

EFFECT OF EARTH COVERING AND WATER BODY ON LAND SURFACE TEMPERATURE (LST)

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Abstract — Land surface covering and water body play an important role on local environment especially on Land Surface Temperature (LST). In study above mentioned concept has been conducted on the drainage basin of Atai-Bhairab-Rupsha river confluence which is an important place both for agriculture and trade in the south-western part of Bangladesh. Here the impact of both surface covering and water body on local environmental factor like LST is being analyzed to determine the main catalyst in ever changing LST. LST study in this area which is changed dramatically recently may be a well-defined index, reflects environmental conditions. LST is mainly altered by the factors like land surface covering such as vegetation represented by NDVI, water body by NDWI, and barren or urban area by NDBI but only few are key factors. The gradual changes of these four parameters (LST, NDVI, NDWI, and NDBI) are studied for the years 1991, 1996, 2002, 2006, 2011 and 2017. From the LST study, it is observed that from 1991 to 2017 highest temperature decreased significantly and the difference between 1991 and 2017 is greater than 10°C. Variation of lowest temperature all these years are insignificant. Meanwhile, from NDVI analysis it is observed that area of vegetation coverage increased in a significant rate from the years 1991 to 2017. The area of water body is being found almost unchanged in this time period from the NDWI analysis. Nevertheless, from the NDBI analysis it is found that the barren area is diminished significantly in this period and is obviously replaced by vegetation. At all, it can be said that the highest value of NDVI in 1991 is greater than 2017 denotes some sort of drought or increasing salinity condition but in general viewpoint vegetation helps to keep surface temperature under control.

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Keywords: Land Surface Covering, Land Surface Temperature, Vegetation, Water body, Urbanization.

1.0 INTRODUCTION

Land surface covering and water body have vast impact on the local ecosystem. Weng & Yang [1] have shown in their research that alteration of the earth surface to urban application demonstrate massive changes in comprehensive usage of the land and provide significant impact on the environment. Land Surface Temperature (LST) plays some vital role in the physics of land surface processes of local environment. LST is mainly affected by different types of land coverings and water body. Choudhury et al. [2] prove in their research that type of land use, changes of land cover have significant impact on land surface temperature. Meanwhile Khandelwal et al. [3] shows elevation variation may affect land surface temperature which is another factor. But Zullo et al. [4] highlights effects of urban growth spatial pattern on land surface temperature. Again Zhao et al. [5] show effect of forest on land surface temperature. So, there are large number of researches works on land covering that effects LST. Rapid urbanization, deforestation, destruction of water body is some of the main causes of fatal environmental catastrophe like global warming. Whereas reforestation, reduction of bare soil, increase of water body may change our environment habitable. LST is a popular indicator of environmental alternation, which largely depends on land covering variants (vegetation, bare land, urban area etc.) and water body.

Satellite images are used which contain information of land covering and pattern such as vegetation, water body, bare soil etc., even it is useful to analyze terrain effect on land surface which is found in the research of Zhao et al. [6]. LST is the radiative land surface skin temperature, measured in the direction of the remote sensor. Top-of-Atmosphere (TOA) brightness temperatures is used to determine LST from the infrared spectral channels of a constellation of geostationary satellites. Albedo, vegetation cover and

soil moisture affect its estimation. LST is a blend of vegetation and bare soil temperatures of earth environment. According to Ahmadi & Nusrath [7] multi spectral remote sensing images are very efficient for obtaining a better understanding of the earth environment. Karaburun [8] says that it is the technique of acquiring information and extracting the features in form of spectral, spatial and temporal form, about some objects, area or phenomenon without coming into physical contact of them.

