URBAN HEAT ISLAND EFFECT ANALYSIS USING INTEGRATED GEOSPATIAL TECHNIQUES: A CASE STUDY ON DHAKA CITY, BANGLADESH

A thesis submitted to the Department of Environmental Science, Faculty of Science and Technology, Bangladesh University of Professionals for Partial Fulfillment of the Requirements for the Degree of BSc in Environmental Science

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Dedication

This research work is dedicated to my parents who have been my source of inspiration. They continually provided me their moral, emotional, spiritual, and financial support to help and encourage me throughout the research work. I dedicate this to my supervisor Israt Jahan ma'am for constantly guiding and teaching me also for her unwavering support and encouragement throughout my work. And, to Almighty Allah for the guidance, strength, power, state of mind, protection, and skills to conduct this research work. All of these I offer to you.

Acknowledgement

I would like to take the opportunity to firstly thank almighty Allah for giving me the strength and opportunity to produce this research material and secondly, I would like to thank my parents for their support and guidance each step of the way. I am also grateful to my honorable research supervisor Assistant professor Israt Jahan for giving me the opportunity to work on this topic and for believing in me.

Declaration

I hereby declare that the research titled " Urban Heat Island Effect Analysis Using Integrated Geospatial Technique: A Case Study on Dhaka City, Bangladesh " was conducted in fulfillment of the requirements for the BSc in Environmental Science degree at Bangladesh University of Professionals. This project is based on my own original research findings as well as references from the published literature. This has not been submitted in part or in its entirety to any other university or degree program. I also certify that this thesis contains no plagiarized material.

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Certificate of the Supervisor

This is to certify that Tazina Mim carried out her thesis under my direction and supervision, resulting in the completion of " Urban Heat Island Effect Analysis Using Integrated Geospatial Technique in Dhaka city". According to my understanding, the researcher appropriately recognized the materials and sources used by other scholars. In addition, the thesis was not submitted to any other universities or institutions for the purpose of earning any other degrees or diplomas.

Therefore, it is suggested that the Thesis be presented to the Department of Environmental Science, Faculty of Science and Technology, Bangladesh University of Professionals, in completion of the criteria for the BSc in Environmental Science degree. I also certify that this Thesis has no plagiarized content. Tazina Mim shall take full responsibility for any plagiarized content.

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Abstract:

The world has been experiencing severe climate change in recent years, which impacts seasonal changes and the earth's temperature in particular. Bangladesh is one of the countries that suffer the most from climate change due to its geographic location, which also influences the length and variance of its seasons. This major issue should be taken into account. Urbanization has one of the biggest contributions in temperature rise. Urban Heat Island effect is the phenomenon which occurs when the temperature of any urban area is more than the nearest rural area. Thus, in this research, the Urban Heat Island effects are assessed utilizing GIS and remote sensing to understand the change of Land Surface Temperature with the change of Land Cover over years. Dhaka City has been chosen to host the study to evaluate the temperature change over years with the change of land cover. In this study, Landsat images from the years 2001, 2011 and 2023 are used. For the three years, land cover is classified using the support vector machine technique, and the classification's precision is assessed using the Cohen kappa score. From Land Cover change detection maps it has been found that the build-up area has increased over time. It was 46% on 2001 and on 2023 it has become 69%. and the vegetation cover has decreased. It has become 4% on 2023 which was 12% on 2001. From land Surface Temperature detection map it has been found that the LST was highest for the build-up area and lowest for water bodies and LST has also been increased over time. And the highest LST has been found 40.6^0 C for 2023 which was 33.5^0 C on 2001. This research discusses and analyzes the spatial correlation between land cover and land surface temperature in order to pinpoint the heat island effect based on the evolution of different land cover types through time. The outcome demonstrates that there is a correlation between urban Land Surface Temperature and changes in Land Cover. This discovery may be utilized to create efficient planning methods to reduce the impact of the Urban Heat Island. In order to offer a framework for taking effective and efficient planning measures in response to the climate change event, this research gives the overall scenario of the urban heat island effect of the city of Dhaka with respect to the change in land cover.

keywords:

Urban Heat Island effect, climate change, GIS, LULC, LST.

