unsupervised image classification [20].

2.1 Concept of Land Surface Temperature (lst)

The Land Surface Temperature (LST) is the radiative skin temperature of the land surface, as measured in the direction of the remote sensor. The LST influences the partition of energy between ground and vegetation [21]. Land surface temperature can be calculated from the thermal band of the Landsat satellite image by spectral radiance calculation. For Landsat 4-5 TM and 7 ETM+, thermal band 6 and for Landsat 8 OLI both thermal bands 10 and 11 can be used to calculate land surface temperature (LST). At first, the digital number (DN) value of thermal bands of satellite images needs to be converted to radiance (Lλ). Radiance can be calculated by this equation Radiance, Lλ = gain*DN+offset [12]. The next step of calculating LST is to convert radiance value into Satellite Brightness Temperature. LST can be derived using several emissivity correction formulas.

2.2 Level of Urbanization and Urban Growth Rate

Level of Urbanization or basically Urbanization refers to the percentage of population living in the urban areas. Level of urbanization can be calculated by the following equation [22].

$$U^n = \frac{U_p}{T_p} \times 100 \qquad (1)$$

Where,

U^n = level of urbanization,
U_p = total urban population,
T_p = total population

Urban Growth rate state an increase in total urban population, whereas urbanization refers to the percentage increase in urban population.

$$U_r = \left(\sqrt[t]{\frac{P_n}{P_0}} - 1\right) \times 100 \qquad (2)$$

Where,

U_r = annual urban growth rate,
P_n = current population,
P_0 = previous population,
t =time period between the preceding and the subsequent [23,14] (National Volume- 3: Urban Area Report, 2014).

2.3 Concept of Normalized Difference Vegetation and Built-Up Index

The Normalized difference vegetation index (NDVI) is the measurement of the amount and vigor of vegetation on the land surface. NDVI is calculated from satellite's reflectance values for both red and near-infrared (NIR) bands [24]. Normalized difference built-up index (NDBI) value is sensitive for the built-up area. At NDBI the variable range of positive value generally indicates the built-up area.

3. MATERIALS AND METHODS

3.1 Study Area Profile

Rajshahi City Corporation (RCC) is one of the major city corporations of Bangladesh. According to Bangladesh Bureau of Statistics census 2001, RCC possess 388811 populations; afterwards in 2011 population rise to 449756 persons [13,14]. Finally, in 2018 the current population of Rajshahi city rises to 700133 persons with an area of 48 square kilometers [25]. This increasing trend of population growth in RCC area with rapid urbanization and industrialization significantly affect the land cover of Rajshahi city. The GIS map of RCC area show an area of 48.0573 km2 and which is acknowledged by the Rajshahi Development Authority [26].

3.2 Data Collection

Data related to the number of populations, RCC area boundary shape file etc. has been collected from various Government and Non-Government Organizations, Websites, journals etc. Satellite image of 30meter spatial resolution for the year of 1998, 2008, and 2018 has been collected from US Geological Survey's [27] website.

3.3 Supervised Image Classification

Supervised image classification is a statistical technique, which used to classify the satellite image in accordance with the pixel and the signature of each land cover through spatial analysis software like 'Erdas Imagine' and 'Arc GIS' [28]. Supervised Image classification method with accuracy assessment has been used to prepare land cover area map of RCC area for the year of 1998, 2008, 2018. Maximum likelihood parametric rules method has been used for the classification. Following classes of LCA is identified for the RCC area has shown in Table 2.

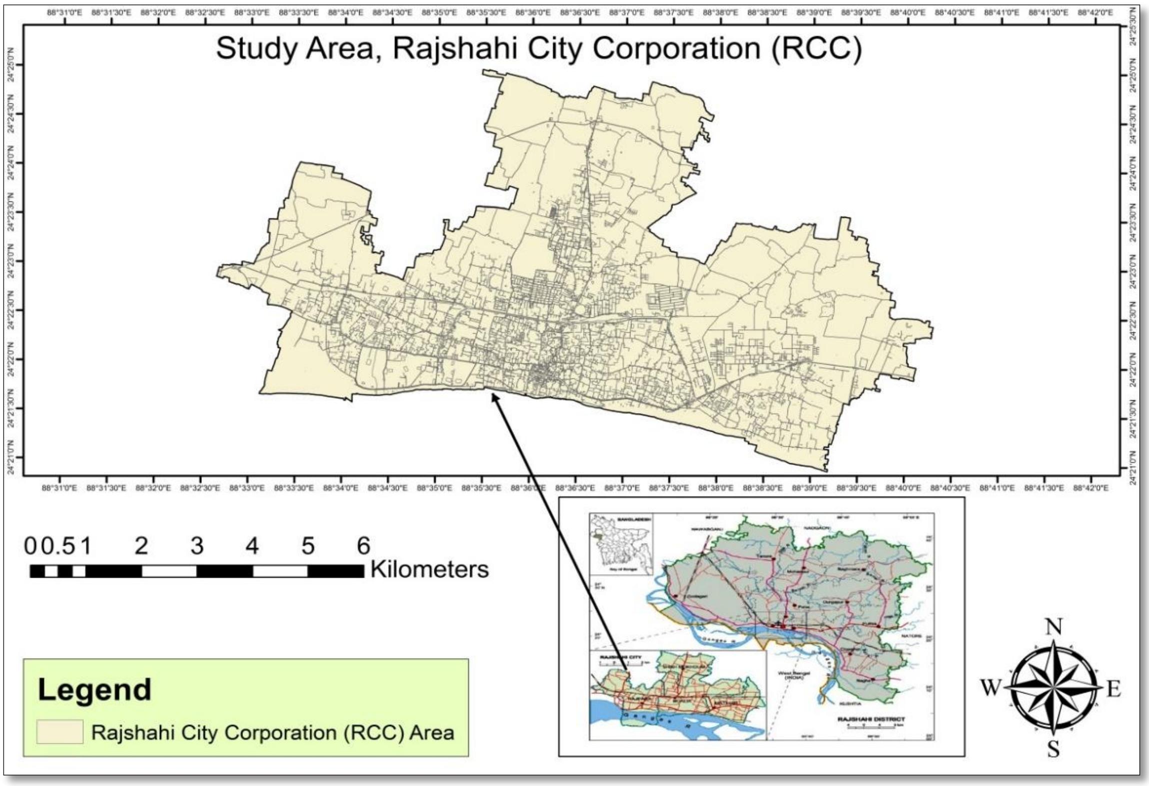


Fig. 1. Location of the Rajshahi city corporation (rcc) area

Table 1. Meta data of the collected satellite image

Descriptions	1998	2008	2018
Spacecraft ID	Landsat 5	Landsat 5	Landsat 8
Date acquired	05 February	17 February	12 February
Cloud cover	0.00	0.00	0.20
Projection zone	UTM zone 45	UTM zone 45	UTM zone 45
Datum	WGS84	WGS84	WGS84

Table 2. Details of each land cover area types

Land cover types	Description
Built-up area	Residential, industrial and commercial areas, settlements and infrastructure.
Bare land	Earth and sand filling, exposed soils, char land, Island, under-developed land, landfills, open space, construction areas and bare land areas.
Vegetation and agricultural land	Agricultural land, crops fields, grassland, trees, forest and vegetable lands, parks and gardens.
Waterbody area	Lake, pond, river, all surface waterbody areas, permanent and seasonal wetlands, canals and reservoirs.

The ending step of image classification is accuracy assessment, which compares the classified image with ground truth data. For accuracy assessment, some reference pixels like as points on the classified image has been generated. For each classified image, 60 reference points from 'Google Earth' images have been randomly selected to cross check from both the reference image and classified image. Following Table 3. represents the accuracy assessment result of the classified image of RCC area for the year of 1998, 2008 and 2018 where the overall accuracy for that period is 83.33%, 85% and 85%.

