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Impact of Urban Cooling Island on Land Surface Temperature Change in Chattogram City

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Abstract

The study aims to identify the changing thermal behavior of the Chattogram City Corporation area by assessing the influence of the UCI's effect on *Land Surface Temperature* (LST). To achieve this purpose, Landsat L1TP satellite images have been geometrically and topographically corrected, and *Normalized Difference Vegetation Index* (NDVI), *Normalized Difference Water Index* (NDWI), and LST have been calculated. The study reveals the changing conditions of urban cooling islands and their relation to the spatial and temporal variation of thermal behavior within the city. As the cooling areas declined over time and the LST gradually increased, rising from a maximum of 25 degrees Celsius in 1989 to 34 degrees Celsius in 2019. The results of the study can be an effective direction for land use planning and sustainable urban development by considering UCIs to mitigate severe thermal impacts and adapt to urban microclimate change.

Keywords: Urban Cooling Island (UCI), Urban Heat Island (UHI), Land Surface Temperature, Chattogram.

Introduction

An urban cooling island (UCI) involves an area with a lower temperature than its surroundings. The UCI effect is created by the shading effects of urban trees and the evapotranspiration process of green and water spaces[1]. Both urban green spaces and water bodies play a crucial role in determining the Cooling Island effect on a city's landscape. Two major factors of Land Use Land Cover (LULC) are the composition and configuration of green spaces. Composition refers to the different types of land use and land cover, while configuration indicates the spatial arrangement and layout of green spaces. Different green space compositions and configurations can minimize the Urban Heat Island (UHI) condition by creating a cool island effect in a small area [2,3]. In addition to green spaces, the presence of water bodies can also minimize the urban heat by generating a cooling island effect. Waterbody is characterized by high thermal inertia and capacity, and low thermal conductivity and radiance. The water body absorbs a lesser amount of heat than concretized areas and stores less solar radiation [4]. Ground surface heat theory suggests that the water body corresponds to a lower temperature and controls its surrounding areas. To minimize urban heat island effects, water bodies and vegetation cover have a significant influence .

Urban vegetation has consistently demonstrated a considerable cooling effect on mitigating urban warming, from the courtyard scale to the urban scale[5]. Many previous studies have suggested that increasing vegetation area and density is an effective strategy to reduce or alleviate the effects of urban warming[6]. Vegetated space, mainly through direct shading and evapotranspiration, can reduce temperatures and form an urban cool island (UCI)[7]. Additionally, vegetated spaces transform a small part of the absorbed solar radiation by photosynthesis, instead of converting that part to heat energy. For example, the mean temperature of the urban forest was lower than the urban area, and the canopy and evapotranspiration effects of the urban forest mainly caused the temperature contrast[8]. To understand how the urban cooling island affects land surface temperature variation, the present paper aimed to find out the changing trend of the urban cooling island (UCI) and its effect on the land surface temperature variation in Chattogram city.

Population growth and rapid urbanization are continuously decreasing green spaces and water bodies by increasing impervious areas. This phenomenon can bring about exaggerated effects on the overall urban environment. Urban development brings living conveniences in terms of functional centralization; however, continual deterioration of the urban environment, such as the urban heat island (UHI) effect, can diminish urban thermal comfort [9]. Alternative to urban heat islands, the concept of urban cool island (UCL) emerged to cool down the temperature of urban areas. Urban experts believe that restoration and extension of water bodies and green spaces can provide comfortable environments and control rising urban temperatures. This is the main basis of urban cooling island effects. The UCI focuses on landscape planning through which the increasing urban temperature can be reduced and also can provide more habitable urban settings.

The urban natural setting is deteriorated by population growth. According to the United Nations, 70% of the world's population is expected to live in cities by 2050[10]. Meanwhile, the global climate has been affected, partly due to carbon dioxide's extended shelf life, and these climatic changes are anticipated to last for at least another 30 to 40 years. Furthermore, because of their specific biophysical characteristics, the consequences of climate change are anticipated to be protracted in metropolitan regions[11]. As a result, regardless of whether greenhouse gas emissions will be reduced in the future, there is a need to develop adaptive strategies to prepare the world’s expanding urban centers to diminish the worst effects of climate change[12]. Green infrastructure, such as trees, parks, forests, and green roofs, offers better thermal comfort than other urban structures[2]. This is especially true for bigger parks and urban woods, which can have daytime temperatures as low as 0.94 degrees Celsius. Aside from cooling the physical space, urban green spaces may also chill the region around them, a phenomenon known as the urban green space cooling effect. The cooling intensity and density are two important cooling benefits of urban green areas[2].

Nevertheless, due to greater evapotranspiration, aquatic areas such as streams and lakes are more efficient than green spaces in urban cooling islands. Water spaces in metropolitan settings serve as cooling islands due to the temperature differential in the surrounding environment[13]. Furthermore, larger, complicated water spaces are more efficient than small and simple ones[1]. The findings are a significant motivation for new water space construction or restoration in response to reducing land surface temperature.

Land surface temperature (LST) is defined as the surface's skin temperature, involving soil surface temperature for bare soil and canopy surface temperature for heavily planted land. LST is expressed by the temperature of the plant canopy, vegetation body, and soil surface on sparsely vegetated terrain[14]. The effective radiating temperature of the Earth's surface, which regulates surface heat and water exchange with the atmosphere, determines LST. The air temperature of the lowest levels of the urban atmosphere is modulated by LST, which fluctuates in response to the surface energy balance. The connection between the LST and the Normalized Difference Vegetation Index (NDVI) is particularly well-recorded. Remote sensing gives spatially generalized data that permits getting the LST at scales from several meters to kilometers.

Land surface temperature (LST) is usually high in densely populated areas, which is known as the heat island effect. Chattogram City is one of the second-largest cities and the commercial capital of Bangladesh. The economic opportunities attract more and more people to the city. Its population was roughly 1 million in 1975, which had grown to 5 million in 2019. The growing population and rapid unplanned urbanization are causing enormous environmental problems, including rising temperatures. Moreover, in the last several decades, the average temperature has risen by 0.471°C to 4.48°C[15]. The temperature rise was greater in the middle. BMD's yearly records the historical temperature data to assess the changing trend over the previous 70 years[16]. In Chattogram, the annual mean temperature has been determined to be on the rise. For the years 1947 to 2007, the total mean annual temperature was determined to be +0.21 degrees Celsius per decade. The average temperature in the winter is 29°C, with a low temperature of 13°C. The maximum temperatures are obtained during the pre-rainy season (summer) and the early months of the wet season. With an average temperature of 31°C, monthly average temperatures have remained high[15]. The loss of water bodies such as Chaktai Khal and Rajakhali Khal within the city exacerbates the problem[15].

