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STUDY OF LAND SURFACE TEMPERATURE CHANGES IN SELECTED DRAINAGE BASIN OF ATAI-BHAIRAB-RUPSHA RIVER BASED ON NDVI AND NDWI ANALYSIS

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ABSTRACT

Land Surface Temperature (LST) is one of the key parameters in the physics of land surface processes from local through global scales. It has a great influence on life cycle of plants and living organisms which play an important role to keep environment livable. One should be careful about the changes of LST and regular observation is necessary. LST largely depends on vegetation, especially healthy vegetation and water body. In this study, satellite image analysis technique has been demonstrated to understand the LST changes in 20 years time span. The study area is 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. Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI) analyses are used to observe the effect of healthy vegetation and water body on LST. NDVI, NDWI and LST maps have been created for the year 1995, 2006 and 2015 at end of the dry season in mid-February, when there is no influence of rainfall effect on vegetation, water body and soil surface temperature. From the analysis, it is found that the highest and lowest values of NDVI are 0.96 and -0.94 respectively in the year 1995, which means the study area was covered by both healthy vegetation and bare soil. As well the highest and lowest values of NDWI ranges from 0.93 and -0.94 respectively which represent both for effective water body, marsh and bare soil area. At that time period the highest and lowest values of LST are observed 36.48^{0}C and 15.96^{0}C respectively. It is observed during the year 2006 that the difference of the highest and lowest values of NDVI and NDWI decreases considerably, which indicates healthy vegetation was significantly replaced by shrub and grassland, means destruction of healthy vegetation and water body. During the year 2015, the changes of the difference between highest and lowest values of NDVI and NDWI are quite same as compared to 2006.

Keywords: *NDVI, NDWI, LST, water body, vegetation*

1. INTRODUCTION

Urbanization and transformation of the earth surface to urban application illustrate huge changes in global usage of the land and provide considerable influence on the environment (Weng & Yang, 2004). The population in global urban areas has risen quickly from 13% in 1900 up to 46% in 2000, and it is believed that it can go up to 69% by 2050. The influence of climate change is foreseeable in the shape of altering weather patterns and extreme weather events, like heavy rainfall, flood, windstorm, heat waves and windstorms (IPCC 2007). One of the main reasons for his type extreme weather condition occurring so frequently is global warming. Rapid urbanization, deforestation, filling up water body is some of the causes of global warming. Land Surface Temperature (LST) is a popular indicator of global warming, which is largely depends on vegetation, amount of water body and mostly urbanization. The Land Surface Temperature (LST) is the radiative skin temperature of the land surface, as measured in the direction of the remote sensor. It is estimated from Top-of-Atmosphere brightness temperatures from the infrared spectral channels of a constellation of geostationary satellites. Its estimation further depends on the albedo, the vegetation cover and the soil moisture. LST is a mixture of vegetation and bare soil temperatures.

The Multi Spectral Remote Sensing images are very efficient for obtaining a better understanding of the earth environment (Ahmadi & Nusrath, 2010). It is the Science and Art of acquiring information and extracting the features in form of Spectral, Spatial and Temporal about some objects, area or phenomenon, such as vegetation, land cover classification, urban area, agriculture land and water resources without coming into physical contact of these objects (Karaburun, 2010). 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. As a plant canopy changes from early spring growth to late-season maturity and senescence, these reflectance properties also change. 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. A vegetation index is an indicator that describes the greenness, the relative density and health of vegetation, for each picture element, or pixel, in a satellite image. 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).

Drought 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 (Zhang & Huai-Liang 2016).Plants experience water stress either when the water supply to their roots becomes limiting or when the transpiration rate becomes intense. Water stress is primarily caused by the water deficit, i.e. drought or high soil salinity (Lisar et al. 2012). 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. It is real-time retrieval of soil moisture, which has high retrieval accuracy (Gao, 1995).

Is this study, we have figured out some relation among LST, NDVI and NDWI, where NDVI is an indicator of vegetation presence and NDWI mainly stands for a very good proxy for plant water stress which mainly denotes availability of water sources, for instance water body and soil moisture.

2. STUDY AREA

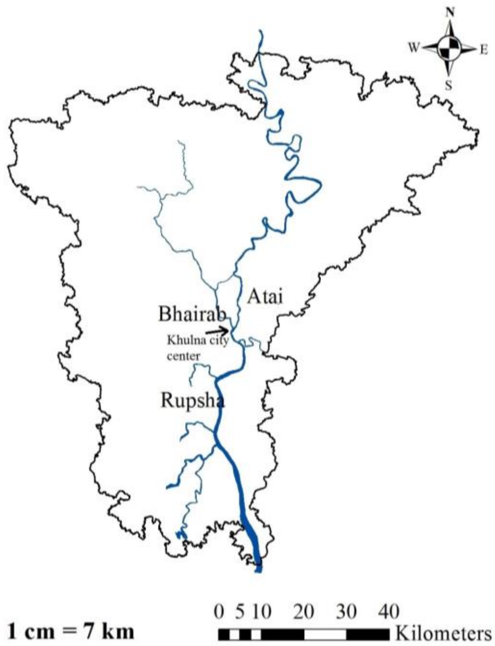

Figure 1: Atai-Bhairab-Rupsha drainage basin

The study area is 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 (Figure 1). The study area covers mainly Khulna district and some portion of Barisal division. Mainly the center of the Khulna city is situated at the confluence area.