Following Fig. 2. represents the supervised image classification of land cover map of RCC area during the year of 1998, 2008 and 2018.

3.4 Land Surface Temperature (LST) Calculation

Spectral radiance calculation method of the thermal bands has been taken to calculate the Land Surface Temperature (LST).

At first, the digital number (DN) value of thermal bands of the satellite images has been converted to radiance (Lλ). Radiance is calculated by this equation Radiance Lλ = gain*DN+offset [12,29]. The next step is to converted radiance value into satellite brightness temperature. Finally, satellite brightness temperature can be derived from spectral radiance by the following equation [12,29,30].

Table 3. Accuracy assessment result of the classified images

Year	User accuracy (%)				Producer accuracy (%)				Overall accuracy (%)
	Built-up	Bare Land	Water-body	Vege-tation	Built-up	Bare Land	Water-body	Vege-tation	
1998	80	80	86.66	86.66	85.71	75	100	76.47	83.33
2008	86.66	80	80	93.33	86.66	75	92	87.5	85
2018	86.66	80	86.66	86.66	81.25	80	86.66	92.85	85

Table 4. Equation of the radiance calculation

Landsat sensor name	Radiance Calculation (L_λ)
Landsat 5 TM	$= (Q_{CAL}/255) *((L_{MAX}-L_{MIN}) + L_{MIN})$
Landsat 8 OLI	$= M_L * Qcal+A_L$

Here, Qcal= Digital Number (DN) of thermal band; L_{MAX}= Maximum spectral radiances; L_{MIN}= Minimum spectral radiances; ML=Band-specific multiplicative rescaling factor; AL=Band-specific additive rescaling factor

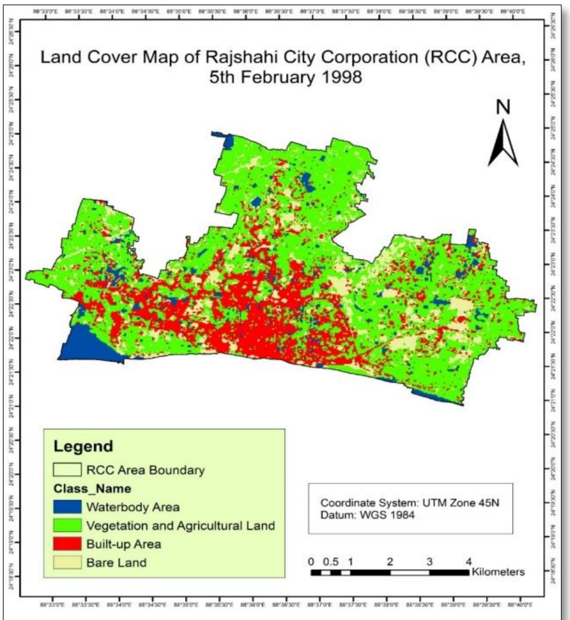
Table 5. Meta data of the collected Landsat satellite image related to LST calculations

Value	Year		
	1998(TM)	2008 (TM)	2018 (OLI)
$Qcal_{MAX}$ & $Qcal_{MIN}$	255, 1	255, 1	65535, 1
L_{MAX} & L_{MIN}	15.303, 1.238	15.303, 1.238	22.00180, 0.10033
K_1	607.76	607.76	774.8853 (Band 10) 480.8883 (Band 11)
K_2	1260.56	1260.56	1321.0789 (Band 10) 1201.1442 (Band 11)
M_L	5.5375E-02	5.5375E-02	3.3420E-04=0.0003342
A_L	1.18243	1.18243	0.10000

Table 6. Equation of satellite brightness temperature calculation

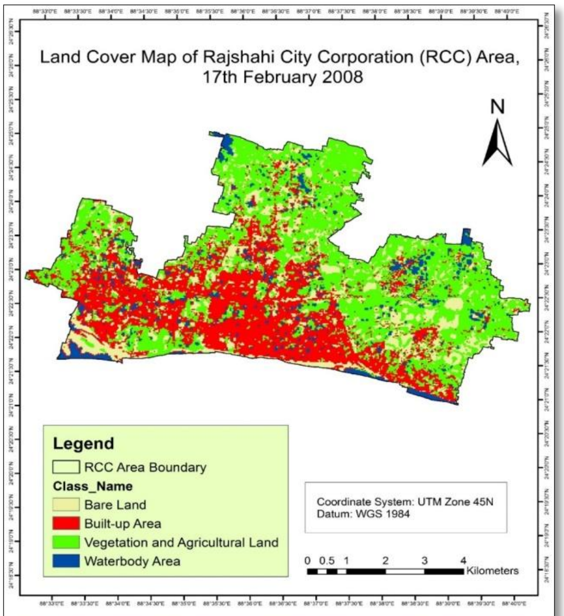
Landsat sensor name	Satellite brightness temperature calculation in degree celsius
Landsat TM and OLI	$T_B = \dfrac{K_2}{\ln\left(\dfrac{K_1}{L_\lambda}+1\right)} - 273.15$

Here, TB= Satellite Brightness Temperature; Lλ = Spectral Radiance
K1 and K2 = Calibrated constant of TM and OLI



Land Cover	Total Pixel Count	Area in Square Kilometers	Area in Percentage
Built-up Area	12207	10.9863	22.86083488
Vegetation & Agricultural Land	29523	26.5707	55.28962301
Bare Land	7679	6.9111	14.38095773
Waterbody Area	3988	3.5892	7.468584377

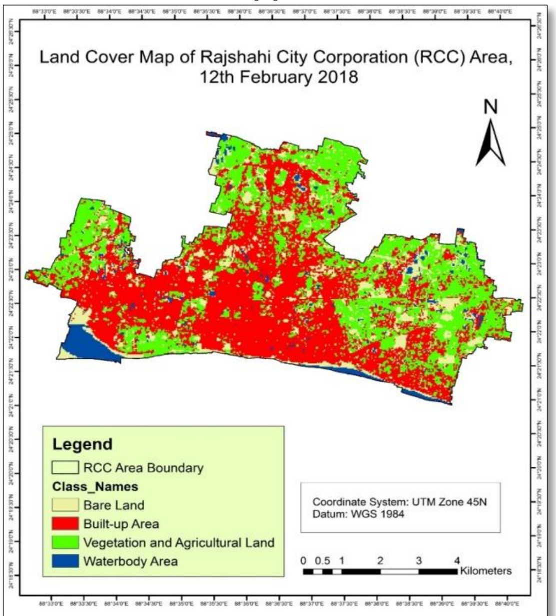
(a)



Land Cover	Total Pixel Count	Area in Square Kilometers	Area in Percentage
Built-up Area	16369	14.7321	30.65528026
Vegetation & Agricultural Land	23695	21.3255	44.37515216
Bare Land	9718	8.7462	18.19952432
Waterbody Area	3615	3.2535	6.770043261

(b)

Top left: (a) 1998
Top right: (b) 2008
Bottom left: (c) 2018
Coordination system: UTM zone 45N
Projection: Transverse Mercator
Datum: WGS 1984
Units: Meter



Land Cover	Total Pixel Count	Area in Square Kilometers	Area in Percentage
Built-up Area	25364	22.8276	47.50079592
Vegetation & Agricultural Land	18112	16.3008	33.91950859
Bare Land	7660	6.894	14.34537521
Waterbody Area	2261	2.0349	4.23432028

(c)

Fig. 2. Land cover map of rajshahi city corporation (rcc) area, (a), (b), (c) represents 1998, 2008, 2018 respectively