Certain pigments in plant leave strongly absorb wavelengths of visible (red) light. The leaves themselves strongly reflect wavelengths of near-infrared light, which is invisible to human eyes. Many sensors carried aboard satellites measure red and near-infrared light waves reflected by land surfaces. Using mathematical formulas (algorithms), scientists transform raw satellite data about these light waves into vegetation indices. Although there are several vegetation indices, one of the most widely used is the Normalized Difference Vegetation Index (NDVI) ranges from +1.0 to -1.0 (Remote Sensing Phenology 2015). The Normalized Difference Water Index (NDWI) is known to be strongly related to the plant water content. It is therefore a very good proxy for plant water stress. According to Gao [9] it is real-time retrieval of soil moisture, which has high retrieval accuracy. Plants experience water stress either when the water supply to their roots becomes limiting or when the transpiration rate becomes intense. According to Lisar et al. [10] initially water stress is caused by drought or high soil salinity. NDWI is an important indicator of detecting drought like catastrophe, as Zhang & Huai-Liang [11] say that it is caused by long-term lack of soil water content which would affect agriculture, ecology and socio-economy; it is particularly harmful to food production as well. Lambin [12] say that urban area is a small fraction of the Earth's surface area but has a disproportionate influence on its surroundings. Mapping urban area in an accurate and regular manner is essential for different planning applications such as watershed run-off prediction. Researchers like Guindon et al. [13], Xu [14], Bhatta [15], and Griffiths et al. [16] have same perspective that remote sensing images are useful for monitoring the spatial distribution and growth of urban built-up areas because of their ability to provide timely and synoptic views of land cover. Zha et al. [17] proposed the normalized difference built-up index (NDBI) to automatically map urban built-up areas. Together NDWI and NDBI) ranges from +1.0 to -1.0.

In this study, an attempt is taken to find out key factor among NDVI, NDWI and NDBI which alters LST mostly. All the parameters mainly indicate the environmental change of the catchment area.

1.1 STUDY AREA

Figure 1 shows the study area of the drainage basin of Atai-Bhairab-Rupsha river confluence which is a significant place both for agriculture and trade in the south-western part of Bangladesh. The study area covers mainly Khulna district and some portion of Barisal division. Mainly the middle of the Khulna city is sited at the confluence area.



Figure 1. Study area with adjacent rivers.

2.0 RESOURCES AND TECHNIQUES

In this study for image analysis, different tools from ArcMap, which is the central application of ArcGIS (version 10.4.1) software have been used. Satellite images of the years 1991, 1996, 2002, 2006, 2011 and 2017 are downloaded from the website <https://glovis.usgs.gov/>. Landsat-5 TM images for years 1991, 1996, 2006, 2011; Landsat-7 ETM+ images for year 2002; Landsat-8 OLI and TIRS images for year 2017 at the middle of the February at UTM zone 46 are downloaded. SRTM 1 Arc-Second Global DEM is downloaded from the website <https://earthexplorer.usgs.gov/> to select the drainage basin. Catchment area is selected from the DEM data, using basin delineation technique of ArcMap.

The area of the different land surface covers is determined from the number of pixels of the raster images. Each pixel of the images covers 30 square meters (except thermal images). So, number of pixels representing land cover is multiplied by 30 square meters and in this way total land cover area calculated. This is a type of unsupervised classification technique.

2.1 AIM OF THE STUDY

The specific objective of this study is as follows

- To study the geographical pattern of the surface cover and water body on the study area.
- To study the historical change of the surface cover and water body of the area.
- Determination of the main type surface pattern (vegetation, water body, barren area) dominates total area.
- To determine predominant factor that alters Land Surface Temperature (LST).

2.2 GOVERNING EQUATION FOR LST AND OTHER INDICES

Normalized Difference Vegetation Index (NDVI) can be calculated by the following equation:

$$NDVI = \frac{NIR - VISR}{NIR + VISR} \quad (1)$$

Where, *NIR* is spectral reflectance measurements acquired in the near infra-red regions and *VISR* is spectral reflectance measurements acquired in the visible red regions. NDVI quantifies vegetation by measuring the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs). NDVI always ranges from -1 to +1.

The formula stands for Normalized Difference Water Index (NDWI) is given below:

$$NDWI = \frac{VISG - NIR}{VISG + NIR} \quad (2)$$

where *VISG* is spectral reflectance measurements acquired in the visible green regions. Like NDVI its value also ranges from 1 to -1. Generally, value higher than 0.5 denotes water body.

Normalized Difference Built-up Index (NDBI) is developed to derive urbanized areas from TM/Landsat 5 or ETM+/Landsat 7 images or OLI/Landsat 8, as described by following equation:

$$NDBI = \frac{SWIR - NIR}{SWIR + NIR} \quad (3)$$

Where, *SWIR* is spectral reflectance measurements acquired in the shortwave infra-red regions.