3. RESOURCES AND TECHNIQUES

In this study for image analysis, different tools from ArcMap, which is the central application of ArcGIS software have been used. The version of this software is ArcGIS 10.4.1. Total 20 years' time span is considered for study. Satellite images of the years 1995, 2006 and 2015 are downloaded from the website https://glovis.usgs.gov/. Landsat-5 TM images for years 1995, 2006 and Landsat-8 OLI/TIRS images for year 2015 of UTM zone 46 are downloaded. Landsat-7 ETM+ images are not considered because on May 31, 2003 the Scan Line Corrector (SLC) in the ETM+ instrument failed, so the image data type is erroneous. Whereas there are some techniques to improve the quality of the image, but here completely error free space born images are consider. SRTM 1 Arc-Second Global DEM is downloaded from the website https://earthexplorer.usgs.gov/ to select the drainage basin.

3.1 Calculation of NDVI and NDWI

Governing equations for analyzing the space-born data are given below. NDVI and NDWI is calculated from the following equations

$$NDVI = \frac{NIR - VISR}{NIR + VISR} \tag{1}$$

$$NDWI = \frac{VISG - NIR}{VISG + NIR} \tag{2}$$

Where,
$NDVI =$ Normalized Difference Vegetation Index
$NDWI =$ Normalized difference water index
$NIR =$ Spectral reflectance measurements acquired in the near infra-red regions
$VISR =$ Spectral reflectance measurements acquired in the visible red regions
$VISG =$ Spectral reflectance measurements acquired in the visible green regions
Here, in case of Landsat-5 TM Band 2, Band 3, Band 4 stand for visible green regions, visible red regions, near infra-red regions respectively and in case of Landsat-8 OLI/TIRS Band 3, Band 4, Band 5 stand for visible green regions, visible red regions, near infra-red regions respectively.

3.2 Calculation of LST

Conversion of digital number to radiance can be performed by the equation given below. For Landsat-5 TM, during 1G-product rendering, image pixels are converted to units of absolute radiance using 32 bit floating-point calculations. Pixel value are then scaled to byte values prior to media output. The following equation (Landsat 7) is used to convert DN's in a 1G product back to radiance units

$$L_\lambda = \left(\frac{LMAX_\lambda - LMIN_\lambda}{QCALMAX - QCALMIN} \right) * \left(QCAL - QCALMIN \right) + LMIN_\lambda \tag{3}$$

Where,
$L_\lambda =$ Spectral Radiance in watts/ (m^2*ster*μm)

$QCAL =$ The quantized calibrated pixel value in DN
$LMIN_\lambda =$ The spectral radiance that is scaled to $QCALMIN$ in watts/ (meter squared*ster*µm)
$LMAX_\lambda =$ The spectral radiance that is scaled to $QCALMAX$ in watts/ (meter squared*ster*µm)
$QCALMIN =$ The minimum quantized calibrated pixel value (corresponding to $LMIN_\lambda$) in DN
$QCALMAX =$ The maximum quantized calibrated pixel value (corresponding to $LMAX_\lambda$) in DN

For Landsat-8 OLI/TIRS, images are processed in units of absolute radiance using 32-bit floating-point calculation. These values are then converted to 16-bit integer values in the finished Level 1 product. These values are converted to spectral radiance using the radiance scaling factors provided in the metadata file by using the following equation (Landsat 8)

$$L_\lambda = M_L Q_{cal} + A_L \qquad (4)$$

Where,
$L_\lambda =$ Spectral Radiance in watts/ (m^2*ster*µm)
$M_L =$ Radiance multiplicative scaling factor for the band (from metadata)
$A_L =$ Radiance additive scaling factor for the band (from metadata)
$Q_{cal} =$ Level 1 pixel value in DN

Radiance is converted to satellite temperature by following equation

$$T = K2 / \ln\left((K1 / L_\lambda) + 1\right) \qquad (5)$$

$T =$ TOA Brightness Temperature (K)
$K2 =$ Calibration constant 2 (1260.56 K) for Landsat-5 TM
=Thermal conversion constant for the band (K2_CONSTANT_BAND_n from metadata) For Landsat-8 OLI/TIRS
$K1 =$ Calibration constant 1 (607.76 watts/ (m^2*ster*µm))
= Thermal conversion constant for the band (K1_CONSTANT_BAND_n from metadata) For Landsat-8 OLI/TIRS