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Chapter 1

Introduction

1.1 Background of the study:

Urban heat island (UHI) means an urban area that is comparatively warmer than the rural area around that urban area because of human activity. The primary causes of this temperature differential, which is most noticeable in the evening and at night, are urban development and human activity. Bangladesh is a developing country. The urbanization process is very fast here. In big cities here increasing temperature is felt compared to nearby rural area. Already we are facing heat waves in summer. There are several reasons behind this. Reasons for what urban heat island creates are basically urbanization for what extensive concrete building, infrastructure, roads absorb heat during night and release at night and lead to elevated temperature. Reduced vegetation in urban area also contributes here cause the less the vegetation, the less the shade, evaporation rate and the less the evapotranspiration. So, the cooling process becomes slower. Also, urban area has lower albedo than rural area so it reflects less than rural area and causes temperature increase. Urban canyon effect is another problem which hampers the natural ventilation process and traps heat and increase the accumulation of pollution which increase temperature. Human activities significantly contribute to heat sources for example transportation, mills, factories, industrial processes, energy consumption, waste heats etc.

Moreover, the more the city expands the more it replaces natural landscapes. Land surface temperature is a highly significant and useful indicator for making many decisions about environmental issues. It is also utilized in many other domains, such as urban planning and environmental models. (Becker, 1990). One of the main reasons for the change in urban land cover is unchecked population increase. The primary driver of urbanization is population growth, which in turn influenced changes in land cover. These changes led to a significant decline in water bodies, forests, and agricultural land, which in turn caused changes in the local climate, particularly in surface temperature. This is because urban land cover has a strong capacity to absorb solar radiation, evaporation rates, and surface thermal storage. Thus, the wider-scale global climate change is directed by these microclimatic effects at the local level, such as rising land surface temperatures. Recent developments in geospatial approaches facilitate real-world problem solving by simplifying and improving analyses linked to urban and environmental issues.

Therefore, in this study, integrated GIS & RS techniques were applied for analyzing and visualizing the relationship between changes in land cover over time and the land surface temperature.

1.2 Problem statement:

1. Urbanization is increasing and with the increase of infrastructure the heat is getting more trapped in the construction areas and the temperature is increasing. This increase of temperature is being a great concern because the temperature of the urban area is significantly higher than the nearest rural areas.

2. The increasing temperature is contributing to the global climate change issue.

3. Urban heat island effect causes heat related health risk. Especially the elderly, children and people with health issues suffer the most. On June 7, 24 students fell sick because of recent heat wave in Dhaka. Even it causes urban heat stress which leads to heat exhaustion, head stroke and other ailment.

2. Energy consumption and greenhouse gas emissions: Urban areas affected by the UHI effect increases cooling demands, leading to higher energy consumption for air conditioning. This not only results in increased energy costs for residents and businesses but also contributes to higher greenhouse gas emissions, aggravating climate change.

3. It also affects the urban infrastructure by affecting structural integrity. Also, it stresses the electricity supply and also it increases the maintenance cost and reduce the resilience and impacts the local climate.

4. The UHI has impact on the urban ecosystem and biodiversity as well. The reduction of greenness for urbanization stresses the flora and fauna of that area. Overall, the UHI has a great impact not only on the human health and other organisms but also on climate change.

5. The more land is converting to build up area the more the Land Surface Temperature is increasing.

1.3 Rationale of the study:

Urban Heat Island effect is an ongoing problem in the whole world specially for Bangladesh. Cause Bangladesh is an overpopulated country. This paper is a study on Dhaka city, the capital of Bangladesh. This study has special significance because urbanizing is rapidly increasing in Dhaka city so, he UHI effect can influence urban planning and development decisions. If UHI effect is not managed properly, urban areas may become less habitable and less attractive for residents, which can have economic and social implications. Understanding UHI effect is essential to implement urban planning and design measures that prioritize green spaces, sustainable construction practices, and improved energy efficiency in Dhaka city. Additionally, public health initiatives to mitigate the health impacts of extreme heat, policies to encourage the adoption of cooling technologies and practices that reduce energy consumption and environmental impact the proper knowledge on Urban Heat Island Effect is compulsory.