Urban Cooling Islands (UCIs) can significantly lessen the intensity of heat island effects. Waterbodies and urban green areas function as cool islands by reducing the relative intensity of heat. The research aimed to identify the cooling island effects as well as their recent variation impacts on the land surface temperature of Chattogram city using satellite images and GIS, RS techniques.

Materials and Methods

Landsat satellite imagery from the United States Geological Survey (USGS) has been used in this study. Imageries of four different years were used to evaluate the normalized difference vegetation index (NDVI), the normalized difference between water index (NDWI), and land surface temperature (LST). All the images were collected in the same season to have less or no phenological variations. The winter season was chosen because of the cloud-free sky. Urbanization and other UCI-related data (such as the rate and level of urbanization, urban open spaces, water bodies, industrialization, the number of vehicles and land use) have been collected from different GOs, NGOs, and literature. Data characteristics are shown in the table (1) below-

Table 1: Data Characteristics

Data	Data Type	Sources	Collection Time	Path/Row	Scale
Landsat TM and OLI/TIRS	Level 1 Terrain Precision	United States Geological Survey (USGS)	01 Feb, 2019 04 Jan, 2009 09 Jan, 1999 13 Jan, 1989	136/44 & 136/45	30m
Ground truth data	-	Google Earth CDA	25 Jan, 2019 19 Nov, 2008 20 Dec, 2000 20 Jan, 1989	-	-

Data pre-processing

Satellite data pre-processing is an essential step in the field of remote sensing. Collected data comes with many disturbances. Acquisition errors and irrelevant data (e.g. clouds and cloud shadows) must also be removed in the pre-processing. So, the data must be pre-processed first. Landsat images come as digital numbers (DN) values for the convenience of storage. These DN values don't have any physical existence or representation. Raw images were radiometrically corrected using equation (1) for the purpose of converting the digital numbers to top of atmosphere reflectance units. Then the images were corrected solar illumination using equation (2).

$$\rho\lambda' = M\rho * Qcal + A\rho \text{...............} \quad (1)$$

Where:

ρ_λ' = TOA planetary reflectance, without correction for solar angle.
M_ρ=Band-specific multiplicative rescaling factor from the metadata
A_ρ =Band-specific additive rescaling factor from the metadata
Q_{cal} = Quantized and calibrated standard product pixel values (DN)

TOA reflectance with a correction for the sun angle is then:

$$\rho\lambda = \rho\lambda' \cos(\theta SZ) = \rho\lambda' \sin(\theta - SE) = \rho\lambda' sin(\theta SE) \text{.......} \quad (2)$$

Where:

ρ_λ= TOA planetary reflectance
θ_{SE} = Local sun elevation angle.
θ_{SZ} =Local solar zenith angle; $\theta_{SZ} = 90° - \theta_{SE}$

Then the images were atmospherically corrected using the dark object subtraction (DOS) method. Dark Object Subtraction is a simple empirical atmospheric correction method for satellite imagery available in QGIS, which assumes that reflectance from dark objects includes a substantial component of atmospheric scattering. Dark object subtraction searches each band for the darkest pixel value. The scattering is removed by subtracting this value from every pixel in the band. This simple technique is effective for haze correction in multispectral data.

Selection of green cover

The NDVI value obtained from corrected satellite photos was used to choose green covers for this investigation. The NDVI was computed using the following formula (3):

$$NDVI = \frac{\text{NIR}-\text{RED}}{\text{NIR}+\text{RED}} \text{...........................} \quad (3)$$

NDVI is an index based on the spectral reflectance of the ground surface feature. Each feature has its own characteristic reflectance varying according to the wavelength. NDVI value ranges between -1 to +1. A Higher value of NDVI infers the presence of healthy vegetation in the area, while its lower value is the indicator of sparse or no vegetation. NDVI has been used for the analysis of change detection of vegetation in many studies.

Selection of water body:

The influence of the UCI on urban areas varies depending on the form and size of the water bodies. These water bodies were carefully selected using an NDWI map, and their key properties were examined. An NDWI map of the study area was then generated using the following standard NDWI formula (4):

$$NDWI = \frac{\text{GREEN} - \text{NIR}}{\text{GREEN} + \text{NIR}} \quad (4)$$

Presence of urban areas in both green cover & water bodies' immediate surroundings can identify the range of UCI impact on reducing LST effect.

Calculation of LST

Conversion to TOA Radiance

Landsat thermal bands were converted to TOA spectral radiance applying the radiance rescaling factors using equation (5).

$$L_\lambda = M_L Qcal + A_L \quad (5)$$

Where:

L_λ = TOA spectral radiance (Watts/(m^2 * srad * µm))

M_L =Band-specific multiplicative rescaling factor from the metadata

A_L=Band-specific additive rescaling factor from the metadata

Q_{cal} = Quantized and calibrated standard product pixel values (DN)

Satellite TIR sensors measure top of the atmosphere (TOA) radiances, from which brightness temperatures (also known as blackbody temperatures) can be derived using Plank's law. The TOA radiances are the mixing result of three fractions of energy: (1) emitted radiance from the Earth's surface, (2) upwelling radiance from the atmosphere, and (3) downwelling radiance from the sky. The difference between the TOA and land surface brightness temperatures ranges generally from 1 to 5 K in the 10–12-Am spectral region, subject to the influence of the atmospheric conditions. Therefore, atmospheric effects, including absorption, upward emission, and downward irradiance reflected from the surface, must be corrected before land surface brightness temperatures are obtained. These brightness temperatures should be further corrected with spectral emissivity values prior to the computation of LST to

account for the roughness properties of the land surface, the amount and nature of vegetation cover, and the thermal properties and moisture content of the soil. Two approaches have been developed to recover LST from multispectral TIR imagery. The first approach utilizes a radiative transfer equation to correct the at-sensor radiance to surface radiance, followed by an emissive model to separate the surface radiance into temperature and emissivity. The second approach applies the split-window technique for sea surfaces to land surfaces, assuming that the emissivity in the channels used for the split window is similar.