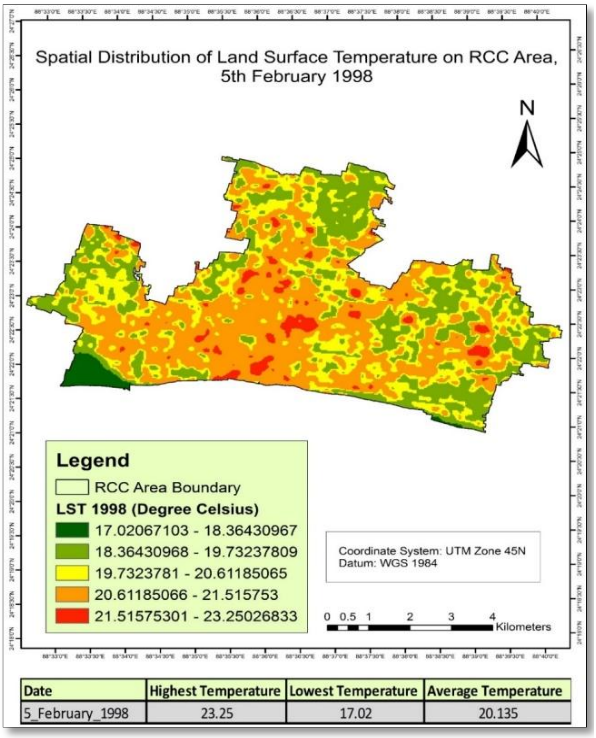
Finally, the following formula is used to emissivity correction [18].

$$LST = \frac{T_B}{1 + \left(\frac{T_B * \lambda}{\rho}\right) * \ln \varepsilon} \tag{3}$$

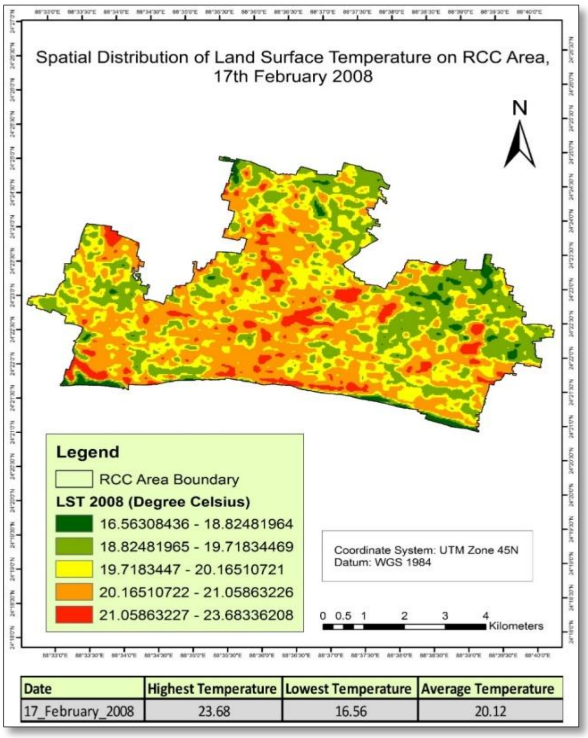
Here,

λ= Wavelength of emitted radiance,
P= Planck Constant 1.438× 10^{-2} mK,
ε = Emissivity

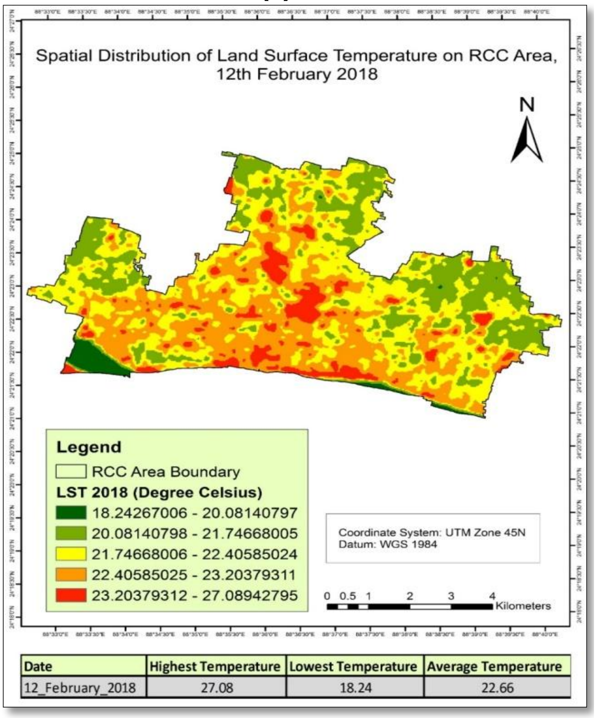
Following Fig. 3. represents the spatial distribution of land surface temperature of RCC area during the year of 1998 where the average temperature was 20.13 degree Celsius.



(a)



(b)



(c)

Top left: (a) 1998
Top right: (b) 2008
Bottom left: (c) 2018
Coordination system: UTM zone 45N
Projection: Transverse Mercator
Datum: WGS 1984
Units: Meter

Fig. 3. Spatial distribution of LST on RCC area, (a), (b), represents 1998, 2008, 2018

4. RESULTS AND DISCUSSION

4.1 Land Cover Change Assessment

Land Cover Area (LCA) consists of all settlement, infrastructure, ponds, rivers, wetlands, canals, trees, parks, open space, vegetable lands, bare land and so on. As industrialization and urbanization increase, RCC area faces significant land cover changes. The land cover map for the year of 1998, 2008 and 2018 has been prepared by using supervised image classification method of Geographic Information System (GIS). The Table 7. summarized how the land cover of Rajshahi city has been changed from the period of 1998 to 2018. In 1998 the vegetation, built-up area, bare land and waterbody area was 26.5707, 10.9863, 6.9111 and 3.5892 square kilometres. In 2008 both vegetation and waterbody area decreased to 21.3255 and 3.2535 square kilometres and the built-up and bare land area increased to 14.7321 and 8.7462 square kilometres. But in 2018, due to rapid urban growth both vegetation, bare land and waterbody area decreased to 16.3008, 6.894 and 2.0349 square kilometres and only the built-up area increased to 22.8276 square kilometres. In this regard at the period of 1998 to 2008, vegetation and waterbody area have been decreased by 10.91%, and 0.69% respectively, on the other hand, built-up area and bare land has been increased by 7.79% and 3.81 % at the same time. These situations almost continued at the period from 2008 to 2018 which results in decreasing rate of vegetation, bare land and waterbody area to 10.45%, 3.85%, and 2.53% in accordance with the increasing rate of built-up area to 16.84%. The overall change of land cover of RCC area from 1998 to 2018 represents a decreasing trend of vegetation, bare land, and waterbody area to 21.37%, 0.03% and 3.23% and the increasing trend of built-up area to 24.63%.

Rapid population growth in Rajshahi city demands new residential, commercial and industrial space which results in cutting down trees and destroying the agricultural land area. The integrated rise of population and built-up area reduced the amount of vegetation, agricultural land, bare land and waterbody area across Rajshahi city for the last twenty years (1998-2018). Mass amount of vacant land of Rajshahi city also replaced by the built-up area and the overall scenario of the last twenty years land cover of Rajshahi city represents a continuous decreasing trend of both vegetation, agricultural land and waterbody area and at the same time continuous increasing trend of built-up area. In this regard, there is a clear indicator of land cover change across Rajshahi city which results in potential threat to the urban environment of the city.

Following Fig. 4. represents the scenario of land cover change from one land cover area type to another land cover during the period of 1998 to 2018, where the conversion from vegetation and agricultural land to built-up area was maximum.