1.4 Research question:

1. In which extent Land Cover is changing over time in Dhaka city?
2. Is there any relationship between Land Use Land Cover change and Land Surface Temperature change in Dhaka city over time?
3. Is urbanization have any impact on the temperature rise in Dhaka city?

1.5 Research objectives:

1. To identify the UHI effect of Dhaka city using integrated geospatial technique.
2. To determine the Land Cover change and Land Surface Temperature change and greenness using geospatial tool LULC, NDVI and LST to understand the reason of UHI effect.
3. To determine the UHI effect in Dhaka city over time from (2001-2023).

1.7 Outline of the thesis

The next chapters are arranged as follows:

- **Chapter Two: Literature Review**

Local and international articles relevant to the thesis's topic are reviewed and summarized in this section.

- **Chapter Three: Conceptual framework**

This chapter outlines the abstract representation of the research study, which corresponds to the research study objective that guides the gathering and analysis of data.

- **Chapter Four: Methodology**

This chapter offers in depth information regarding data gathering and data analysis methods. Also, this describes how the research and analysis is done.

- **Chapter Five: Results & Discussion**

Under this section, the results of the data analysis are interpreted and elaborately described.

- **Chapter Six: Recommendations & Conclusions**

This chapter includes some suggestions for minimizing the issues.

Chapter2

Literature review

2.1 Urban Heat Island effect:

According to Hoffman et al. (2011) urban heat island is a crucial situation and it causes several health impact and heat stress to different species. He did a statistical analysis on urban heat island effect of Hamburg and they used linear regression model to understand the relation between different meteorological factors and UHI effect. Also, they applied different climatic model, RCM, REMO, LCM etc. for understanding the UHI effect on climate change. According to Rohinton Emmenuel et al. (2012). Temperature difference between urban area and nearest rural area can determine the urban heat island effect. And they used LCZ (local climate zone) concept to understand different land cover difference. Also, they identified correlation between local climate and land use/land cover variations in and around Glasgow. According to Koeppen-Geiger's climate classification, the region was characterized by temperate climate type, specially made mild due to stronger maritime. Naimur Rahman et al (2022), described the UHI impact for different cities in Bangladesh and they used remote sensing and GIS technique. And they described heat island impact using LULC and LST. they aimed to quantify spatiotemporal associations of UHI intensity during the winter period between 2000 and 2019 using remote-sensing and geo-spatial tools. Landsat-8 and Landsat-5 imageries of these major districts during the dry winter period from 2000 to 2020 were used for this purpose, with overall precision varying from 81% to 93%. The results of LULC classification and LST estimation showed the existence of multiple UHIs in all major districts, which showed upward trends, except for the Rajshahi and Rangpur districts. A substantial increase in urban expansion was observed in Barisal > 32%, Mymensingh > 18%, Dhaka > 17%, Chattogram > 14%, and Rangpur > 13%, while a significant decrease in built-up areas was noticed in Sylhet < −1.45% and Rajshahi < −3.72%. They found that large districts have greater UHIs than small districts. High UHI intensities were observed in Mymensingh > 10 ◦C, Chattogram > 9 ◦C, and Barisal > 8◦C compared to other districts due to dense population and unplanned urbanization. They also described LST hotspot zones. Md Islam et al (2019) described UHI impact using GIS and remote sensing on khulna city, Bangladesh. They conducted research on Urban heat island effect analysis using integrated GIS and remote sensing to assess the land surface temperature variation with spatial distribution of land cover. Khulna city was selected to conduct the research to assess the urban heat island effect in relation to the land cover change over the years. The Landsat imagery from 2001, 2011 and 2018 years are used in this research. The support vector machine algorithm was used to classify land cover for the 3 years and the accuracy of the classification is evaluated by the Cohen kappa score. Spatial co-relation between land cover and land surface temperature was discussed and analyzed here to identify the heat island effect based on the change of land cover types over the years.