Conversion to Top of Atmosphere Brightness Temperature

Thermal band data were converted from spectral radiance to top of atmosphere brightness temperature using equation (6)

$$BT = \frac{K_2}{ln(K_1 L_\lambda + 1)} - 273.15 \quad (6)$$

Where:

BT = Top of atmosphere brightness temperature (°C)

L_λ =TOA spectral radiance (Watts/(m2 * srad * µm))

K_1 =Band-specific thermal conversion constant from the metadata

K_2 =Band-specific thermal conversion constant from the metadata

Emissivity Calculation

To get land surface temperature from brightness temperature, it is necessary to do an emissivity correction. NDVI is a great indicator of emissivity. It can be used to determine the proportion of vegetation, which then can be used to calculate emissivity. Here, we determined the values of the proportion of vegetation (P_V) using equation (7).

$$P_V = \left(\frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}}\right)^2 \quad (7)$$

From the above equation (7), the proportion of vegetation is used to get the emissivity value by applying equation (8).

$$\varepsilon = 0.004 * P_V + 0.986 \quad (8)$$

The effect of land surface emissivity on satellite measurements can be generalized into three categories: (1) emissivity causes a reduction of surface-emitted radiance; (2) non- black surfaces reflect radiance; and (3) the anisotropy of reflectivity and emissivity may reduce or increase the total radiance from the surface. Therefore, retrieval of LST from multispectral TIR data requires an accurate measurement of the emissive values of the surface. The emissivity of the surface is controlled by such factors as water content, chemical composition, structure, and roughness. For vegetated surfaces, emissivity can vary significantly with plant species, areal density, and growth stage. In the meantime, emissivity is a function of wavelength, commonly referred to as spectral emissivity. Estimation of emissivity for ground objects from passive sensor data has been measured using different techniques. Among these techniques are the normalized emissivity method, thermal spectral indices, spectral ratio method, Alpha residual method, NDVI method, classification-based estimation, and the temperature emissivity separation method.

LST estimation

For the estimation of land surface temperature (LST), brightness temperature (BT), and emissivity (Ɛ) is used from the above calculations. Correction of emissivity was done using equation (9)

$$\mathbf{LST} = \frac{\mathbf{BT}}{\mathbf{1 + (0.00115 * BT / 1.4388) * \ln(\varepsilon))}} \quad \ldots\ldots\ldots (9)$$

Reliability and Validity

For the derivation of LST, the Plank equation has been made popular among researchers. For example, the Planck equation is widely used for the derivation of LST from different thermal sensors. Unlike other algorithms (e.g. SCA, SWA), this method is easy to use and does not require atmospheric parameters or calculated LST for different Landsat sensors. and found that the Plank function produces the best results from Landsat 8 TIRS.

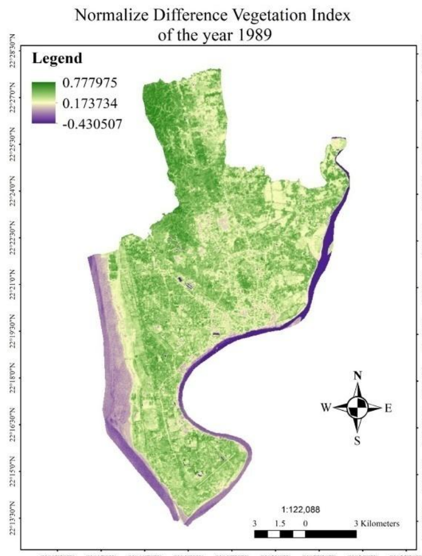
Results and Discussion

NDVI and NDWI estimation

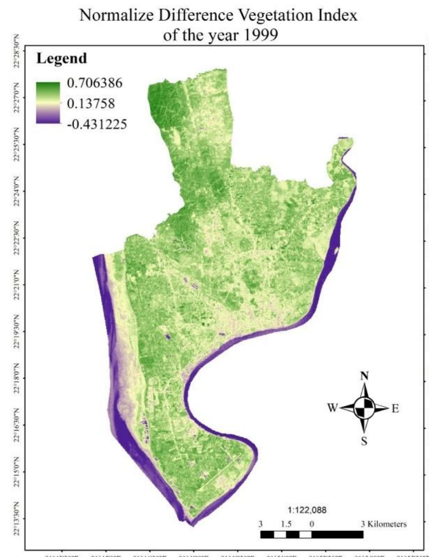
To identify the cooling island effect of the city, the green spaces and water bodies have been identified. As stated earlier, NDVI is a good indicator to detect and classify vegetation cover. NDVI values greater than 0.1 means vegetated areas, were applied to identify the green areas in Chattogram city. On the other hand, NDWI is a reliable marker of water bodies in an area. Using the NDWI values higher than 0.1, water bodies of Chattogram city were spotted. The area of the surface urban heat island has been documented by LST values. In determining the LST of a certain area, the thermal band of Landsat satellite images has become increasingly popular.

NDVI of four different years (1989, 1999, 2009, and 2019) of the city have been generated. NDVI for these years is shown as maps (Map 1, 2, 3, 4). Similarly, NDWI values for four different years (1989, 1999, 2009, and 2019) of the city have been generated for identifying water bodies. NDWI for these years is shown as maps 5, 6, 7, and 8 respectively. For the homogeneity of the datasets, area, and condition of vegetated areas and water bodies, the same months were taken for image acquisition.

