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SPATIO-TEMPORAL ASSESSMENT OF THE IMPACT OF LAND COVER CHANGE IN THE NORTH-WEST REGION OF BANGLADESH

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ABSTRACT

Temperature is one of the most important climatic parameters and it is highly influenced by vegetation coverage of any region. Bangladesh is located at the lowermost reaches of the three mighty rivers, the Ganges, the Brahmaputra and the Meghna. The physiology and geography of the north-west region of Bangladesh is much more critical compare to others. This region mainly consists of Barind tract, Diara, agricultural lands and chars etc. During summer this region experiences scorching heat and people suffer from extreme events due to water scarcity. On the other hand, this region experiences very cold winter. In Bangladesh, the weather data is absolutely localized and based on recorded data of particular weather stations of particular time period, which very often prove to be insufficient in the case of analyzing several natural events. Hence, the requirement of an integrated system or approach is eminent that will enable the analyzing and assessment of monitoring land cover along with temperature both spatially and temporally. In this study surface temperature and land cover have been observed using remote sensing technology. Landsat 5 TM data of different years namely 2008, 2010 and 2011 have been utilized. After various pre-processing e.g. band compositing, radiometric corrections etc. Normalized Difference of Vegetation Index (NDVI) and land surface temperature (LST) has been calculated and the respective maps are created. It has been found that the temperature is comparatively low in vegetation area and high in non-vegetation area. Finally relation between LST and NDVI has been established by monitoring several random points and in this study they are found to be negatively correlated.

Keywords: *Remote sensing, Landsat, Normalized Difference of Vegetation Index (NDVI), Land surface temperature (LST), Geographical Information System*

1. INTRODUCTION

Bangladesh, a low-lying deltaic country with an area of 147,470 square kilometres, has been remarked as one of the most vulnerable countries of the world in phrases of natural and anthropogenic hazards. The physical geography of Bangladesh can be categorised by two distinctive features: a broad deltaic plain subject to frequent flooding, and a small hilly region crossed by swiftly flowing rivers (Geography of Bangladesh, 2017), which has made the country vulnerable to different geo and hydro-metrological hazards. In addition, increased temperature and variations in rainfall are the governing elements of climate change that is affecting the lives and livelihoods of Bangladeshi people.

Land coverage pattern and its associated change have a great significance on the surface temperature. Living in a threatening era of global warming, it has become increasingly important to understand the relationship between land cover patterns of a region with the corresponding spatial and temporal temperature distribution. This knowledge is important not only to learn its impacts on environmental issues but also on human health (Stone & Rodgers, 2001). Energy consumption, increment in land coverage with high heat radiated artifical materials, fall in vegetation and water pervious surface which helps to reduce surface temperature through evapotranspiration etc are some examples of anthropogenic heat emission (Kumar et al., 2012) and are the major reasons behind the increment in surface temperature.

Although there are 34 weather stations in Bangladesh, sometimes adequate data with required interval is not available. Due to lack of adequate data and integrated approaches in Bangladesh, monitoring and evaluating climatic events which includes their origin, pattern, characteristics and corresponding impacts, often become difficult. Hence more studies and new integrated approaches are needed to be introduced in this sector.

In 1979, Normalized Difference Vegetation Index (NDVI) is first proposed by Tucker as an index of vegetation health and density. Weng et al. (2004) observed that the vegetation cover has a slightly stronger negative correlation with land surface temperature (LST). Joshi and Bhatt (2012) stated that the built-up areas have higher temperature as compared to the areas with vegetation and water body. On the other hand, Gorgani et al. (2013) tried to correlate NDVI and LST by utilizing Landsat 5 TM and Landsat 7 ETM+ satellites image and found that they have strong negative correlation.

In this research, with the help of geospatial technologies, Normalized Difference Vegetation Index (NDVI) has been monitored with respect to land surface temperature (LST). The specific objectives of this study are to:

a) Generation of NDVI and LST maps.
b) Assess relation between LST with NDVI
c) Monitor land cover change with respect to spatio-temporal land surface temperature distribution.

2. STUDY AREA

In this research a total area of 16,446 square kilometres is covered by the study area. It has fallen under Rajshahi division and its geographic location is 24º 33' North latitudes and 89º 10' East longitudes. Seven north-western districts namely; Bogra, Joypurhat, Naogaon, Natore, Pabna, Rajshahi and Sirajgan is covered by the study area. The climate of this region is generally marked with high temperature, considerable humidity and moderate rainfall. The hot season commences early in March and continues till the middle of July. The average annual temperature is 25.8°C and annual rainfall is 1419 mm of this region (Climate-data.org, n.d.). Common natural events are drought, flash flood, tornado etc (C. Change & Perspectives, 2016) and people of this region mostly suffer due to insufficiency of water in summer.