During 1G-product rendering image pixels are converted to units of absolute radiance using 32 bit floating-point calculations. Pixel values are then scaled to byte values prior to media output. The following equation is used to convert DN's in a 1 G product back to radiance unit for TM and ETM+:

$$L_{\lambda} = \left(\frac{LMAX_{\lambda} - LMIN_{\lambda}}{QCALMAX - QCALMIN} \right) * (QCAL - QCALMIN) + LMIN_{\lambda} \quad (4)$$

Here L_{λ} is spectral radiance in watts/ (m²*ster*μm), $QCAL$ is the quantized calibrated pixel value in DN, $LMIN_{\lambda}$ is the spectral radiance that is scaled to $QCALMIN$ in watts/ (meter squared*ster*μm), $LMAX_{\lambda}$ is the spectral radiance that is scaled to $QCALMAX$ in watts/ (meter squared*ster*μm), $QCALMIN$ is the minimum quantized calibrated pixel value (corresponding to $LMIN_{\lambda}$) in DN, $QCALMAX$ is the maximum quantized calibrated pixel value (corresponding to $LMAX_{\lambda}$) in DN.

The following equation is used to convert DN's in a 1 G product back to radiance unit for TIRS:

$$L_{\lambda} = M_L * Q_{cal} + A_L \quad (5)$$

Here, M_L is radiance multiplicative scaling factor for the band (RADIANCE_MULT_BAND_n from the metadata), Q_{cal} is L1 pixel value in DN, A_L is radiance additive scaling factor for the band (RADIANCE_ADD_BAND_n from the metadata).

ETM+ Band 6 (thermal) and TIRS Band 10 and 11 imagery can also be converted from spectral radiance to a more physically useful variable. This is the effective at satellite temperatures of the viewed Earth-atmosphere system under an assumption of unity emissivity and using pre-launch calibration constants. The conversion formula is:

$$T = \frac{K2}{\ln\left(\frac{K1}{L_{\lambda}} + 1\right)} \quad (6)$$

T is brightness temperature (K), $K2$ is calibration constant 2, $K1$ is calibration constant 1. Proportion of vegetation P_v is determined by following equation:

$$P_v = \left(\frac{NDVI - NDVI_{MIN}}{NDVI_{MAX} - NDVI_{MIN}} \right)^2 \quad (7)$$

Land surface emissivity e is determined by following equation:

$$e = 0.004P_v + 0.986 \quad (8)$$

Land surface temperature LST (°C) is determined by following equation:

$$LST = \frac{T}{1 + \frac{wT}{p} \times \ln(e)} - 273.15 \quad (9)$$

where w is wavelength of emitted radiance (μm), $p = hc/s = 1.438 \times 10^{-2}$ mK, h is Planck's constant (6.626×10^{-34} Js), s is Boltzmann constant (1.38×10^{-23} J/K), c is Velocity of light (2.998×10^8 m/s).

3.0 RESULT AND DISCUSSION

Spatial distribution of temperature variation in the years 1991, 1996, 2002, 2006, 2011 and 2017 has been shown in Figure 2. The summary of highest and lowest LST from Figure 2 has been given away in the Table 1. Figure 3 shows also the line diagram of LST variation, where the ranges of highest and lowest temperature is clearly visible. From Figure 3 and Figure 2 (and also in table 1) it is revealed that during the years 1991, 1996, 2002 and 2006 (in this four years) the variation of the highest LST is not so much observed. On the other hand, in these four years the lowest LST varies from 22.28°C to 28.64°C . In the years 2011 and 2017, the highest LST differs from 35.55 to 33.59 and lowest LST from 17.44 to 19.73 which indicate that the LST drops dramatically accompanying with other four years. These phenomena is very difficult to understand, may perhaps be the reasons for the global temperature increases day by day. But in this study, Land Surface Temperature (LST) is studied, rather than atmospheric temperature. LST is an important factor, which is influenced by different local parameters and influences local biodiversity.