Proportion of vegetation is determined by following equation

$$P_v = \left(\frac{NDVI - NDVI_{MIN}}{NDVI_{MAX} - NDVI_{MIN}} \right)^2 \qquad (6)$$

Where,
$P_v =$ Proportion of vegetation

Land surface emissivity is determined by following equation

$$e = 0.004 P_v + 0.986 \qquad (7)$$

Where,
$e =$ Land surface emissivity

Land surface temperature is determined by following equation

$$LST = T / (1 + (wT / p) \times \ln(\mathrm{e})) \qquad (8)$$

Where,
$LST =$ Land Surface Temperature (K)
$w =$ Wavelength of emitted radiance (μm)
$p = hc/s = 1.438 \times 10^{-2}$ (mK)
$h =$ Panck's constant (6.626×10^{-34} Js)
$s =$ Boltzmann constant (1.38×10^{-23} J/K)
$c =$ Velocity of light (2.998×10^{-8} m/s)

Landsat-5 TM has only one thermal band (Band 6), whereas Landsat-8 OLI/TIRS has two thermal bands (Band 10 and Band 11). So in case of Landsat-8 OLI/TIRS, LST is calculated individually both for Band 10 and Band 11 and then average is calculated. These values are calculated in Kelvin scale which is finally converted to Degree Celsius scale by the following equation

$$LST(^0C) = LST(K) - 273.15 \tag{9}$$

4. RESULTS AND DISCUSSION

The values of NDVI, NDWI and LST of mid-February for the years 1995, 2006 and 2015 are shown in the Figure 2. NDVI values range from +1.0 to -1.0. Values close to zero (-0.1 to 0.1) generally correspond to barren areas of rock, sand, or snow. Lastly, low, positive values represent shrub and grassland (approximately 0.2 to 0.4), high NDVI values (approximately 0.6 to 0.9) correspond to dense vegetation such as that found in temperate and tropical forests or crops at their peak growth stage. While The NDWI index is most appropriate for water body mapping. The water body has strong absorbability and low radiation in the range from visible to infrared wavelengths. The index uses the green and Near Infra-red bands of remote sensing images based on this phenomenon. The NDWI can enhance the water information effectively in most cases. It is sensitive to built-up land and often results in over-estimated water bodies. Values of water bodies are larger than 0.5. Vegetation has much smaller values, which results in distinguishing vegetation from water bodies easier. Values -1 to 0 represents Bright surface with no vegetation or water content (Uysal & Polat, 2015).

The values of NDVI, NDWI and LST of mid-February of the years 1995, 2006 and 2015 are shortened in the Table 1 from Figure 2. Data of 2006 is analysed instead of 2005, as Landsat-5 TM satellite image data of 2005 is not suitable for analysis. Because during mid-February 2005 all the images of study area are covered with cloud that brings erroneous result.