2.2 Causes of Urban Heat Island effect:

Built Environment: The UHI impact is greatly influenced by the built environment in metropolitan settings. According to research by Oke (1982), temperatures rise as a result of the high density of roads, buildings, and other infrastructure components that absorb and reradiate solar energy. Cities experience the creation of hotspots as a result, particularly throughout the day.

Insufficient Vegetation:

Urban areas frequently lack vegetation and green spaces. According to Akbari et al. (2009), this lack of vegetation exacerbates the UHI effect by lessening the cooling effect that trees and green spaces give.

Heat Caused by Humans:

Heat is released into the atmosphere by human activities including industry, air conditioning, and transportation. Scholars such as Sailor (2011) have shown that this heat caused by humans greatly increases the UHI effect, particularly in densely populated urban areas.

Enhanced Heat Retention and Absorption:

The enhanced absorption and retention of heat in urban areas is one of the main reasons of the urban heat island effect. When it comes to absorbing heat, urban surfaces like concrete and asphalt are more capable than natural surfaces like greenery. The phenomena in question has been extensively examined by Sailor (2011) and Akbari et al. (1992).

Modified Surface Coverage and Decreased Green Area:

The UHI effect is also exacerbated by the loss of green space and vegetation brought about by urbanization. Research by Oke (1982) and Imhoff et al. (2010), for example, highlight how adding impermeable surfaces to natural land cover increases heat absorption and decreases evapotranspiration cooling.

Transportation and Building Heat Emissions:

The release of heat from automobiles and buildings is another significant factor in the UHI effect. Temperatures in metropolitan areas are raised by the discharge of heat from heated buildings and cars. Declet-Barreto et al. (2013) talk about how vehicle emissions and building energy use cause urban heat.

Modifications to Wind and Microclimate Patterns:

The UHI effect is exacerbated in urban areas by changes in local microclimates and wind patterns. Tall buildings can obstruct the natural airflow, causing heated air pockets to become stagnant. Chow (2012) and Roth and Oke (1994) investigate these impacts on urban microclimates.

Human-caused Heat:

The UHI impact is exacerbated by heat produced by human activity, including industrial processes, energy use, and even human metabolism. Gately and Hutyra (2017) measure the effect of man-made heat on urban warming in their study.

Diminished Cooling and Shade Effects:

The removal of huge, shading trees and the alteration of natural water bodies reduce shade and cooling benefits, which further exacerbates the UHI effect. The role of plants in providing shade and cooling advantages is covered by Harlan et al. (2006).

Building Materials and Urban Geometry:

The UHI effect can be influenced by the construction materials used, the geometry and layout of metropolitan areas, and other factors. Low-albedo materials and surfaces exposed to the sun can radiate heat. (Santamouris (2015) and Li et al. (2020))

2.3 Impact of Urban Heat Island effect:

Effects on Health:

Increased mortality rates and heat-related illnesses can result from the heightened temperatures linked to UHIs. In a study done in Phoenix, Arizona, Harlan et al. (2013) found a link between UHIs and negative health impacts, highlighting the necessity of urban heat mitigation techniques to safeguard public health.

Energy Usage:

Urban regions have greater temperatures, which results in higher energy usage for air conditioning and cooling. Santamouris's (2015) research revealed that urban heat islands (UHIs) increase energy costs and add to greenhouse gas emissions, hence highlighting the need for energy-efficient building designs and urban planning.

Environmental Degradation:

Unnatural heat waves (UHIs) cause disturbances to ecosystems, increased air pollution, and changed microclimates. The ecological effects of urban heat islands (UHIs) on urban flora and fauna were examined by Pataki et al. (2011), who highlighted the necessity of sustainable urban growth.

2.4 Strategies for Reducing the Impact of the Urban Heat Island:

Urban Planning and Design:

To lessen the UHI effect, urban planners should optimise building layouts, provide more tree canopy cover, and integrate green infrastructure. According to Akbari et al. (2016), intelligent urban planning should encourage natural ventilation and minimise the use of heat-absorbing materials in urban areas.