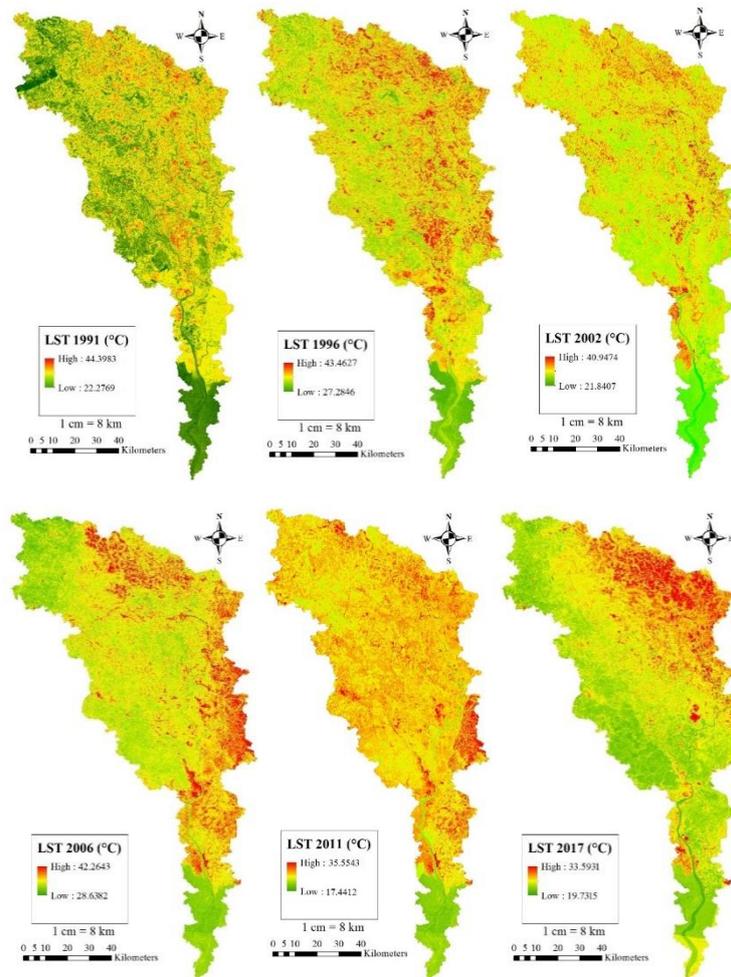


Figure 2. Spatial distribution of temperature variation at study area in the years 1991, 1996, 2002, 2006, 2011 and 2017

Table 1 Summary of LST values from figure 3 for different years

Year	1991	1996	2002	2006	2011	2017
Highest	44.4	43.46	40.95	42.26	35.55	33.59
LST(°C) Lowest	22.28	27.28	21.85	28.64	17.44	19.73

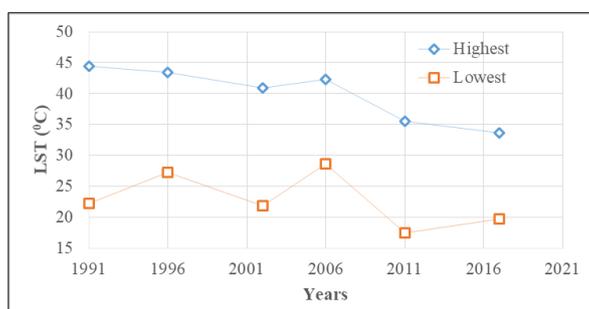


Figure 3. Line diagram of LST (°C) in the years 1991, 1996, 2002, 2006, 2011 and 2017.

Figure 4 shows the surface covered by vegetation and other type area of features according to NDVI. From the Figure, it is shown that vegetation covered area is reduced maximum in size for the year 2002 and once more it increases gradually to a highest range at 2017. The other type area of covering seen almost identical excepting for the year 2002.

The surface covered by water-body and other type area of features according to NDWI has been presented in Figure 5. From this Figure it is revealed that during the year 2002 the area of water body is greater than the year 1996. So, it is clear that the lost area of vegetation covering in 2002 is partially replaced by some type of water logging. And in 2017, area covered by water body and other features shows almost same result as 1996. So during 2002 increase of water covering area is not a permanent natural or man-made water body but some type of temporary water logging.

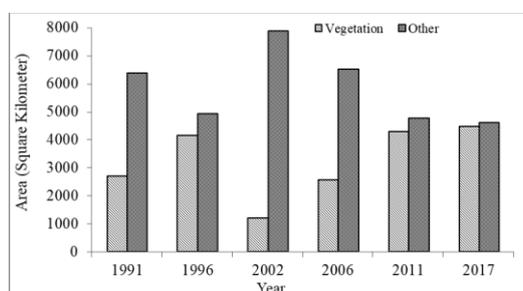


Figure 4. Surface covered by vegetation and other type area of features according to NDVI.