The overall scenario of the land cover change across RCC during the last two decades have been shown in the Fig. 4. as different colours and the data of that change has been shown in the Table. The table represents the how the vegetation and agricultural land area have been replaced by different land cover area type. During the period of 1998 to 2018 the highest loss among the all land cover area type was vegetation and agricultural land area and which is about 14.049 square kilometres where the total area of RCC is 48.0573 square kilometres. In this regard, significant amount of vegetation and agricultural land areas have been converted to other land cover area types which totally change the overall land cover scenario of Rajshahi city since 1998, on the other hand 13.6962 square kilometres area of different land cover types have been converted to the built-up area. Therefore, the built-up area gains the highest amount of land area from other land cover area types since 1998.

Table 7. Land cover change scenario in RCC area (1998 to 2018)

Land cover area	Year			Land cover area change (1998 to 2018)		
	1998 (Km^2)	2008 (Km^2)	2018 (Km^2)	1998-2008 (%)	2008-2018 (%)	1998-2018 (%)
Built-up	10.9863	14.7321	22.8276	+7.79	+16.84	+24.63
Vegetation	26.5707	21.3255	16.3008	-10.91	-10.45	-21.37
Bare land	6.9111	8.7462	6.894	+3.81	-3.85	-0.03
Waterbody	3.5892	3.2535	2.0349	-0.69	-2.53	-3.23
Total area	48.0573	48.0573	48.0573	-	-	-

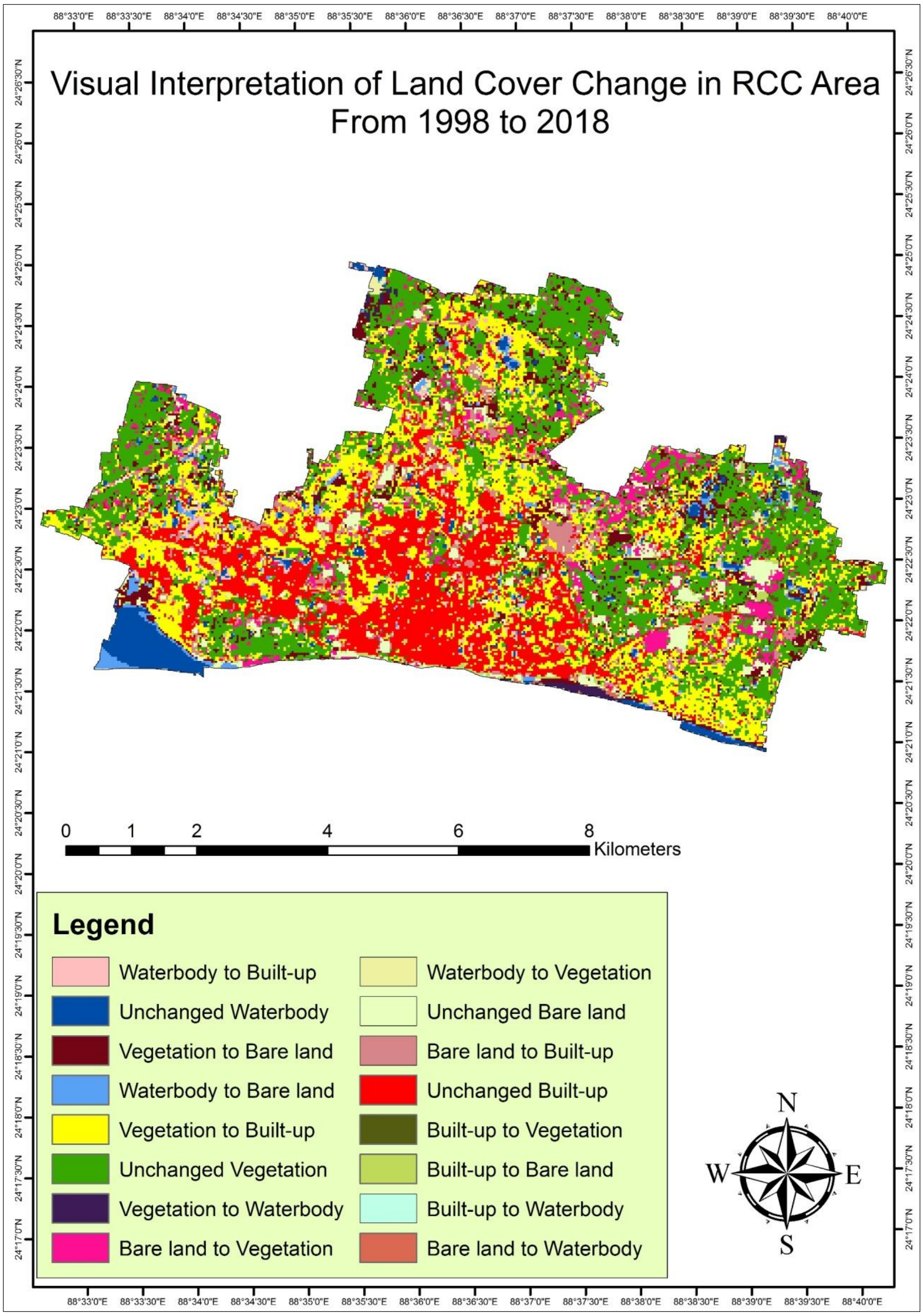


Fig. 4. Land cover area change from 1998 to 2018

4.1.1 Trend of changing land cover area in RCC

Fig. 5. shows the trend of different land cover area of RCC area. Almost all land cover area types possess either positive or negative trend but the only built-up area possess constant increasing trend during the period of 1998, 2008 and 2018. In Fig. 5. 2 a linear trend line is illustrated with an equation which can predict the future prediction of the built-up area in RCC. The equation shows the correlation value which is 0.9868 that indicates the highly correlated variables in the equation.

Table 8. Change matrix of each land cover type during the period of 1998 to 2018

Land cover in 1998 (Km^2)	Land cover in 2018 (Km^2)				
	Vegetation and Agricultural land	**Waterbody area**	**Bare-land**	**Built-up area**	**Total area (1998)**
Vegetation and Agricultural land	12.5217	0.3447	3.2076	10.4967	26.5707
Waterbody area	0.2916	1.5948	0.9297	0.7731	3.5892
Bare land	2.4975	0.0423	1.9449	2.4264	6.9111
Built-up area	0.99	0.0531	0.8118	9.1314	10.9863
Total area (2018)	16.3008	2.0349	6.894	22.8276	