Cool Pavement and Roof Technologies:

According to Rosenfeld et al. (1995), cool pavement solutions and cool roofing provide efficient ways to lower surface temperatures by reflecting sunlight and releasing less heat. Numerous urban areas have widely embraced these technologies.

Community Education and Engagement:

It's critical to involve local communities in UHI mitigation initiatives. Chu et al. (2016) have shown that community involvement can raise awareness and support local efforts.

As urbanization keeps growing, the Urban Heat Island effect is still a major worry. The causes and effects of UHIs have been emphasized in this literature review, along with the significance of mitigation efforts. Urban planners, legislators, and communities must collaborate to put into place efficient UHI effect reduction strategies that will ultimately result in more sustainable and livable urban settings.

2.5 Process of analyzing UHI effect:
Studies on Land Cover changes:

A metropolitan region is a dynamic, complicated system. Many determinants, including social, economic, demographic, environmental, topographical, and cultural aspects, influence a city's ability to grow. It is not simple to model such dynamic systems. Over time, several tools have been developed. years to support the land use change and urban growth modelling. Several well-liked bundles include Land Use Scanner, Environment Explorer, SAMBA, Geomod, SLEUTH, CLUE and the Land Transformation Model. Once more, these instruments make use of several techniques in land cover change using techniques like Markov Chain, Cellular Automata, and Logistic Artificial Neural Network (ANN), and regression. (Pontius et al., 2005)

Every tool has benefits and drawbacks of its own. As an illustration, Geomod is solely intended to replicate a one-way transition between different land cover categories. Once more, every technique has advantages and disadvantages of its own. Markov Chain, for instance, works better when the trend of changing land cover is understood. However, neither spatial distribution nor spatial reliance are present in this approach. The Cellular Automata approach uses predefined transition rules to represent each array cell's state based on the neighboring cells' prior states. Since these topics have already been covered elsewhere, the goal of this study is not to evaluate the merits and demerits of every model that has been employed in the literature. The MLP Neural Network technique chooses the appropriate settings on its own and how they ought to be altered in order to enhance the data model. It uses the back propagation technique to classify remotely sensed pictures using a Multi-Layer Perceptron neural network classifier. formula. A non-parametric regression analysis between input variables and one is likewise carried out using the MLP. Predicted memberships are the dependent variable whose output contains a single output neuron. Its distribution-free nature, which eliminates the need for an underlying model, is one of its key benefits. (Silva et al.,2002)

Land Surface Temperature measurement:

Depending on the kind of UHI, researchers have recognized it using a variety of elements (such as temporal and spatial) of comparison used in their research. For instance, assessing LST differences between two time periods allowed for the identification of UHI. in the intervals of the same position. This technique is frequently used to assess the effects of urban expansion on the UHI effect (e.g., variations in temperature between pre- and post-urban environments). By comparing the temperatures in rural and urban areas, others have detected UHI. Consequently, Instead of, comparing different historical periods, comparisons are conducted between geographical units. Still, most based on the temperatures that have been recorded in various locations. (Lowrey et al.,1987)

In order to determine UHI based on LST, researchers have more recently begun to use data from satellite or aircraft remote sensing. This technology also makes it possible to track changes in land cover over time. Because of these two sorts of opportunities (such as determining surface temperature and tracking changes in land cover), researchers were able to look into the relationships between changes in land cover and changes in LST at a particular site over two time periods, or more specifically, how changes in land cover affected the UHI effect. In the recent past, scientists measured UHI for investigations carried out at the regional scale by deriving LST using data from the National Oceanic and Atmospheric Administration (NOAA).

However, in recent years, smaller-scale investigations have frequently made use of the thermal infrared (TIR) data from Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+). Mixed-type images have been utilized in others research. For instance, Liu and Zhang (2011) determined the intensity of UHI in Hong Kong City by analyzing Landsat TM and ASTER photos. In order to look into the relationships between changes in land cover and LST, various kinds of land cover indexes have also been created. Research has indicated that among the many indices, there is a substantial correlation between LST and the normalized difference vegetation index (NDVI), normalized difference built-up index (NDBI), normalized difference water index (NDWI), and normalized difference bareness index (NDBI).