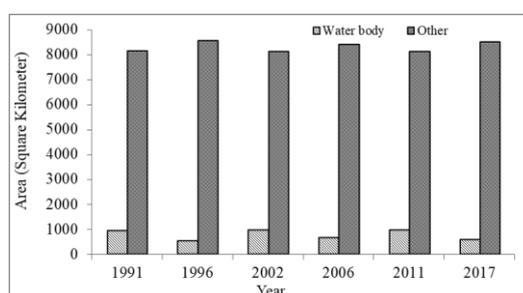


Figure 5. Surface covered by water-body and other type area of features according to NDWI.

The Figure 6 shows the surface covered by build-up and barren area and other type area of features according to NDBI. Index like NDBI highlights both urban and barren land area at a same time. Figure 6

illustrations that from 1991 to 1996 especially barren area (because urban area always increasing) slightly replaced by different features like water body or vegetation. In 2002 barren area regain the same area as 1991. Then the barren area is shrunk gradually in between 2006 and 2011. But in 2017, barren area is dramatically reduced and covered by other type of coverings like water body or vegetation. In the current situation, developed urban area is not reduced, which means the barren area is replaced.

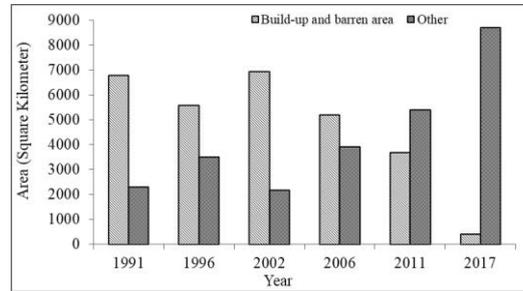


Figure 6. Surface covered by build-up and barren area and other type area (water body or vegetation) of features according to NDBI.

The comparison of figure 4 to 6 are discussed critically in the forwards line. From Figure 5 it is observed that water body is not increased remarkably from 1991 to 2017. But, it is observed from Figure 4 that vegetation cover is increased at a significant amount. Whatever during 2002, vegetation cover is reduced significantly. The possible reason may be excess drought condition, when small plants are less likely to survive. So from the above discussion it is clear that reduced barren area is replaced by mainly vegetation cover. Obviously some of the barren area is replaced by urban area. In NDBI analysis barren area cannot be separated from urban area. So amount of area of barren land is replaced by urban region, cannot be defined here. But from Figure 6 we can say that, rest of the amount of build-up urban area and barren land covers during 2017 is mainly urban region, because in this domain developed urban area is not abandoned.

The satellite images showing the chronological conversion of barren area to vegetation covered area for different years has been given away in Figure 7.



Figure 7. Satellite images showing the chronological conversion of barren area to vegetation covered area for different years.

From these figure (yearly images) the rapid increment of urban area is observed nevertheless vegetation covered area dominates the urban area increment. From this RGB true color image it is also found that, during 1991 near the bank of the rivers and canals dense vegetation is being found. Also greenness of this vegetation represents healthy state, which brings high NDVI value, represented in Figure 8. Except bank area other portion of the land area represents barren area visibly. This barren area is gradually replaced by land cover of more greenness in the year 2017, which represents vegetation. Presently barren area is occupied by mostly crop field all through the year due to advanced and efficient irrigation system.