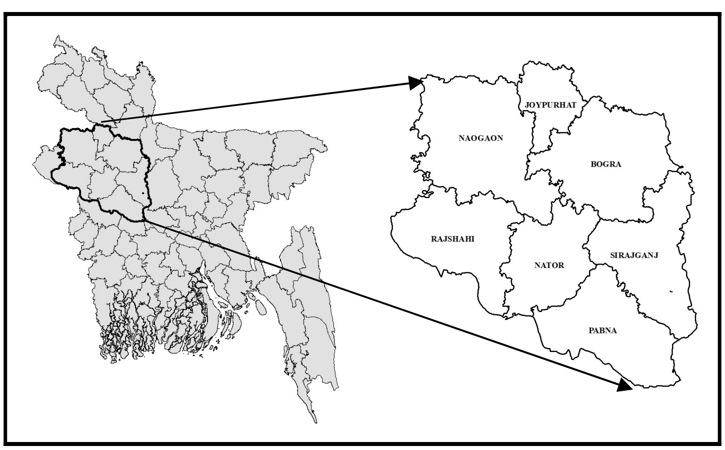

Figure 1: Study Area

3. METHODOLOGY

3.1 Data Collection and Pre-processing

Three years' time series data namely 2008, 2010 and 2011 of Landsat TM with path/row of 138/43 has been downloaded from the US Geological Survey (USGS) Global Visualization Viewer. These data are Level 1 Terrain Corrected (L1T) product. Table 1 represents some of the most useful technical specifications of the downloaded images.

In the part of image pre-processing, each band (except band 6) of every image, has gone through two steps of the radiometric correction using the following equations (I. Change & Maine, 2012). Values of different parameters of the equations can be found from the metadata files (MTL files), which is available for each band for each Landsat scene.

(a) Conversion of digital number to radiance:

$$L_\lambda = ((LMAX_\lambda – LMIN_\lambda)/ (QCALMAX\text{-}QCALMIN))*((Band\ Layer\text{-}(QCALMIN))+LMIN_\lambda)$$

where, L_λ = Spectral radiance, $L_{\lambda max}$ and $L_{\lambda min}$ = highest and lowest possible values of radiance, $QCAL_{max}$ and $QCAL_{min}$ = calibrated maximum and minimum cell values.

(b) Conversion of radiance to reflectance:

$$\rho_\lambda = (\pi * L_\lambda * d^2) / (ESUN_\lambda * \cos \theta_s)$$

where, ρ_λ= Top of atmosphere (TOA) reflectance of each pixel, L_λ = spectral radiance at the sensor aperture, d = distance from the earth to the sun in astronomical unit, $ESUN_\lambda$= mean solar exoatmospheric irradiance, θ = angle between the sun and the satellite.

Table 1: Specification of Landsat TM Images

`	Satellite	Path/Row	Julian Day of Acquired Image	Wavelength (micrometer)
2008	Landsat-5 TM	138/43	336	Band 1: 0.45-0.52 Band 2: 0.52-0.60
2010			309	Band 3: 0.63-0.69 Band 4: 0.76-0.90 Band 5: 1.55-1.75
2011			312	Band 6: 10.4-12.5 Band 7: 2.08-2.35

After radiometric corrections, the study area is clipped (Graham, 2010) using the corresponding shapefile. For each year, band-wise clipping is done in this step.

3.2 Normalized Difference Vegetation Index (NDVI)

Normalized Difference Vegetation Index (NDVI) is called a measure of greenness or vegetation. When sunlight falls on a plant, most of the red wavelengths in the visible portion of the spectrum (400-700 nm) are absorbed by chlorophyll in the leaves, whereas the cell structure of leaves reflects the majority of NIR radiation (700-1100 nm) (Babu et al., 2016). NDVI is a satellite data driven index that measures chlorophyll absorption in the red portion of the spectrum relative to reflectance or radiance in the near infrared. So, NDVI is based on Landsat (TM) band 2 (Red) and band 4 (Near-Infrared) and it is calculated by using the following equation.

$$NDVI = (NIR−RED)/(NIR+RED)$$

NDVI varies from +1 to -1. The negative values of NDVI generally represent free standing water and values of 0.1 and below stand for barren areas of rock, sand or snow. Moderate values of (0.2-0.3) correspond to shrub and grass lands. High values between (0.6 – 0.8) indicate temperate and tropical rainforests (Seminar, n.d.). In this study, after calculating NDVI, it has been reclassified into five classes according to table 2.