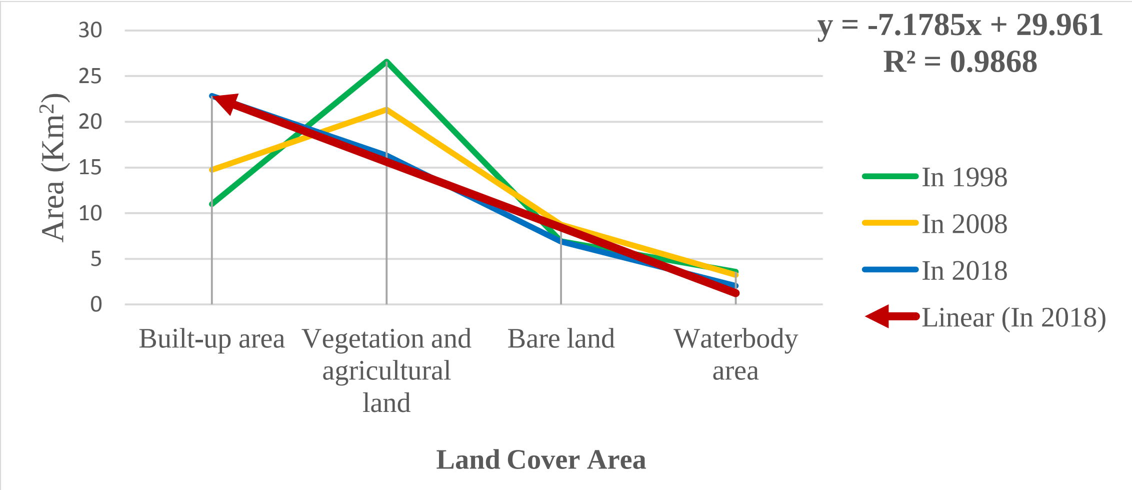


Fig. 5. Trend of land cover area change from 1998 to 2018

4.1.2 Direction wise expansion of built-up area in RCC

Following Fig. 6. shows the direction wise expansion of built-up area in RCC during the period of 1998 to 2018 and Table 9. illustrates the all data related to the direction wise expansion of built-up area in RCC. According to the table, in 1998 west part of the RCC area possess most of the built-up area which is about 2.663 square kilometres on the other hand east and south-east part of RCC area possess 2.349 and 1.532 square kilometres of built-up area. This is because the influence of the central business district, Rajshahi University and Padma river on east, south-east and the west part of the city. In 2008, west and east and south-east part of the city expand to 4.471, 2.490 and 2.416 square kilometres on the other hand north and north-west portion area cover 1.428 and 1.343 square kilometres area. But in 2018 a dramatic built-up area growth appeared in RCC with expansion of the both part of the city where east and west part possess 5.413 and 5.378 square kilometres of built up area in accordance with 3.324, 2.522, 2.667, 2.013 square kilometres expansion at the north, north-east, south east and north west part of the city.

4.2 level of Urbanization in RCC Area

Level of Urbanization refers to the portion of population living in the urban areas [22]. The population of RCC area in 2001, 2008 and 2011 were 388811, 430532 and 449756 respectively. Currently in 2018, the city has an approximate population of 700133 within its 48 square kilometers area. The total population of Rajshahi zila in 2001, 2008 and 2011 were 2286874, 2498572 and 2595197 respectively. The present population of Rajshahi zila is approximately 2835437. The urbanization level has also drastically changed over last decades. Urbanization level of different time periods from 2001 to 2018 has been calculated to better understand the chronological changes of urbanization over time.

Level of Urbanization in 2001,

$$U^n = \frac{388811}{2286874} \times 100 = 17.00\%$$

Level of Urbanization in 2008,

$$U^n = \frac{430532}{2498572} \times 100 = 17.23\%$$

Level of Urbanization in 2011,

$$U^n = \frac{449756}{2595197} \times 100 = 17.33\%$$

Level of Urbanization in 2018,

$$U^n = \frac{700133}{2835437} \times 100 = 24.69\%$$

This result shows the degree of urbanization in Rajshahi City Corporation area from 2001 to 2018. The level of urbanization has been changed dramatically from 17% to 24.69% over last decades. As urbanization means the portion of urban population in the total population of a city who are living in urban areas, 24.69 percent of RCC area's total population lived in urban areas in 2018.

4.3 Urban Growth Rate in RCC Area

Urban Growth rate refers to an increase in total urban population, whereas urbanization refers to the percentage increase in urban population. Urban growth and land cover change have been a key issue regarding any development activity in local and regional level. The future land use planning of urban areas requires complete knowledge about the urban growth rate. The population of RCC area in 2001, 2008 and 2011

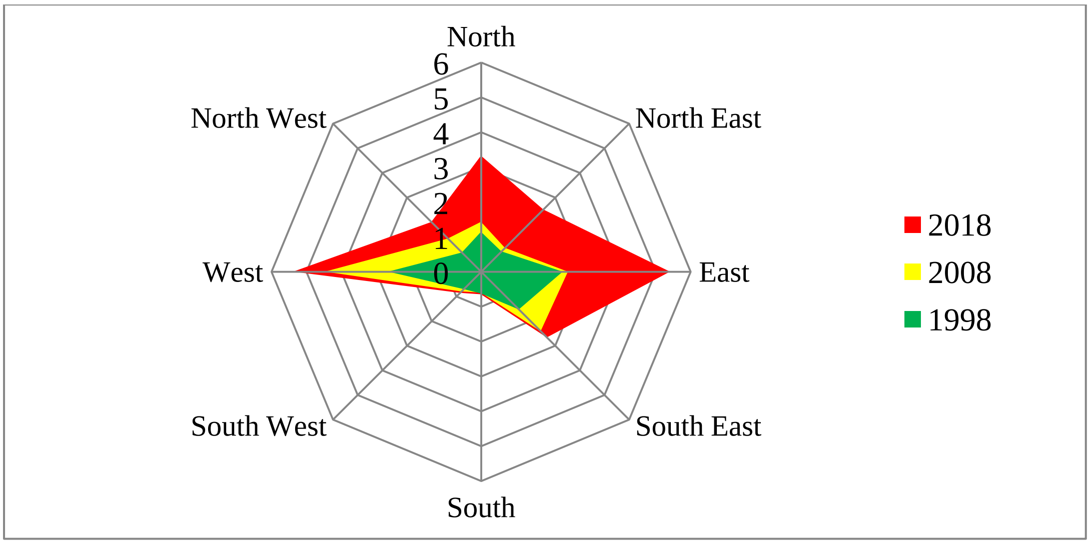


Fig. 6. Direction wise expansion of built-up area (km^2) in RCC from 1998 to 2018

Table 9. Direction wise distribution of the built-up area (km^2) in RCC (1998-2018)

Representative Year	North	South	East	West	South East	South West	North East	North West
1998	1.142	0.626	2.349	2.663	1.532	0.705	0.824	0.776
2008	1.428	0.600	2.490	4.471	2.416	0.801	0.968	1.343
2018	3.324	0.649	5.413	5.378	2.664	0.858	2.522	2.013

Table 10. Urban growth rate of RCC area

Urban Growth Rate from 2001 to 2011	$U_r = \left(\sqrt[10]{\frac{449756}{388811}} - 1\right) \times 100 = \mathbf{1.47\%}$
Urban Growth Rate from 2008 to 2018	$U_r = \left(\sqrt[10]{\frac{700133}{430532}} - 1\right) \times 100 = \mathbf{4.98\%}$

were 388811, 430532 and 449756 respectively. Currently, the city has an approximate population of 700133 within its 48 square kilometers area in 2018. The calculated result shows that, urban growth rate from 2001 to 2011 was 1.47% which has increased to 4.98% in 2018.

4.4 Land Surface Temperature (LST) Change Assessment

Following Fig. 7. represent the scenario of change in LST within RCC area over the decade.

According to the Fig. 7. the highest temperature for the year of 1998, 2008 and 2018 is 23.25, 23.68 and 27.08^{0}C which represents a consistent increasing of the LST during the periods on the other hand the highest temperature difference between the 1998 to 2008 is only 0.43^{0}C but the difference increased to 3.4^0 Celsius for the duration from 2008 to 2018. The statistical data also shows that the lowest temperature for the year of 1998, 2008 and 2018 is 17.02^{0}C, 16.56^{0}C and 18.24^{0}C, which shows that lowest temperature in 2008 is 0.46^{0}C lower than the temperature in the 1998. It should be mention that temperature varies according to the air temperature of the day, in this regard slight change in temperature can happened. The lowest temperature for the year of 2018 is 18.24^{0}C which is 1.22^{0}C and 1.68^{0}C higher than the lowest temperature in 1998 and 2008. Increment of the both highest and lowest temperature indicates significant change in surface temperature in RCC area during the last twenty years. Fig. 7. also shows a significant variation in the average temperature for the year of 1998, 2008 and 2018. The variation of mean temperature during the period of 1998 to 2008 is 0.015^{0}C but at the period of 2008 to 2018 variation rise to 2.54^{0}C.