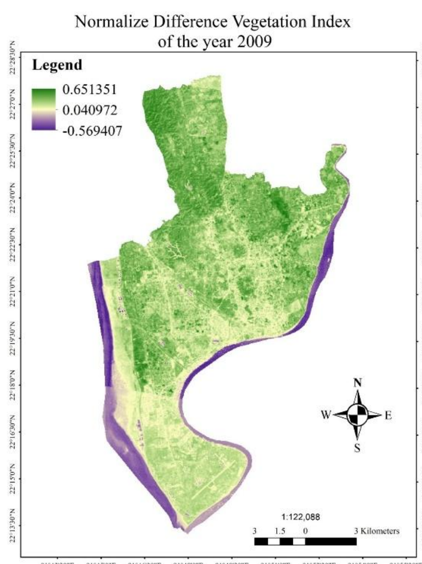
Map 1: NDVI Values for 1989



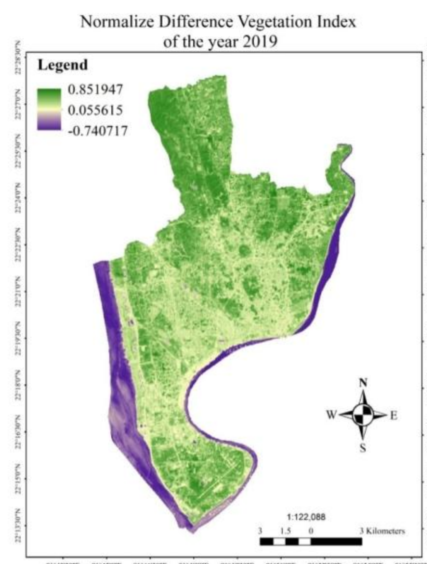
Map 2: NDVI Values for 1999



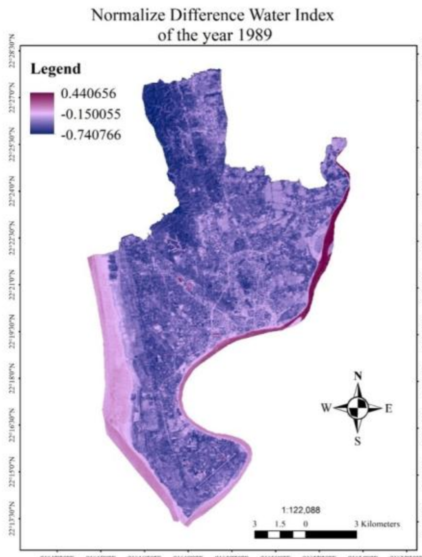
Map 3: NDVI Values for 2009



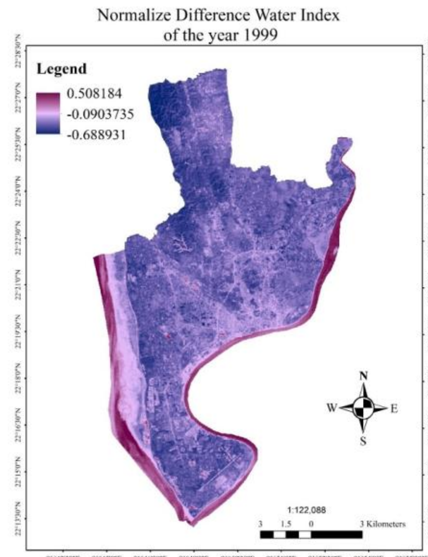
Map 4: NDVI Values for 2019



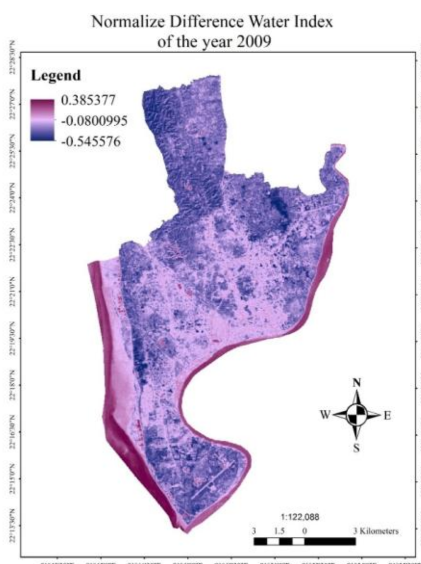
Map 5: NDWI Values for 1989



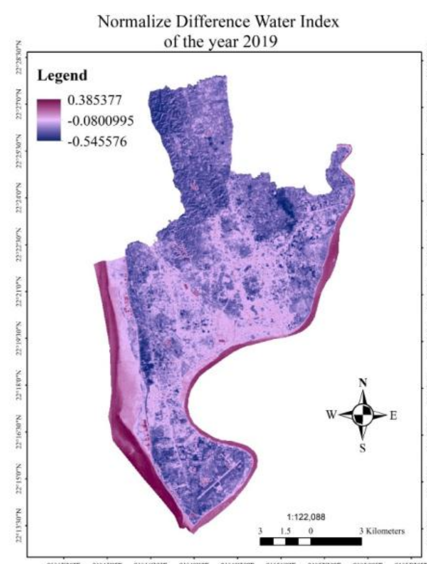
Map 6: NDWI Values for 1999



Map 7: NDWI Values for 2009



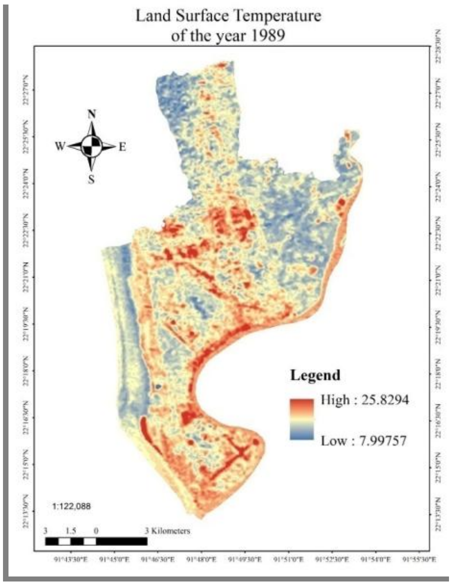
Map 8: NDWI Values for 2019



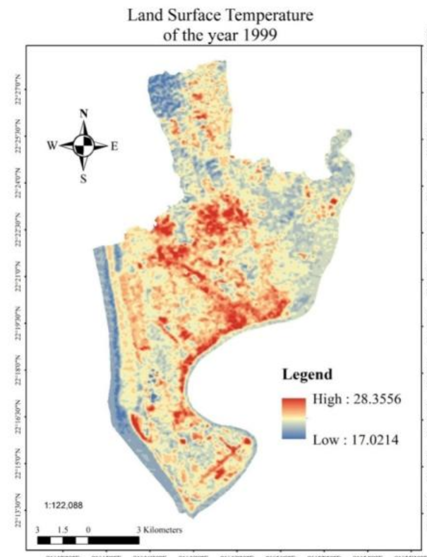
Land Surface Temperature Detection

To detect the land surface temperature, the city's surface temperature values of four different years (1989, 1999, 2009, 2019) have also been generated. LST for these years are shown as maps 9, 10, 11, and 12, respectively, for the homogeneity of the datasets, area, and related conditions as well as the same months were taken for the image acquisition as similar to NDVI and NDWI detections.