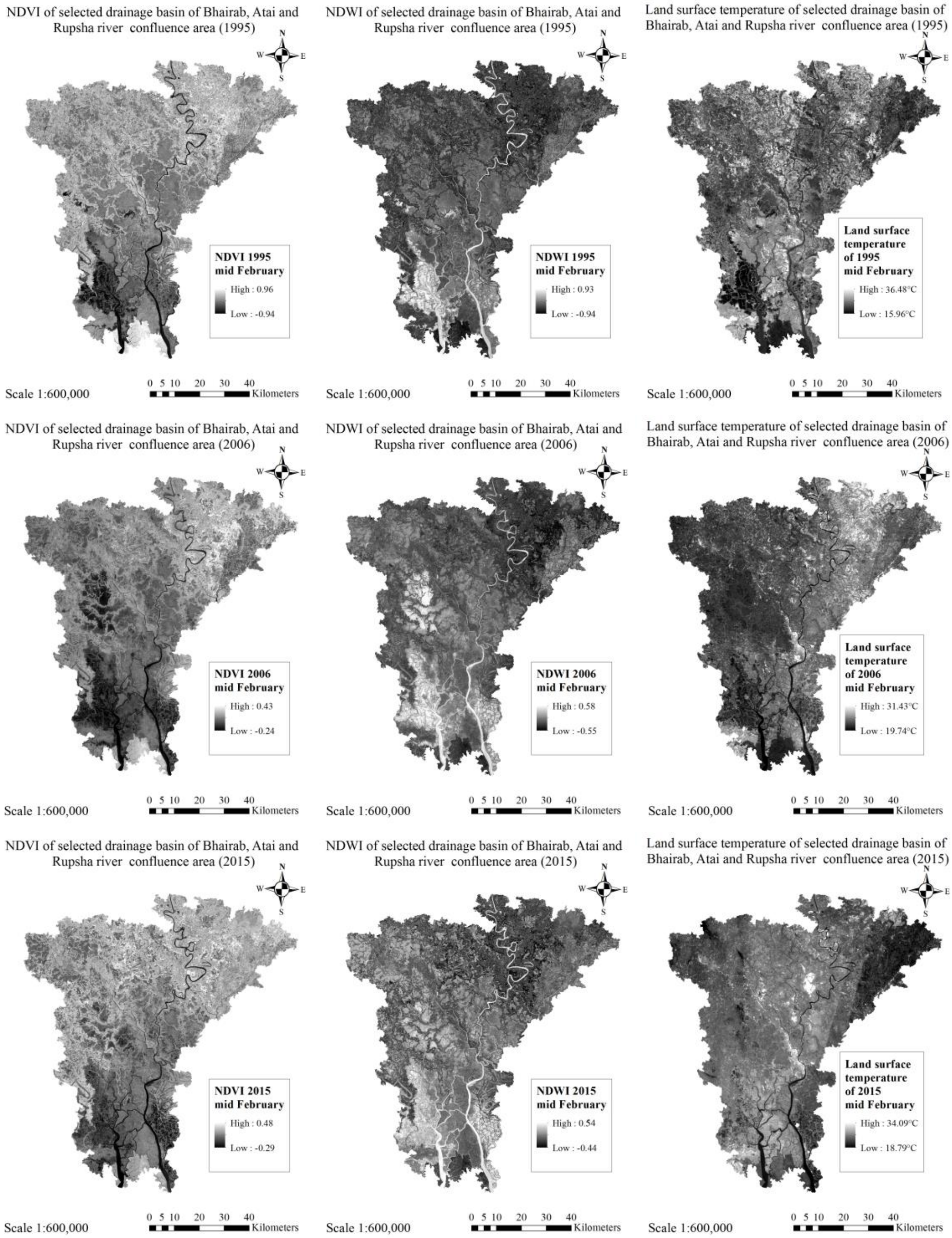

Figure 2: NDVI, NDWI and LST of years 1995, 2006 and 2015 of study area

Table 1: List of NDVI, NDWI and LST values from figure 2 for different years

Year		1995	2006	2015
NDVI	Highest	0.96	0.43	0.48
	Lowest	-0.94	-0.24	-0.29
NDWI	Highest	0.93	0.58	0.54
	Lowest	-0.94	-0.55	-0.44
LST(^{0}C)	Highest	36.48	31.43	34.09
	Lowest	15.96	19.74	18.79

It is observed from Table 1, that the highest and lowest values of NDVI are 0.96 and -0.94 respectively during mid-February 1995, which means this study area was covered by both healthy vegetation and bare soil. As well highest and lowest values of NDWI range from 0.93 and -0.94 respectively which represent both for effective water body, marsh and bare soil area. At that time highest LST was 36.48^{0}C and lowest was 15.96^{0}C. This temperature variation is possible because of areas of both dense vegetation cover, good number of water body and also bare land surface area. Because vegetation cover and water body both have a great influence to keep local weather condition in a reasonable state. Whereas empty land area without minimum vegetation cover act like desert area which is much warmer in day time and colder at night.

Also from the Table 1, it is observed detail scenario of the study area during 2006 mid-February. Both the differences of highest and lowest values of NDVI and NDWI decrease significantly. These indicate healthy vegetation was significantly replaced by shrub and grassland, means destruction of healthy vegetation and water body. The lowest values of NDVI and NDWI represent not only barren soil but some human activities like cultivation or civilization. During this time, the highest LST is 31.43^{0}C and lowest is 19.74^{0}C. It shows that highest temperature decreases and lowest temperature increases. It indicates barren soil seems like covered with minimum vegetation so desert like symptom decreases like high day time temperature. Also as healthy vegetation and water body decrease, local temperature also affected as they have high impact on local environment so lowest LST also increased.

Further it is seen from the Table 1, during mid-February 2015, the change of the difference between highest and lowest are NDVI and NDWI are quite same as compared 2006. Lowest LST was quite same as 2006, nearly 1^{0}C difference while above 2^{0}C increment is observed than 2006's highest LST. This means gradual destruction of water body and shrinkage of healthy vegetation also the barren soil, healthy vegetation and marsh area are replaced by cultivable land and urban area. The NDVI and NDWI values also represent the same scenario.

5. CONCLUSIONS

Vegetation and water body play an important role to keep local environment suitable for living. In this study, it is easily understand that during 1995 due to some barren soil area, highest temperature was greater and in 2006 and 2015 the highest temperature was lower than 1995 but lowest temperature of these two years also increased. In a comparison between the year 2006 and 2015, a sign of temperature increase is observed. This means, whatever the barren soil area is replaced by urban and cultivable area, increase of temperature is continuing in a holistic level.

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