4.5 Relationship between Land Surface Temperature (LST) and Land Cover Area

Land cover area such as built-up area, waterbody area, vegetation, agricultural land, and bare land has different influence in the spatial distribution of Land Surface Temperature (LST). The LST also varies in accordance with the density of the land cover area. Table 11. shows the maximum, minimum and mean temperature of different land cover for the year of 1998, 2008 and 2018. According to the table, waterbody area represents the minimum temperature and which is 17.02 degree Celsius for the year of 1998 and the bare land area represents the maximum temperature for the year of 2018 and which is 27.08 degree Celsius. During the last two decades, waterbody area represents the lowest mean temperature, on the other hand, bare land area represents the highest mean temperature for the year of 1998 and 2008 which is about 20.95 and 20.23 degree Celsius. The reason behind the highest temperature in bare land area is existence of large number of sand particles as well as char land in RCC area which reflect highest thermal signal to the satellite band. In 2018 the built-up

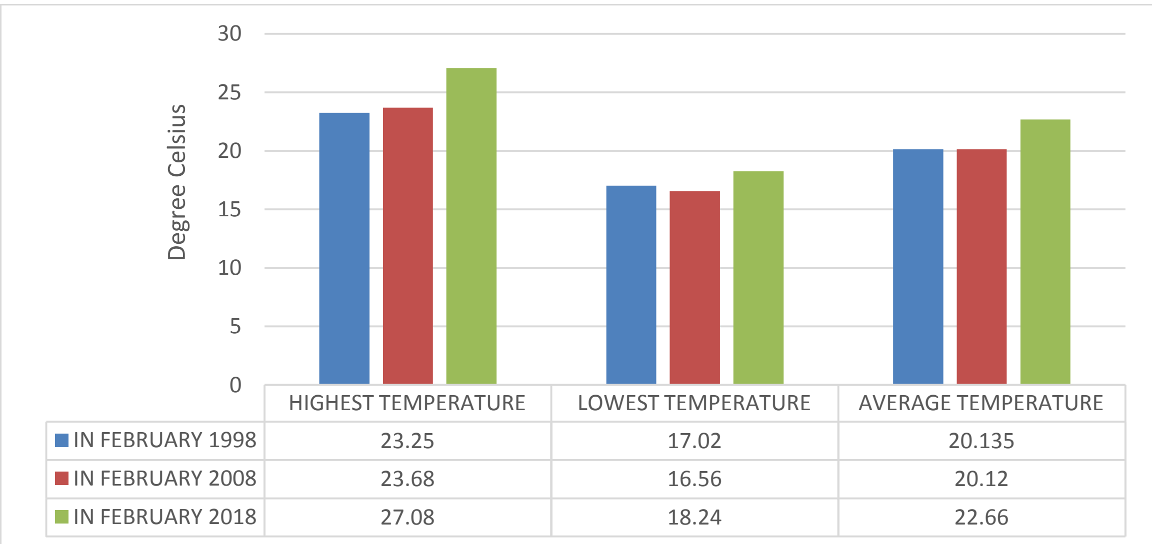


Fig. 7. Land surface temperature change from 1998 to 2018

Table 11. Maximum, minimum and mean temperatures of different land cover for the year of 1998, 2008 and 2018

Date	Land cover area	Land surface temperature (^{0}C)		
		Maximum	Minimum	Mean
5-February 1998	Vegetation and agricultural land	22.81	17.93	20.14
	Waterbody area	21.94	17.02	19.30
	Bare land	23.25	18.83	20.95
	Built-up area	23.25	18.83	20.85
17-February 2008	Vegetation and agricultural land	23.25	17.93	19.68
	Waterbody area	21.50	**16.56**	19.10
	Bare land	23.68	17.93	20.23
	Built-up area	22.37	18.38	20.08
12-February 2018	Vegetation and agricultural land	24.00	20.14	21.90
	Waterbody area	23.59	18.24	20.05
	Bare land	**27.08**	19.43	**22.42**
	Built-up area	24.82	20.58	**22.50**

area represents the highest mean temperature accounted as 22.50 degree Celsius and for the year of 1998 and 2008 the mean temperature of the built-up area was 20.85 and 20.08 degree Celsius. Built-up area also represents the minimum temperature difference from the highest mean temperature of each year. In 1998, the temperature difference between built-up area and bare land is 0.10 degree Celsius and in 2008 the temperature difference between built-up area and bare land is 0.15 degree Celsius. In this regard, the temperature of the built-up area always closes to the highest mean temperature.

Following Fig. 8. represents the relation among maximum LST and different land cover area types. According to the figures both bare land and built-up area represents upward trends in terms of both maximum minimum and mean temperature.

4.6 Relationship between Normalized Difference Built-Up Index (NDBI) and LST

Land surface temperature (LST) is always influenced by the land cover indices. As NDBI is a major land cover indicator, therefore, NDBI is used to identify the correlation scenario between LST and NDBI. Higher positive values of NDBI such as value greater than 0.3 represents sand or bare land type land cover area, on the other

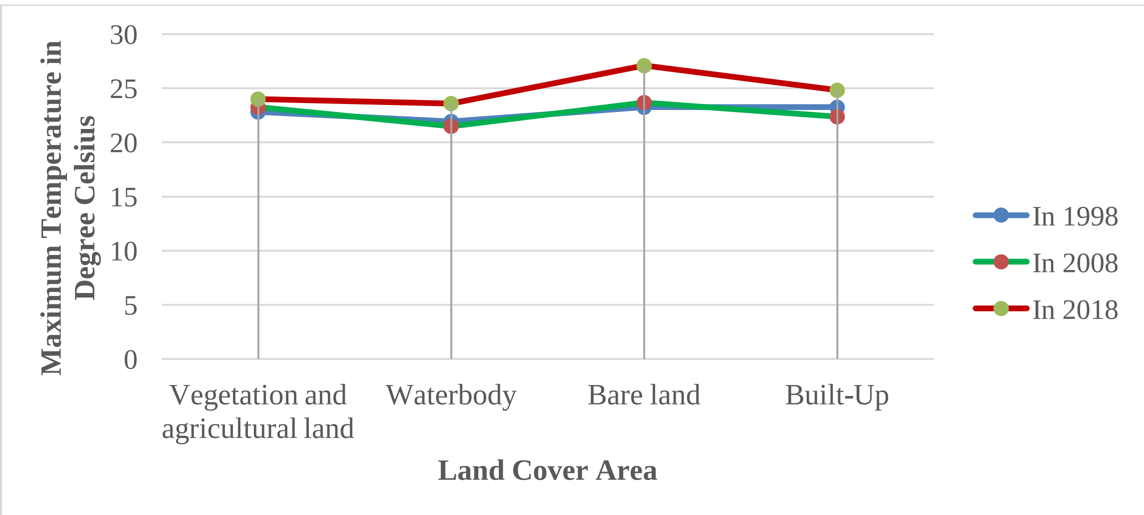


Fig. 8. Relationship among maximum LST and different land cover types

Table 12. NDBI and LST values of RCC area for the year of 1998, 2008 and 2018

NDBI 1998	LST 1998	NDBI 2008	LST 2008	NDBI 2018	LST 2018
-0.38019	17.02067	-0.22567	16.56308	-0.24326	18.83245
-0.31783	17.46041	-0.17647	17.00985	-0.20697	19.73448
-0.25158	17.46041	-0.13016	17.45661	-0.17874	20.56711
-0.18923	18.36431	-0.08385	17.93129	-0.15455	21.1222
-0.13467	18.82848	-0.04333	18.37806	-0.13237	21.50383
-0.08401	19.26821	-0.0086	19.27158	-0.11221	21.81607
-0.03335	19.73238	0.034817	19.71834	-0.09205	22.09361
0.013419	20.17211	0.072443	20.16511	-0.07189	22.37116
0.056287	20.61185	0.10428	20.61187	-0.05173	22.6487
0.095258	21.07602	0.136117	21.05863	-0.03157	22.96094
0.134229	21.51575	0.167955	21.50539	-0.0114	23.30787
0.169303	21.95549	0.199792	21.95216	0.010772	23.6895
0.208274	22.39523	0.237418	22.39892	0.038998	24.24459
0.251142	22.83496	0.283727	22.81776	0.101497	25.49354
0.438202	23.25027	0.376344	23.68336	0.202301	27.08943

hand NDBI value between 0.1 to 0.3 represents the built-up area [12]. Table 12. represents the 15 break values of NDBI and LST of RCC area for the year of 1998, 2008 and 2018. According to the study strong positive correlation between NDBI and LST were found and the strong positive correlation represents higher the NDBI value the higher the LST.