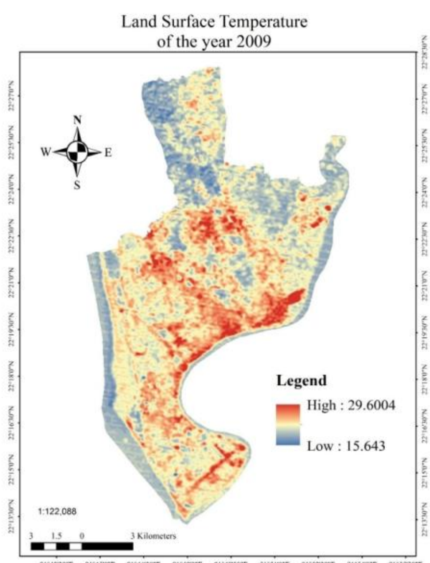
Map 9: LST of 1989



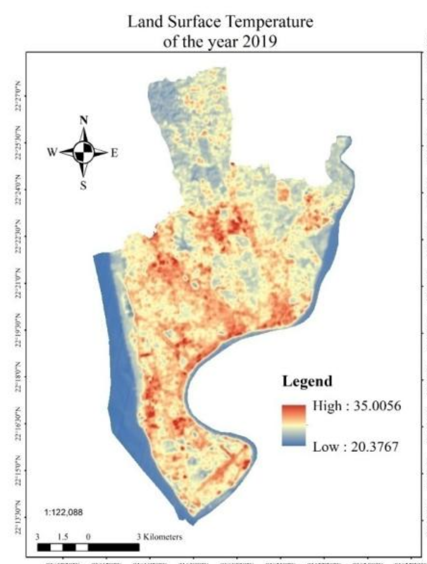
Map 10: LST of 1999



Map 11: LST of 2009



Map 12: LST of 2019



In the early 90s, the highest NDVI values indicated healthy green coverage, particularly the tree cover, followed by agricultural land or grass areas (Figure 1). High vegetation density in urban areas significantly reduces the urban heat island effects, especially cooling down the ambient and surface temperature of the area within a certain threshold zone. Also, the NDWI values of the waterbodies are close to 0, signifying the cooling island effect of those areas.

The NDVI and NDWI values for tree cover, barren land, and agricultural regions for the year 1999 (Figure 2) showed a noticeable change; particularly, a significant alteration was observed concerning urban areas. Urban expansion was slower and reduced the built-up areas in 1999; however, water bodies have been significantly demolished (Figure 2). The NDVI values for the urban class have further reduced in 1999 (Figure 2). It happened for the tree cover and agricultural areas as well. With the rapid urbanization process, green spaces have been reduced in the urban centers, reducing the cooling island effect of those green spaces. Nevertheless, the values for NDVI and NDWI for 2009 and 2019 remained identical in the 5 classes (Figure 4).