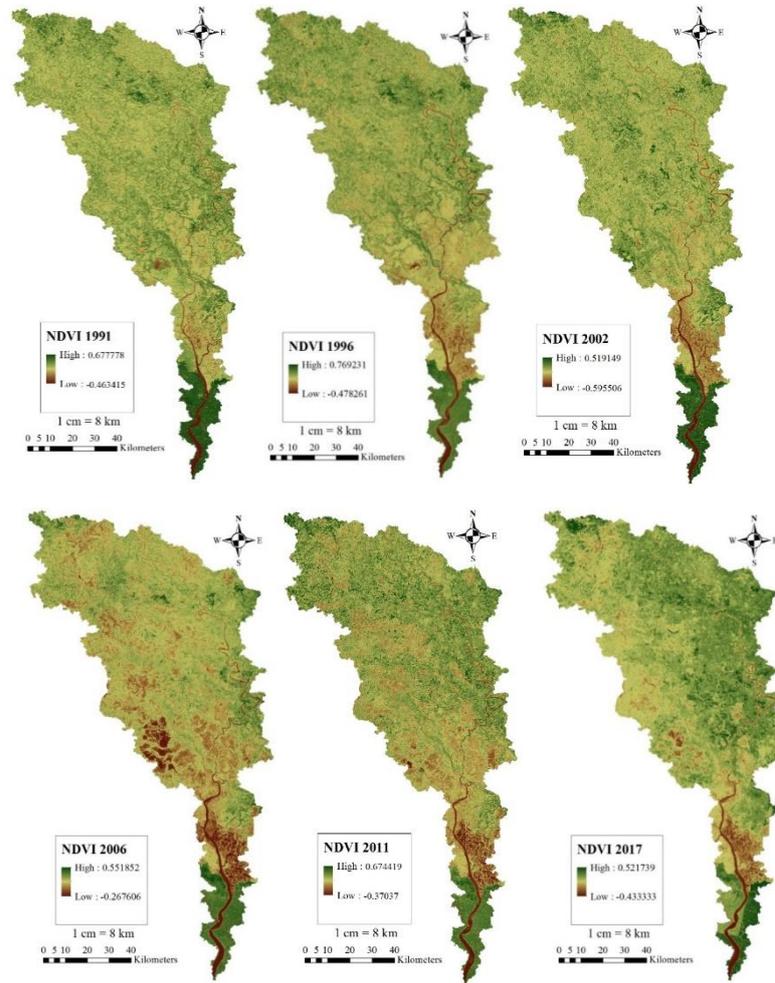


Figure 8. Highest, lowest value of NDVI and spatial coverage of vegetation during 1996, 2006 and 2017

Table 2: Summary of NDVI values from Figure 8 for different years

Year	1991	1996	2002	2006	2011	2017
Highest	0.68	0.77	0.52	0.55	0.67	0.52
Lowest	-0.46	-0.48	-0.6	-0.27	-0.37	-0.43

Figure 8 shows the NDVI ranges in the year 1991, 1996, 2002, 2006, 2011 and 2017 with spatial distribution of vegetation cover. Here vegetation cover (green color) of 2017 shows maximum coverage than other years. But 1996 shows the highest NDVI value is 0.77, second highest 0.68 is in 1991 and 2017 has the lowest 0.52 value, similar to 2002 (table 2). NDVI value greater than 0.60 represents healthy vegetation, large tropical forest or tree and lower positive value means small bush or unhealthy vegetation. Figure 7 shows that open barren area of year 1991 and 1996 along the river and canal bank is reduced by crop field in 2017. This is why vegetation cover in 2017 is higher than 1991 and 1996 but NDVI value is lowest than other years (except 2002). Main cause of NDVI value drop in 2017 may be gradual increment

of salinity in the southern part of Bangladesh and the study period is a dry season, which triggers the unhealthy condition of vegetation.

Figure 9 shows the spatial distribution of water body and range of NDWI in year 1991, 1996, 2002, 2006, 2011 and 2017. The Table 3 shows the summary of NDWI values from figure 9 for different years. NDWI value larger than 0.50 denotes the water body. Here every highest value of all these years is greater than 0.50.