Following Fig. 9. represents correlation between LST and NDBI for the year of 1998 is 0.9747 which is very strong correlation with higher the NDBI the higher the LST.

Figs. 10. and 11. represents the correlation between the LST and the NDBI for the year of 2008 and 2018 where the horizontal axis represents the NDBI values and the vertical axis represents the LST values. A linear trend line is illustrated over the LST values with an equation for future analysis of the LST. In 2008 correlation value is found between NDBI and LST which is 0.9939 on the other hand correlation value for the year of 2018 is 0.9921. The both correlation values represent strong positive correlation and as positive NDBI value represents built-up area, bare land, earth fill and sandy land cover types, so increasing amount of this type of land cover may results in more LST in RCC area. In this regard, necessary steps need to be taken to control the growth of built-up area type land cover to minimize the LST in RCC area.

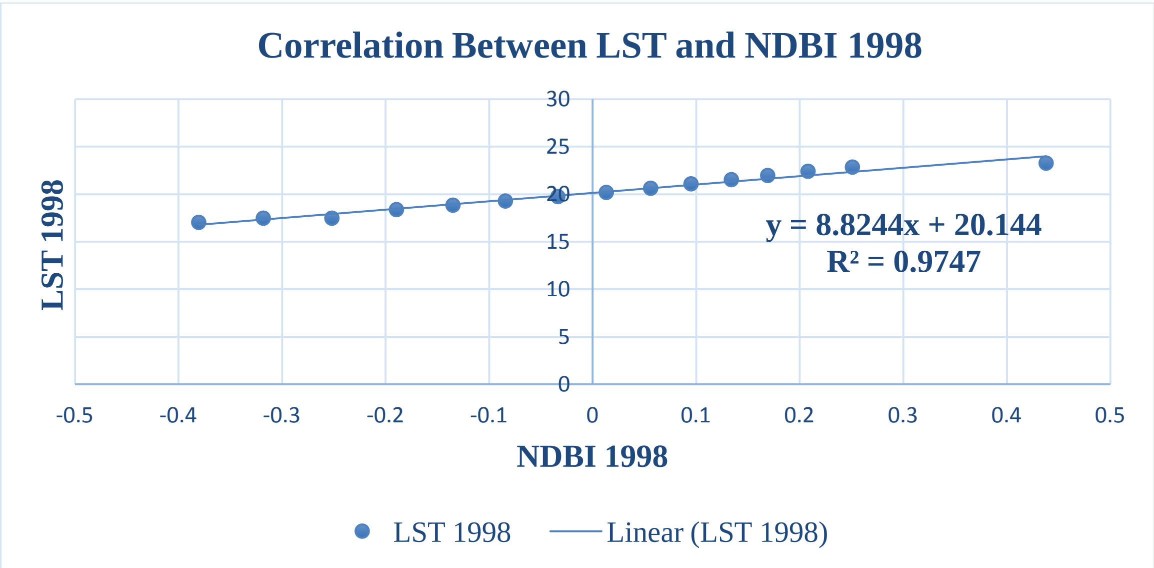


Fig. 9. Correlation between LST and NDBI of RCC for the year of 1998

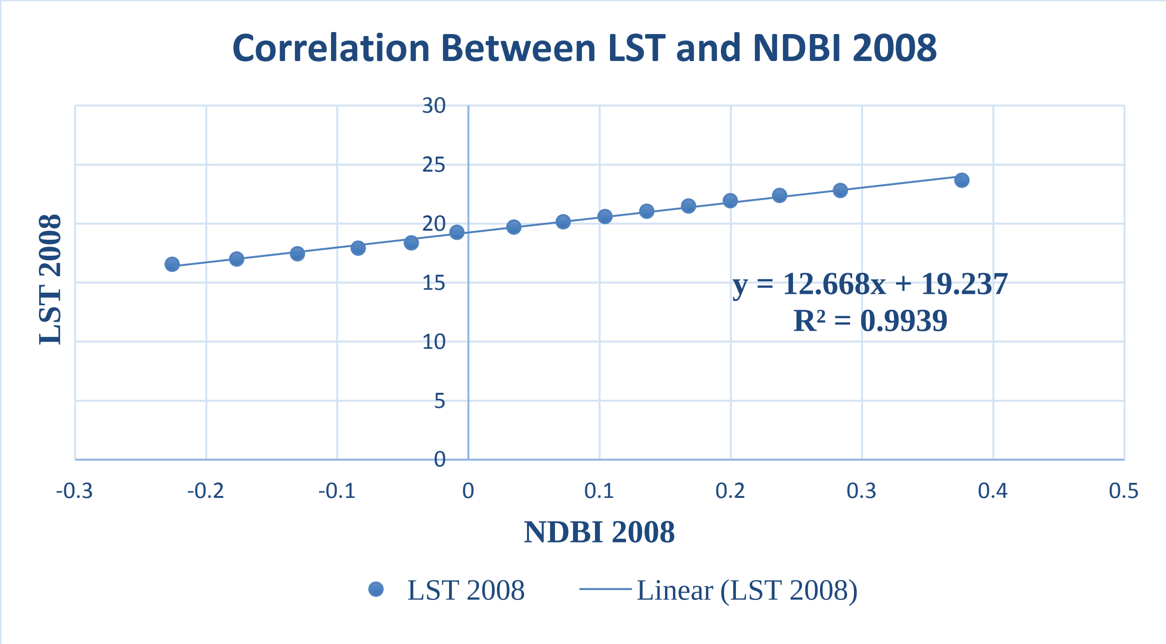


Fig. 10. Correlation between LST and NDBI of RCC for the year of 2008

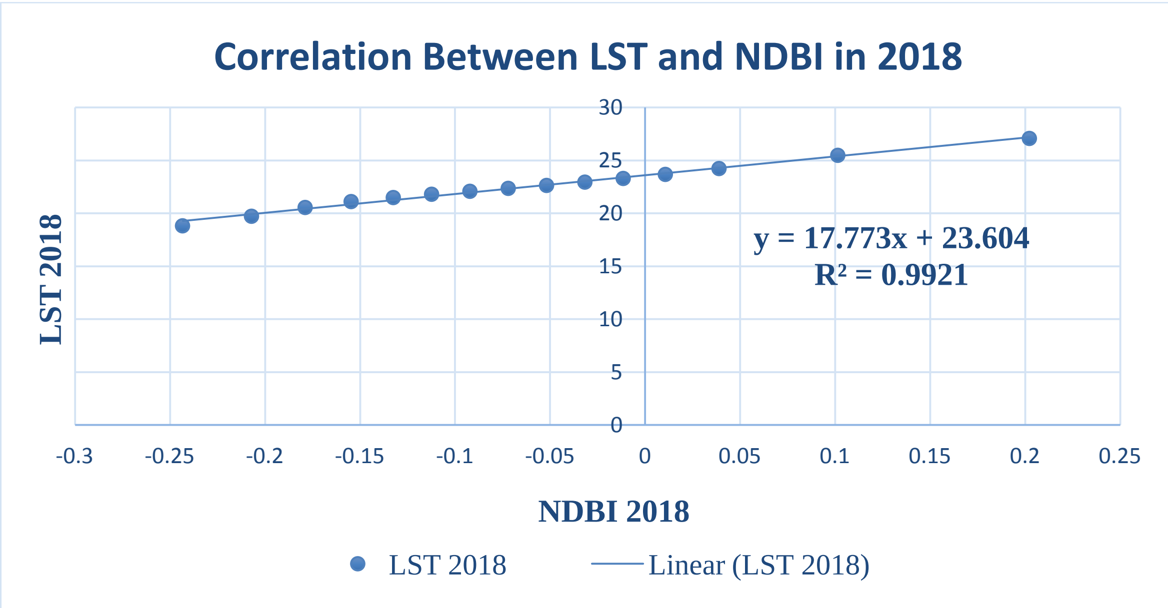


Fig. 11. Correlation between LST and NDBI of RCC for the year of 2018

4.7 Land Surface Temperature (LST) Change with the Change of Land Cover Area

Fig. 12. represents visual interpretation of LST in accordance with the change in land cover area in RCC, where image (a), (b), (c) represents the land cover and the LST for the year of 1998, 2008 and 2018. The change of temperature during the last two decades has been found as, 3.830 C. The maximum temperature for the year of 1998, 2008 and 2018 is increasing consistently and the maximum, minimum and mean LST for the year of 2018 is higher than temperature range in 1998 and 2008. Visual interpretation scenario of the LST and land cover indicates the change in land cover across RCC area for the last two decades is one of the major reasons behind this change in LST.

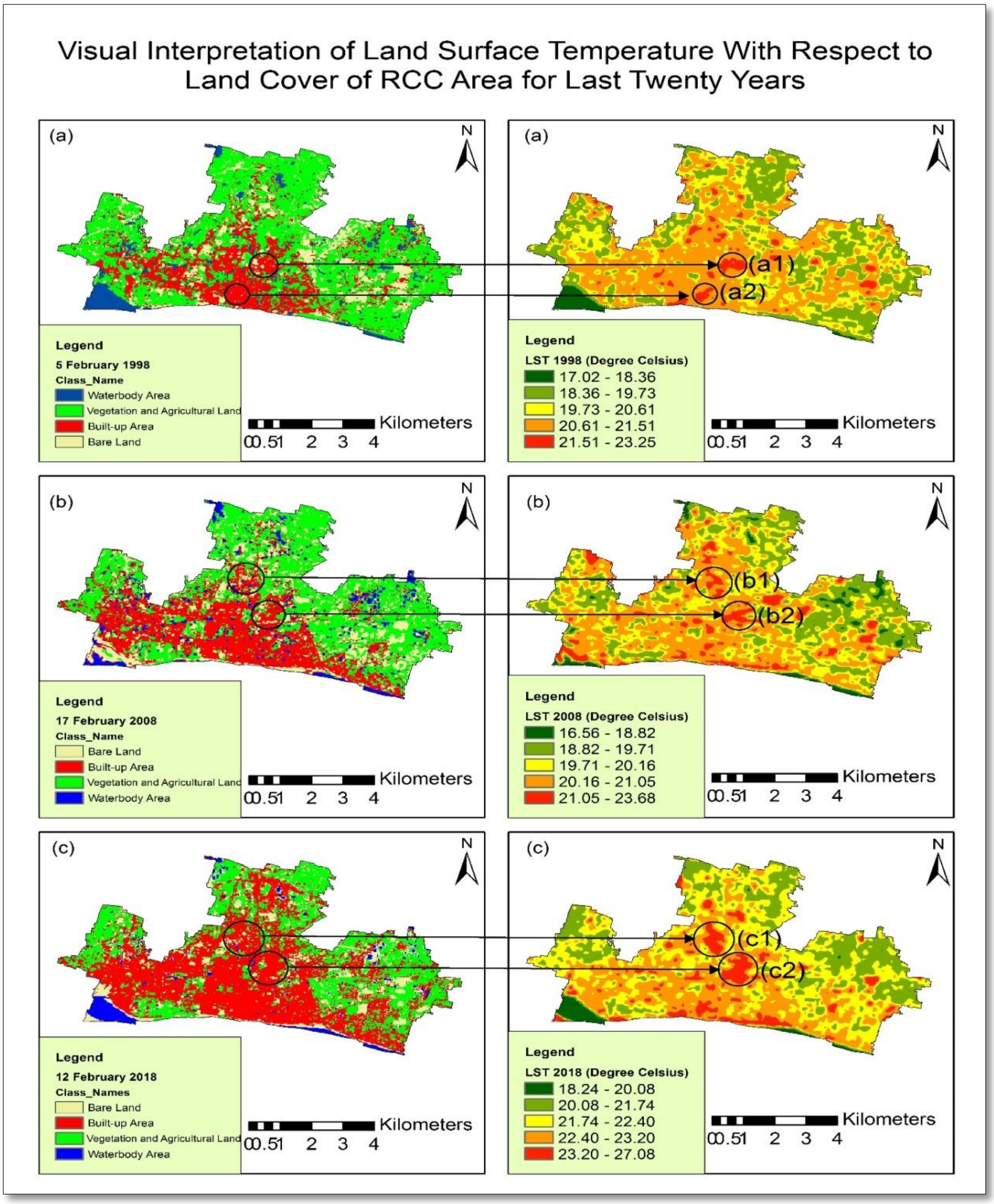


Fig. 12. Visual interpretation of the land surface temperature with respect to the land cover of RCC area (1998-2018)