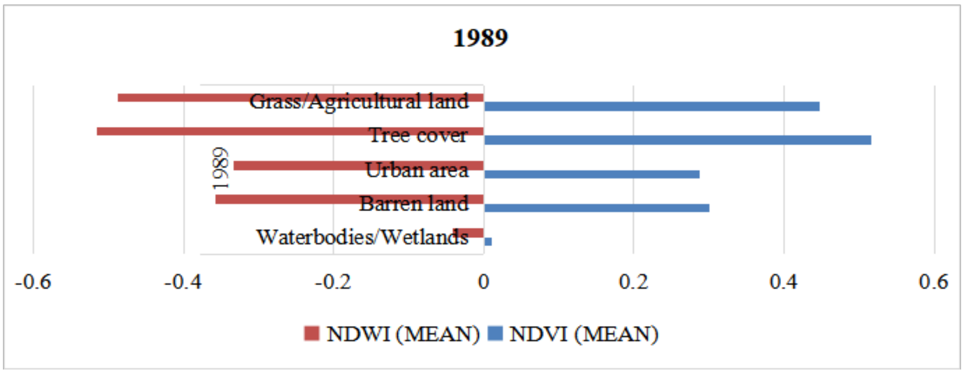


Figure 1 Class-wise classification of NDVI and NDWI values for 1989

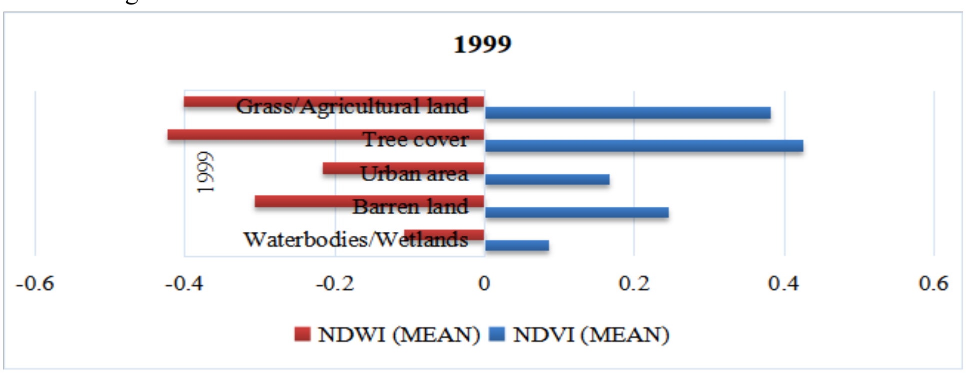


Figure 2 Class-wise classification of NDVI and NDWI values for 1999

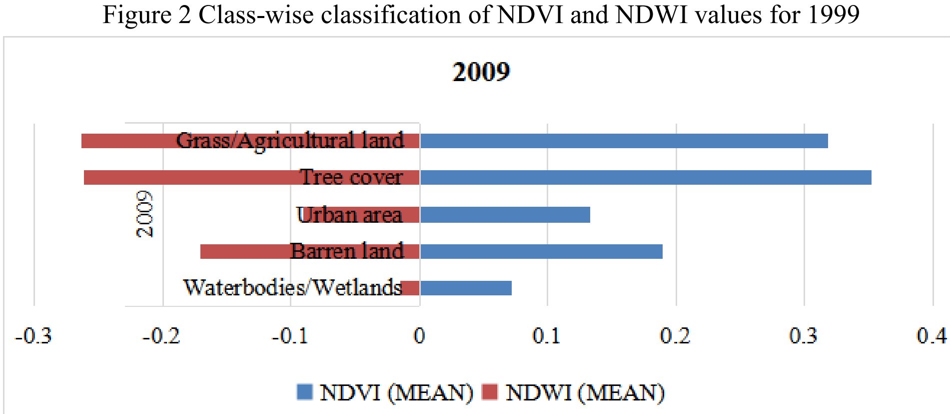


Figure 3 Class-wise classification of NDVI and NDWI values for 2009

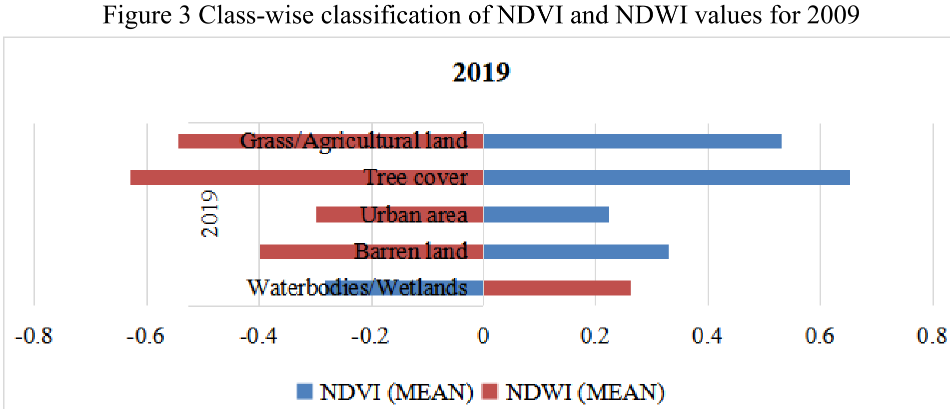


Figure 4 Class-wise classification of NDVI and NDWI values for 2019

LST estimation based on different LULC classes

The LST of the study area for the years of 1989, 1999, 2009, and 2019 was estimated based on different LULC classes and given in Table 5 to Figure 8, respectively.

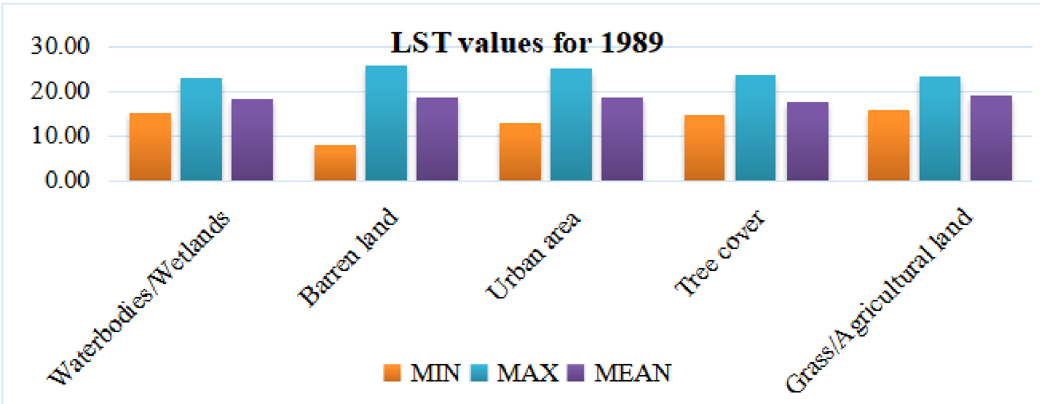


Figure 5 Class wise LST values for 1989

Figure 5 shows the class-wise LST of the year 1989. The maximum LST values lie in the urban and barren land areas, as well as the mean values. High-rise buildings in the urban areas, a lack of green spaces, decrease in the surface albedo. Evapotranspiration rate in the urban and barren land areas is lower relative to their agricultural counterparts areas, which ultimately increases the LST values

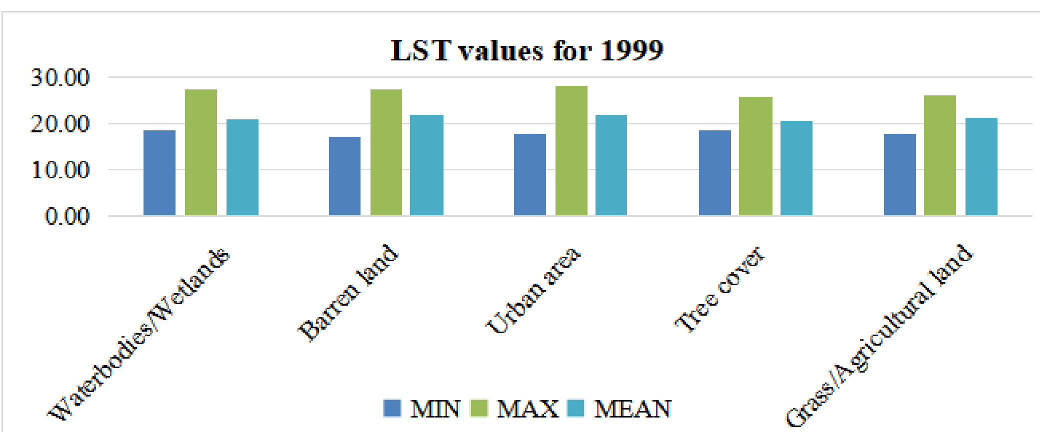


Figure 6 Class wise LST values for 1999

It has been observed from Figure 6 that the LST values for almost every category exceeded the previous year (1989). It can easily be said that, for the massive unplanned urbanization process, the green spaces have been reduced in the city centers, forcing the LST to rise unprecedentedly.