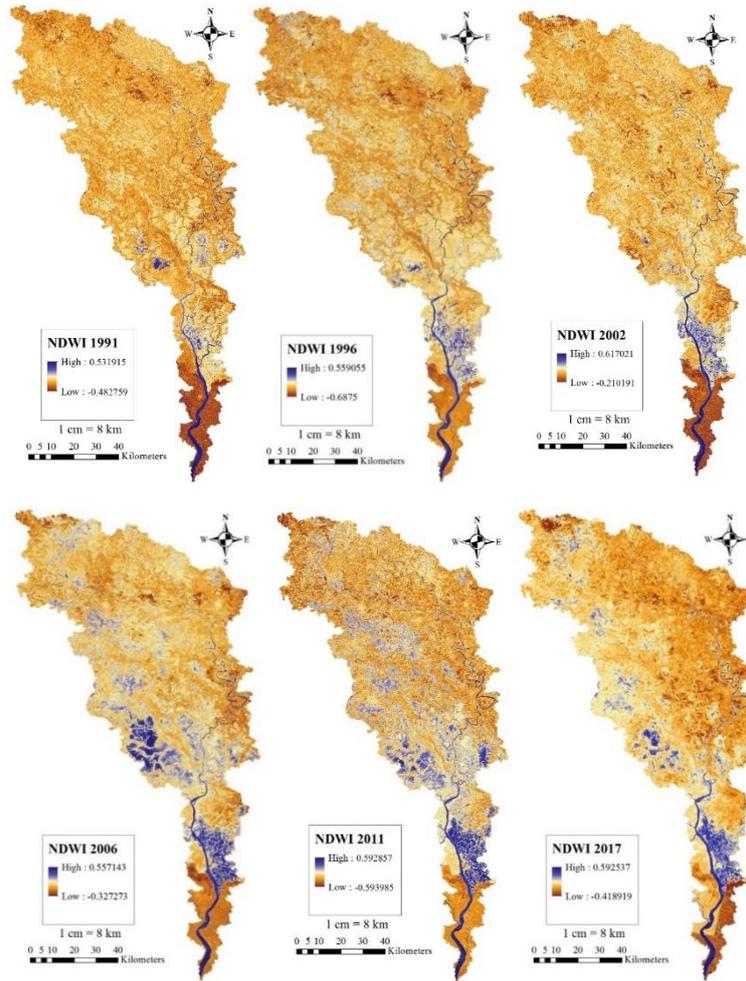


Figure 9. Highest, lowest value of NDWI and spatial coverage of water body during 1996, 2006 and 2017

Table 3: Summary of NDWI values from Figure 9 for different years

Year	1991	1996	2002	2006	2011	2017
Highest	0.53	0.56	0.62	0.56	0.59	0.59
Lowest	-0.48	-0.69	-0.21	-0.33	-0.59	-0.42

Figure 10 shows the build-up and barren areas, as well as the other vegetation and water body type coverage. Result observed from Figure 6 is clearly visualized spatially in Figure 10. Here year 1991 and 2002 show almost same result but year 2017 shows something different. If Figure 10 is compared with Figure 8 and 9, then it is clear that the black colored area in Figure 10 actually vegetation and water body covered area. So, in the previous study years most of the area is covered with barren and build-up urban region but in 2017 most of the barren area is replaced by vegetation. Only south-western corner shows the build-up and barren area mainly. It is pretty sure, that zone is mainly build-up urban region because Khulna city and Mongla Port are situated in this region along the Rupsha and Passur riverbank.