According to the Table 11. highest LST zones found either in the built-up or in the bare land area on the other hand, lowest LST zones are found in waterbody, vegetation and agricultural land cover types. In Fig. 12. (a1), (a2) area represents one of the major LST possessed zones in RCC for the year of 1998 and which situated over dense built-up area in Rajshahi city and in 2008 the increment of the built-up area results in increment in spatial distribution of LST. Finally point (c1) and (c2) represents the expanding of the heat zones around (b1) and (b2) in 2018. Some place with Bare land area alongside Padma river that represents higher temperature in 2008 and 2018 which was previously covered with vegetation and waterbody in 1998 with minimum temperature. Without land cover area changing, there is no physical changed happen in such area. In this regard it is clear that change in land cover area is one of the major reasons behind the change in LST in RCC area.

5. CONCLUSION

Rajshahi City Corporation (RCC) area has been experiencing a rapid population growth over the last two decades which leads to rapid urban development within the city. Therefore, green space, waterbody and bare land areas have been replaced by impervious built-up areas such as concrete infrastructure, paved roads and other building surface. According to the findings, the amount of built-up areas has been doubled during the period of 1998 to 2018. As the built-up area is increasing day by day within Rajshahi city and Land Surface Temperature (LST) represents significant positive correlation with the built-up index, therefore the growth of built-up areas leads to Urban Heat Island (UHI) effect within the city. According to the study it is also found that LST is high in high dense built-up areas. In this regard, growth rate of built-up areas within Rajshahi city should be controlled by proper urban planning such as decentralization of urban area, density zoning etc.

LST values not only influenced by the built-up index but also influenced by the existence of vegetation and waterbody area within Rajshahi city. Some areas of bare land near Padma river shows higher temperature in 2008 and 2018 which was previously covered with vegetation and waterbody areas in 1998 with minimum temperature. Without land cover change, there is no physical changed happened in such area. In this regard it is clear that change in land cover area is one of the major reasons behind the change in LST in RCC area. Therefore, it is important to conserve the green space and waterbody area by enforcement of proper rules and regulation on the other hand several planting programs should be taken to increase the amount of green space within RCC area. Otherwise, if the current trend of land cover and LST change continues, it will adversely affect the microclimate of Rajshahi city.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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