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ORIGINAL RESEARCH PAPER

Geography

TRANSFORMING SCENARIO OF SURFACE TEMPERATURE AT AGARTALA CITY, TRIPURA USING RS AND GIS

KEY WORDS: Agartala city, NDVI, LST, Urbanization, Exposed lands

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ABSTRACT

The urban air temperature is gradually rising in all cities in the world. One of the possible causes is the drastic reduction in the greenery area in cities and is more prominent in cities which are developing as a rapid urbanizing city like Agartala, Tripura. Understanding the distribution of Land Surface Temperature (LST) and Vegetation Cover (NDVI) and its spatial variation will be helpful to depict its dynamics and mechanism for finding out solutions. For the present study Landsat imageries of different time period were obtained from USGS. The imageries were processed to prepare valuable maps in GIS environment. The results gathered from NDVI images show that there is a decreasing trend in vegetation covers over the city. The LST derived from Landsat imageries, also shows an increasing trend with spatial expansion of surface temperature. There is a clear negative relationship between LST and NDVI. It is due to continuous process of urbanization like construction of settlement, building of Government offices, wetland fillings and clearing of vegetation which ultimately exposes the vegetative cover of land to sun light. It is obvious that more exposed lands, more will be the temperature.

INTRODUCTION:

After the industrial revolution, the population started to increase in alarming rate and caused a rapid urbanization. Whilst 3% of the global population lived in urban areas in the 1800s, nowadays this ratio exceeds 50%. The tendency will likely continue in the forthcoming decades: according to some estimation (e.g. UN, 2015), the expansion of urban areas can reach 66% by the 2050s. Urbanization contributes to the change of land-use and environmental factors. The natural landscape being replaced by artificial materials generated a remarkable change in physical features: roads, pavements have lower albedo, higher volumetric heat capacity and thermal conductivity compared to the natural sites. The modification of the surface energy balance can also be observed in the urban areas. Because of the lower albedo, less incoming (shortwave) radiation is reflected from the ground, thus more heat (energy) is stored in the urban fabric (Molnar, 2016). Land Surface temperature (LST) is an indication of equilibrium thermodynamic state resulting from the energy balance of fluxes between the atmosphere, surface, and subsurface soil (Schmugge et al., 2002). LST possesses soil surface temperature, canopy, and vegetation body. Land Surface Temperature is an important parameter to determine the energy exchange between the surfaces of the earth (Shah et al., 2013; Orhan et al., 2014) and the radiant temperature that will help to understand the change of the surface temperature. Identification of changes on LST over a period of time is one of the most important environmental parameters in the study domain. The radiant temperature can be calculated and interference for the terrain condition for future perspective (Balamurugan et al., 2009). Moreover, Traffic, industry, domestic energy usage (heating, cooling, cooking etc.) induces a large quantity of anthropogenic heat (AH) emission. Emission of stored and anthropogenic heat leads to an energy surplus in the inner cities (Molnar, 2016).

The main objective of our investigation is to analyze the variability of Land Surface Temperature through spatially and temporally over the Agartala City, Tripura. To the best of the author's knowledge, there have been no similar investigations till yet at Agartala city, Tripura. Therefore, this work aims to provide a beneficial basis for further research on the study area for Government and Private sector.

Materials and Methods:

Agartala, the capital of Tripura, is located 23°45' N to 23°52' N latitudes and 91°15' E to 91°20' E longitudes. The right bank of river Haora passes the city and it's called the life of Agartala. The city is governed by Agartala Municipal Corporation (AMC) and divided into four zones namely North, East, Central and South zones (JNNURM, 2006). The total population of Agartala city in 2011 was 4, 00,004 with a density of 6831 person/sq^2.

Here, for the purpose of present study, used Landsat imagery of three different time period namely LandSat-5 TM, Landsat-7 ETM$^+$ and LandSat-8 OLI for the month of February, 2000, 2010 and 2016 has been taken to understand the temporal and spatial variability of Land Surface Temperature over the Agartala city, Tripura. The LandSat images were processed and final outcomes were done in GIS environment with the help of ArcGIS 9.3 and Erdas 9.1.

Derivation of Different Indices and Maps from imageries:

The Normalized Difference Vegetation Index (NDVI) is a measure of the amount and vigor of vegetation at the surface. The reason NDVI is related to vegetation health. To calculate NDVI, Near Infrared and Red are used. The range of NDVI value is -1 to 1. The index is defined by

$NDVI = (Band_{NIR} - Band_{IR}) / (Band_{NIR} + Band_{IR})$ Eq. 1

Accurate measurements of sub-pixel Fractional vegetation cover (FVC) can be derived from remote sensing measurements of NDVI (Source: Kaspersen et al., 2012).

$FVC = (NDVI - NDVI_{min} / NDVI_{max} - NDVI_{min})^2$ Eq. 2

$NDVI_{min}$ = Lowest value of bare soil

$NDVI_{max}$ = Highest value of Vegetative cover

Emissivity is derived from the following method (Source: Orhan and Yakar, 2016)

$P = 0.004*FVC + 0.968$ Eq. 3

Land Surface Temperature (LST):

The digital number (DN) of thermal infrared band is converted into spectral radiance (L) using the equation supplied by the Landsat user's hand book (8) (Source: Kumar et al., 2012).