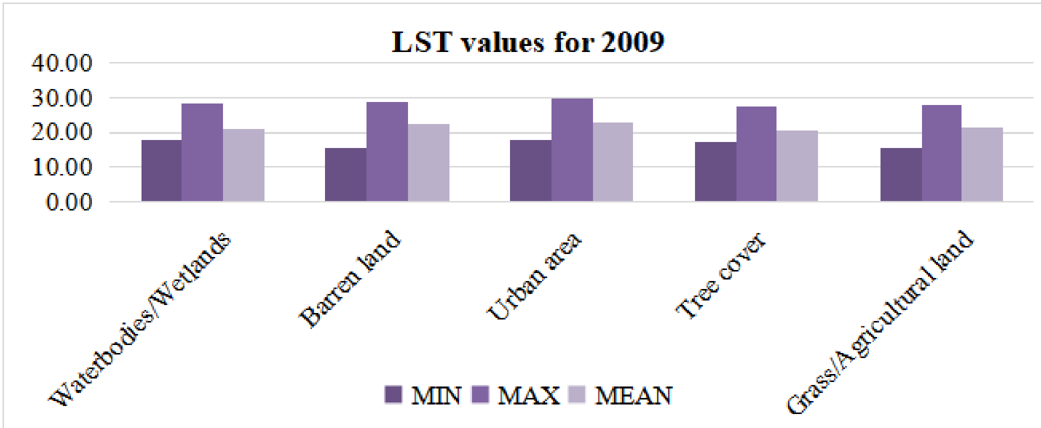


Figure 7 Class-wise LST values for 2009

In the year 2009, the mean and maximum values of LST for the urban class have increased since 1999 (Figure 7). Without the tree cover class, all of the other classes showed an increasing trend of LST in terms of min, max, and mean.

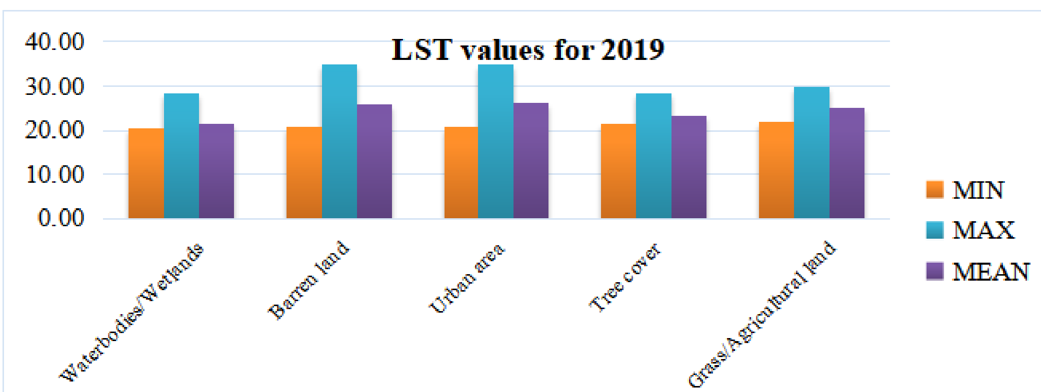


Figure 8 Class wise LST values for 2019

From 2009 to 2019, the barren land and urban area class saw a massive increase in LST for mean and max values (Figure 8). The maximum values for both of these classes reached as high as 35 degrees Celsius. It is understandable for the fact that with the rise of unprecedented urbanization and the global warming process, the LST values are higher for the urban centers.

Correlation between NDVI/NDWI and LST values

Using correlation techniques in R Studio, the correlation between NDWI with LST and NDVI with LST has been derived.

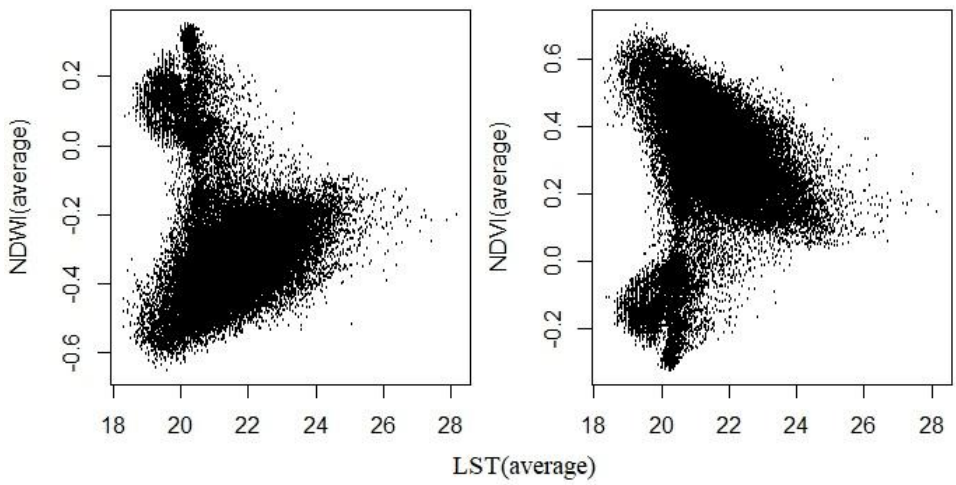


Figure 9 Correlation between NDWI and NDWI with LST

Figure 9 shows a significant correlation between the NDVI, NDWI values, and the mean LST values. High NDVI significantly reduces the LST. As evident from the above graph, the higher concentration of LST values lies on the far-right side, where the NDVI values are lower, and vice versa. The opposite scenario is seen for the NDWI values.

The analysis indicates that the cooling island areas are dispersedly located throughout the study area. High vegetation cover is present in the North and Northeastern part of the city, providing a cooling effect to the city dwellers. Karnaphuli River in the Eastern part of the city serves as a huge cooling area of the city. The southern part of the study area has a higher concentration of water bodies than its northern counterparts. The waterbodies have lower LST values than any other classes. Therefore, the waterbodies are ideal cooling islands for lowering down the ambient and surface temperature of the urban centers.