Table 2: Reclassification Schemes for NDVI

Class	Pixel Value
Water	<0
Barren Area	(0 - .1)
Soil	(.1 - .2)
Shrub & Grassland	(.2 - .3)
Dense Vegetation Canopy	(.3 - .8)

3.3 Land Surface Temperature (LST)

Land surface temperature is associated with thermal band of any Landsat image. To analyse the surface temperature variations, band 6 (thermal band) of Landsat TM image, has been processed using the following stepwise formulas:

Step 1. Conversion of the Digital Number to Spectral Radiance (L_λ):

$$L_\lambda = ((LMAX_\lambda - LMIN_\lambda)/ (QCALMAX\text{-}QCALMIN) *((Thermal\ Band\text{-}(QCALMIN))+LMIN_\lambda)$$

where, L_λ = Spectral radiance, $L_{\lambda max}$ and $L_{\lambda min}$ = highest and lowest possible values of radiance, QCALmax and QCALmin = calibrated maximum and minimum cell values.

Step 2. Conversion of Spectral Radiance to Temperature in Kelvin:

$$Tb = K_2 / ln ((K_1/L_\lambda) + 1)$$

where, K_1, K_2 = Calibration Constant 1 and Constant 2 and their values are 607.76 and 1260.56 respectively for Landsat 5 TM, Tb = Surface Temperature.

Step 3. Conversion of Kelvin to Celsius:

$$Tb = Tb - 273$$

After calculating LST respective maps with suitable colour combination have been produced for observation purpose.

3.4 Correlation between NDVI and LST

In order to find the relation between NDVI and LST, 100 random points (Roni, 2013) have been generated using the study area shapefile. After that, from both NDVI and LST, values of each point have been extracted. Finally, these values are plotted against each other and the correlation coefficient has been calculated.

4. RESULTS AND DISCUSSION

As discussed earlier after calculating NDVI, it has been reclassified into five classes. All output maps both of NDVI and LST have been shown in above figure 2. If we compare the maps, it can be seen that the temperature is comparatively low in water and vegetation areas where temperature is comparatively higher in soil and barren i.e. built-up areas. In this study, it has been found that from 2008 to 2011, surface temperature is increased by 6.55°C.

The correlation factors for LST-NDVI that have been calculated using 100 random points for each year, were found -0.221, -0.201 and -0.218 for the year 2008, 2010 and 2011 respectively. From all three factors it can be seen that LST and NDVI are negatively correlated. The scatter plot shows the correlation between LST-NDVI in figure 3.

In this study, it has been found that NDVI is negatively correlated with surface temperature which means areas with least vegetation are going through higher land surface temperature. Hence, surface temperature increases with increased built-up intensity and decreases with increased greenness and moisture intensity. Again, surface temperature is increasing day by day and it is highly influenced by land coverage and its corresponding change.