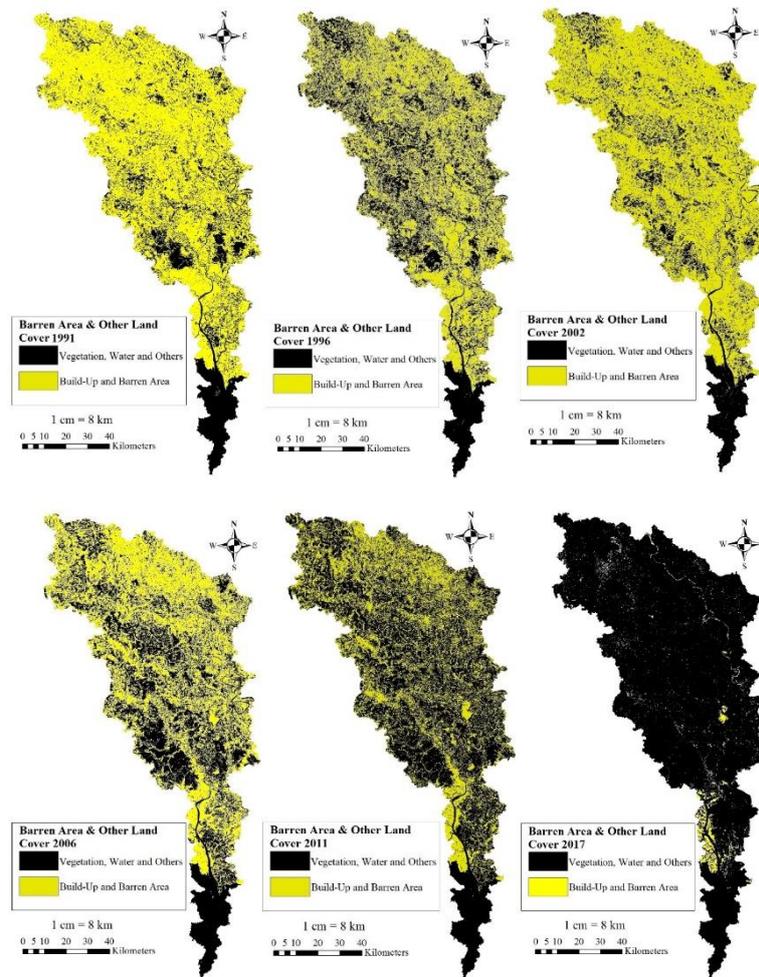


Figure 10. Spatial distribution of build-up and barren areas and other type area (vegetation, water) of coverage during year 1996, 2006 and 2017.

The vegetation covers the barren area in 2017 is mainly crop field, which is clearly understood from the highest value of NDVI at Figure 8, in 2017. Some portion of the dense mangrove forest (Sundriban) is also situated in the southern side of the study area, which should bring higher NDVI value in 2017. But due to drought condition of the middle of February and probably the salinity, causes water stresses in the mangrove forest, which triggers low NDVI value in 2017.

From all the discussions above, the reasons of LST drop in 2017 can clearly be understood. From Figure 2 and 3, it is observed that highest LST in year 1991, 1996, 2002, and 2006 is near to each other and lowest LST ranges from 21.8407 °C to 28.6382 °C. But in 2017 both highest and lowest LST drop, as compared with 1991, 1996, 2002 and 2006. From above NDVI, NDWI and NDBI study, it is observed that NDWI has no significant effect on LST change. Because in Figure 9, highest values of NDWI in the study years are almost same to each other and every time these are greater than 0.5, means water body. Figure 5 shows the area of water body in 2006 is almost double in amount than 1996 and 2017 and this area during 2017, slightly increases than 1996. But LST of 2006 is almost same to 1996 and significantly higher than 2017. So neither LST of 2017, nor 1996 is related with LST of 2006, in the point of view of NDWI. The dominating factor controlling LST is NDVI, which is observed in previous discussion. From Figure 4 it is observed that vegetation cover is maximum in year 2017, whatever most of the vegetation includes grassland and crop field. Figure 6 shows the reduced condition of barren and urban area, which

is actually replaced by crop or grassland that is already mentioned before. Again Figure 7 and Figure 10 shows the present condition of the barren land area.

At present urban area is increasing gradually. In this study area, urban region is very small in size. Most of the area belongs to barren area, crop field, bushes, marsh land, and water body and mangrove forests. Barren area without any covering like vegetation, acts like desert. In a desert area temperature variation is observed in a massive amount. In desert, temperature rises at a maximum level during day light and at night it drops in a minimum level and maximum variation of day and night time temperature is being observed. This study shows that, when maximum area is covered by barren land during 1991, 1996, 2002 and 2006, then LST is also maximum. Figure 6 and 10 show the same result and spatial distribution of barren and urban area during year first four study years and in this two year value of LSTs also same. And in year 2017 most of the barren land is covered by small vegetation and also LST drops, it means vegetation plays an important role for dropping LST in the study area. Recent years, cultivation in land property increases significantly. At the very past time generally rice produced once in crop field which was increased two times a year. Now a days extended use of fertilizer and irrigation increases the production of a land area. Which means, in Bangladesh some of the land area produces crops three times a year, even in dry season with the help of irrigation. Hence vegetation covering is the key factor (converting barren land area to a crop land in 2017), which is mainly responsible for controlling LST in the study area.

4.0 CONCLUSION

From all above discussion it is not very difficult to understand that uncovered bare soil and urbanized zone exchange more heat than other covered soil surface or water body. But the key factor that controls over heating of earth surface is vegetation. Vast water body may keep surrounding more comfortable but vegetation keeps soil temperature more suitable. Hence in urban area more open space should be provided where more trees must be planted. Even if it is not possible to plant trees but bush type land covering may provide more resistance against soil heat increment. Hence in uncovered barren area along with urban area more vegetation covered zone should be provided which is the key factor of controlling land surface temperature (LST).

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