$L\lambda = \{L_{MAX} - L_{MIN} / Q_{CALMAX} - Q_{CALMIN}\}*DN - 1 + L_{MIN}$ Eq. 4

L_{MAX} = the spectral radiance that is scaled to *QCALMAX* in W/(m2 * sr * µm)

L_{MIN} = the spectral radiance that is scaled to *QCALMIN* in W/(m2 * sr * µm)

Q_{CALMAX} = the maximum quantized calibrated pixel value (corresponding to L_{MAX}) in DN = 255

Q_{CALMIN} = the minimum quantized calibrated pixel value (corresponding to L_{MIN}) in DN = 1

The effective at-sensor brightness temperature (TB) also known as black body temperature is obtained from the spectral radiance using Plank's inverse function.

$T_B = K2/ \ln(1 + K1/L\ )$ (Unit: Kelvin) Eq. 5

The calibration constants *K1* and *K2* obtained from Landsat data user's manual.

Accurate measurements of sub-pixel fractional vegetation cover (FR) can be derived from remote sensing measurements of NDVI.

The final Land Surface Temperature (LST) is estimated by the following formula:
$LST = T_B / 1+(L\lambda + T_B/FVC)*\ln(P)$ (Unit: Kelvin) Eq. 6
Conversion from Kelvin to Degree Celsius
LST (^{0}C) = LST (Kelvin) – 272.15

RESULTS AND DISCUSSIONS:

Figures (1) of NDVI show a spatial distribution of vegetation cover as well as health from Landsat images. The NDVI values estimated from Landsat images of different time periods shows a decreasing trend as in 2000 the value was 0.610145 which was decreased to 0.470476 and further decreased to 0.420727. Therefore, it is seen from the images that vegetation covers are in decreasing trend and pattern is visible from NDVI images. The NDVI values not only decreased since 16 years but the spatial extent is also decreasing. It is seen from the images that lower values of NDVI indicates the built up areas with water bodies and bare soils. The pattern of NDVI images portray that except central and southern part of Agartala city, rest of the areas are having pretty much vegetation in 2000; but in 2010, the image shows the built up area is increasing towards northern, south-eastern and north-eastern part of the city due to the effect of urbanization and continuous migration. At the last, in 2016, there is a drastic change in vegetation cover as the process of urbanization is spreading almost all parts of the city and there is hardly any vegetation cover over the areas which sustain healthy environment for the human beings are living there. So according to NDVI values, spatial extent of vegetation cover at Agartala city is in danger state and clearing of vegetation is also visible from NVDI values.

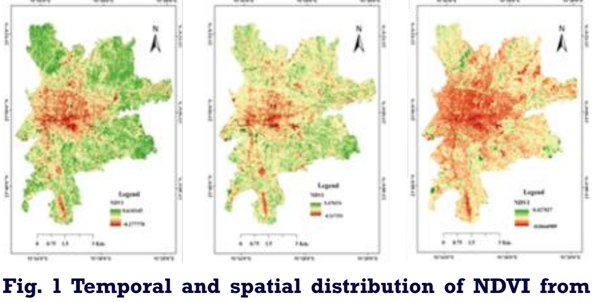

Fig. 1 Temporal and spatial distribution of NDVI from 2000 (A), 2010 (B) and 2016 (C) of Landsat images

Figure (2) of Land Surface Temperature (LST) show the spatial distribution of temperature over the Agartala city derived from Landsat images of different time periods. In 2000, the LST was rages from 30.4264 to 22.0492 0C and in 2010, LST rages from 31.6561 to 24.5674 0C and LST further increased 32.5542 to 24.6798 0C. The images portray that in 2000 LST was concentrated in few pockets of central, Northern, southern and some parts of south-eastern part. But in 2010 LST was increased and spreads from north to south with western and some parts of south-eastern direction. Again, from the image of 2016, LST further increased and this time value shows that except north-western and north-eastern part, remaining parts of the city having very high temperature which is not at all good for living environment. It is evident from the images that temporally surface temperature is increasing and even spatially too. It is due to continuous process of urbanization like construction of settlement, building of Government offices, wetland fillings and clearing of vegetation which ultimately exposes the vegetative cover of land to sun light. It is obvious that more exposed lands, more will be the temperature.

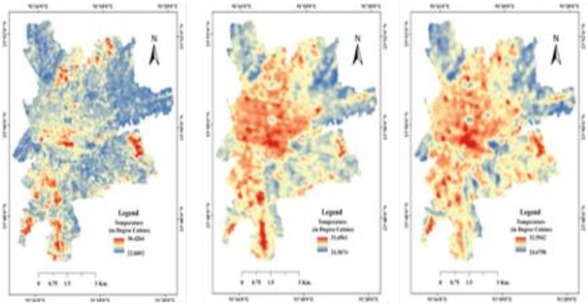

Fig. 2 Temporal and spatial distribution of Land Surface Temperature (LST) from 2000 (A), 2010 (B) and 2016 (C) of Landsat images

CONCLUSION:

Agartala is a second largest city in North-East India and only city in Tripura. It is a commercial and capital city of Tripura. With urbanization most of the land surface is covered with concrete, asphalt and other such impervious materials. This leads to increase in Land Surface Temperature (LST) and lowering of vegetation cover over the city. The city is experiencing more heat in central part than the edges. In this study an attempted is made to show the increasing trend of LST with lowering of Vegetation cover. Remote sensing has the capability of monitoring such changes, extracting the change in information from satellite data. In this work Landsat images of Agartala city was used from USGS earth explorer web site. From the LST images it is clearly understood that surface temperature is more in central part of the city than its edges. It is also clearly evident from the LST and NDVI images that LST is strongly and negatively correlated with NDVI. This information assists in monitoring the dynamics of LST and NDVI, resulting out of changing demands of increasing population and associated issues like Urban Heat Island. If the trend goes in this manner, than Agartala city will become a Urban Heat Island like Guwahati.

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