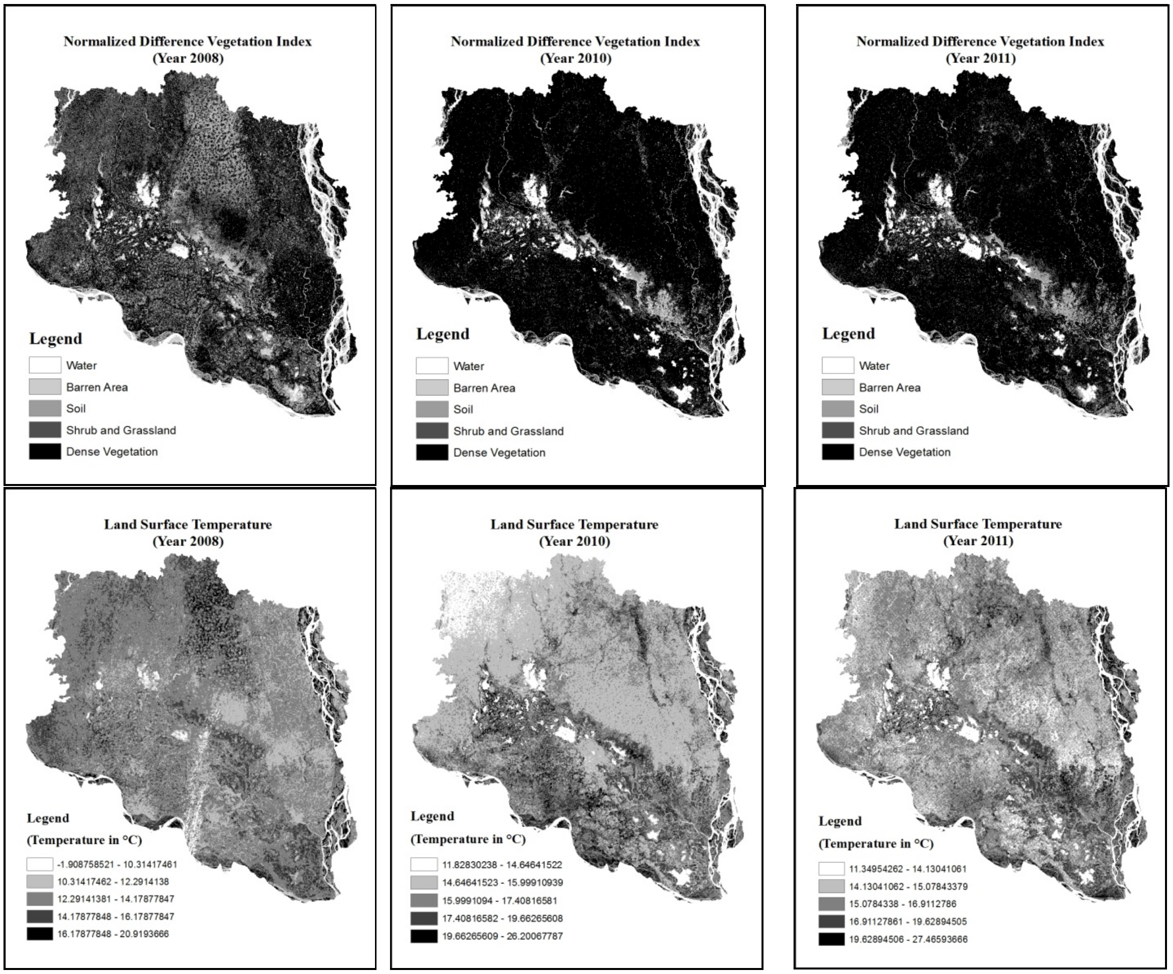

Figure 2: Output maps of both NDVI and LST

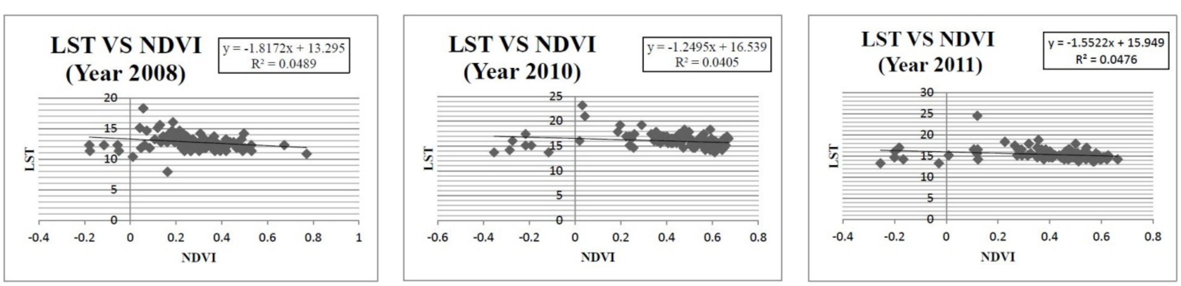

Figure 3: Scatter Plots

In this research, due to unavailability of the summer season's cloud free image, winter season's images were used. It can be a reason of lower valued correlation factors that have been found in this study. Again, due to budget limitation, ground truthing and collection of high resolution satellite images was not possible. That's why; all analyses are done using low resolution of freely available Landsat image.

5. CONCLUSIONS

This research was an attempt of mapping and monitoring land cover change with respect to spatio-temporal land surface temperature for the north-western region of Bangladesh. In spite of having some deficiencies as discussed earlier, the methodology of this study can be considered as an effective one in the sector of observing climatic issues.

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