Change detection of Cooling Island areas: Throughout the spanned study period, the numbers and total areas of water bodies, as well as the vegetation cover, have decreased significantly, leaving less cooling effect. The waterbodies of the study area were around 6000 hectares in 1999, which sharply declined to a mere 3000 hectares in 2019. The vegetation cover was slightly above 5000 hectares in 1989. But with the massive urbanization, this huge number decreased to around 2000 hectares. The cooling areas decreased with the span of time, and the heat island areas increased with urbanization.

***Change Detection in LST*:** The LST values for the year 1989 ranged from 19 to 25 degrees Celsius. But with the span of time, LST values increased both spatially and temporally. The LST values were mainly concentrated in the mid portion area in 1989, but it spread throughout the entire map with the span of time. The temperature became as high as 35 degrees Celsius in 2019. In previous years, the UHI effect was mainly centered in the mid portion of the map of the study areas, but gradually it spread throughout the whole map with increased LST. From the class-wise LST values, it has been identified that the barren land and the urban areas have higher rates of Heat Island effects than any other categories. The water bodies have the least amount of heat island effects considering its less LST values for every year of the studied map.

On average, urban wetlands were cooler than their surrounding landscapes, indicating that the cooling effects of wetlands are significant in a heat-prone urban environment. The result of our study confirmed that areas with a higher concentration of water bodies have significantly less LST. The cooling effect of the wetland should therefore be included in the assessment of wetland ecosystem services. However, the observation shows that the UCI intensity does not correct linearly with wetland area but is strongly influenced by wetland shape[17]. Their findings suggest that the cooling effect reaches a threshold as wetland area increases. Consequently, to maximize benefits, a single large water body could be replaced with several smaller water bodies of equivalent total area. Thus, considering the scarcity of urban land[17]. In addition, “the cooling effect of wetlands may be intensified by constructing them in a small size with a relatively regular shape because we do not have enough urban land to create large wetlands with a natural complex shape”[17].

It is great for a city to have a vast number of water bodies rather than a substantial number of them. In addition, “evaporative cooling performance of water bodies to its surrounding microclimate” at a height of 2m at two locations, Kallang and SungeiApi-api case study was conducted [8]. Both locations are characterized by “having vast water bodies and encircled by greenery.” The cooling effect is likely to start at 9 am when the solar radiation reaches around 150-200 W/m² in the morning and end at around 6 pm when the solar radiation is less than 75-100 W/m² in the evening. During the daytime, with clear day conditions, evaporative cooling impacts are reduced in the range of 0.1°C - 0.2°C over a span of 35m away from the waterway.

The temperature in the urban area influenced by the spatial distribution of water bodies and water fraction in the city is investigated based on an idealized circular city. The variable of this simulation study was the size and spatial configuration of the surface water cover and the temperature of the water. The result of this simulation study demonstrates “a nonlinear relationship of the cooling effect of water bodies with the fractional water cover, size of the water bodies and distribution of water bodies within the city with respect to wind direction.” One of the important observations from this simulation study is that although relatively large lakes show more cooling effect close to their edges and in downwind areas, several smaller water bodies can influence a larger area of the city through their cooling effect if distributed equally within the urban area[18].

Land Surface Temperature (LST) is directly linked with Land Use/ Land Cover change. And the land cover change occurs due to human activities and movement, either directly or indirectly. The most crucial factor playing behind it is urbanization and industrialization. It changes the structure, therefore, causes an imbalance in the equilibrium condition of the environment. In the map of 1989 and 1999, the temperature was mostly low to moderate. Because there were many green spaces as well as innumerable water bodies at that time to cool down the temperature, it has been seen that with the vast majority of vegetation and waterbodies, the surface temperature was between 19 to 25 degrees Celsius. In 2019, however, a vast change in temperature is observed, and most of the area represents a moderate, high, and very high class of temperature on the map. In 2019, it is beyond imagination, and almost every land cover type represents very high temperatures; some are high temperature zones, and a few are moderate. The temperature in 2019 rose as high as 34 degrees Celsius 2019 due to UHI. These analyses directly portray the feature of Urban Heat Island (UHI), created due to urbanization. Deforestation, desertification, and pollution are the root causes of extreme heat and climate change. Pollution is a common phenomenon in cities that triggers heat. The city is occupied by industrial areas that habitually generate environmental pollution. Lead-based paint used on highways, roads, and on buildings is one of the causes of environmental pollution. For example, an extensively dispersed pollutant that found its way into the soil. Some solid Ingredients, such as concrete, bricks, asphalt, etc., absorb and reflect energy differently than vegetation and soil because cities are built of solid materials that produce heat. So, Cities remain always warm at night while the countryside has cooled. Human activities produce a wide range of Green greenhouse gas (GHG) emissions into the environment, including carbon dioxide (CO_2), Methane (CH_4), carbon monoxide (CO), ozone (O_3), and sulfur dioxide SO_2, and many other pollutants every day. For this reason, the air is always polluted in cities. The dust and GHG emissions freed into the environment alter patterns of precipitation over the cities. Cities often catch more rain than the surrounding villages since dust can produce the condensation of water vapor into rain droplets. There is also complete eradication of habitats of native species as an outcome of urbanization, and they are pushed out of cities due to extreme heat and climatic fluctuation.

Conclusion

The waterbodies and green vegetation have a crucial role in determining a city's surface temperature. Chattogram city had a vast number of those in the early period of this study, therefore indicating low thermal temperature and lower LST effect. However, with unprecedented urbanization and drastic city overpopulation, the green spaces and waterbodies have gradually decreased. Therefore, the UCI effect of the city have decreased with time. The findings will contribute to devising sustainable urban planning and urban environmental development which would be able to reduce the health-related problems, e.g., heat stress, of the urban dwellers associated with rising temperature and climate change. In response to rising land surface temperature, conserving green spaces and restoring existing water bodies should be prioritized in urban planning. Moreover, areas dominated by built-up areas need more attention for afforestation and constructing artificial water spaces. Further research should be done to understand the potential, opportunities, and challenges in constructing new greens and water bodies in the ‘hot spots’ of high land surface temperature. It is also necessary to conduct studies to understand people’s understanding, knowledge, and awareness about urban cooling islands and how to engage them in the process of conservation and restoration planning.

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