Worldwide, NDVI is used to map desert encroachment, monitor drought, map vegetation density, and track and forecast agricultural production. It also helps predict dangerous fire zones. A single-band dataset primarily representing healthy biomass is produced by the NDVI technique. This index produces values between 1.0 and 1.0, with values close to zero primarily coming from rock and bare soil, while any negative values are primarily caused by clouds, water, and snow. Very low NDVI values (0.1 and below) are indicative of desolate regions that are either rock, sand, or snow, or agricultural. High levels denote temperate and tropical rainforests (0.6 to 0.8), whereas moderate values (0.2 to 0.3) reflect parks, shrublands, and grasslands.

The water content and status of plants are implied by NDWI. The NDBI is aware of populated areas. It has recently been employed as a gauge to show how big built-up areas are. Different barren lands can be classified using NDBI. By establishing the proper threshold values, these indices are utilized to categorize various land cover types. Numerous studies have been conducted in the literature to show the link between LST and NDVI. The decrease in plant cover is associated with the urban thermal environment. Built-up areas are extracted and mapped using NDBI. The analysis of NDWI and NDBI is being done to determine the bareness of the soil and the water content of the plant, respectively.

Building density, land use patterns, and the rate of urbanization all have a direct impact on the intensity of LST. The composition of built-up areas, vegetation, and water bodies, for example, are all tied to patterns of land use/cover changes and LST. There is a correlation between NDBI and LST, as demonstrated by Rinner and Hussain, who also demonstrated that LST is excessive in Toronto where commercial and industrial land uses are situated. Chen et al. have demonstrated that LST has gained prominence in Guangdong Province, southern China, places that have seen substantial urbanization. The dynamics of heat island dispersion in space were also examined in this work. In 1990, the distribution was mixed, with land under development, semi-bare land, and bare land all having warmer surface types than others. By 1990, however, the distribution had altered to UHI.

Oh, and Quattrochi discovered that changes in land use in the Atlanta Metropolitan Area of Georgia had a major UHI effect at the urban boundary. High temperature anomalies were found to be strongly correlated with built-up land by Xiong et al. areas that are highly industrialized and densely populated. They examined Landsat TM/ETM+ data. photos, NDVI, and NDBI indices for Guangzhou, South China, UHI analysis. Chinese et al. revealed that in Beijing, China, there is a positive correlation between impervious surface and LST. According to Weng and Yang, low One of the primary causes of Guangzhou, China's UHI effect is the amount of vegetation there. Those created maps of land cover and LST using Landsat TM data.

In terms of measuring LST, the following observations can be made based on the review mentioned above. While there are several elements associated to urban land cover that influence LST, most studies have looked at only one of these aspects to establish the correlation. Consequently, the correlations shown in these researches do not separate the impact of other variables.

Mitigation strategies of Urban Heat Island Effect:

According to Alberti M (2016) cool surfaces and shades of trees can be used to reduce the energy use and to improve air quality also, Temperature of buildings and the surrounding region can be lowered by using cool or reflective roofing materials, which reflect more sunshine and absorb less heat. Nowak, D. J., & Dwyer, J. F. (2000) says by increasing the urban forest ecosystem UHI effect can be reduced also this paper describes that road side tree plantation and roof top gardening can also mitigate the UHI effect. Cooler urban environments can be achieved by increasing surface albedo and reducing heat absorption through the use of reflective or permeable materials for pavements. Because of the process of evaporative cooling, adding water features such as lakes and ponds helps cool the surrounding land.

Gorddard, R et. al (2011) says, Informing the people on the significance of implementing sustainable practices can reduce the UHI effect. Involving local communities in initiatives that support sustainable urban growth and green living can contribute to UHI effect reduction. Promoting the creation of community gardens, which improve green spaces and build resilience and community involvement can also contribute to the UHI effect reduction.

By implementing land use regulations that support green spaces, reduce impermeable surfaces, and encourage sustainable urban development can contribute to UHI effect reduction. Enforcing building codes that mandate the use of energy-efficient designs, cool roofing materials, and green building standards are also effective technique. Heisler et. al, (2000).

2.6 Research gap:

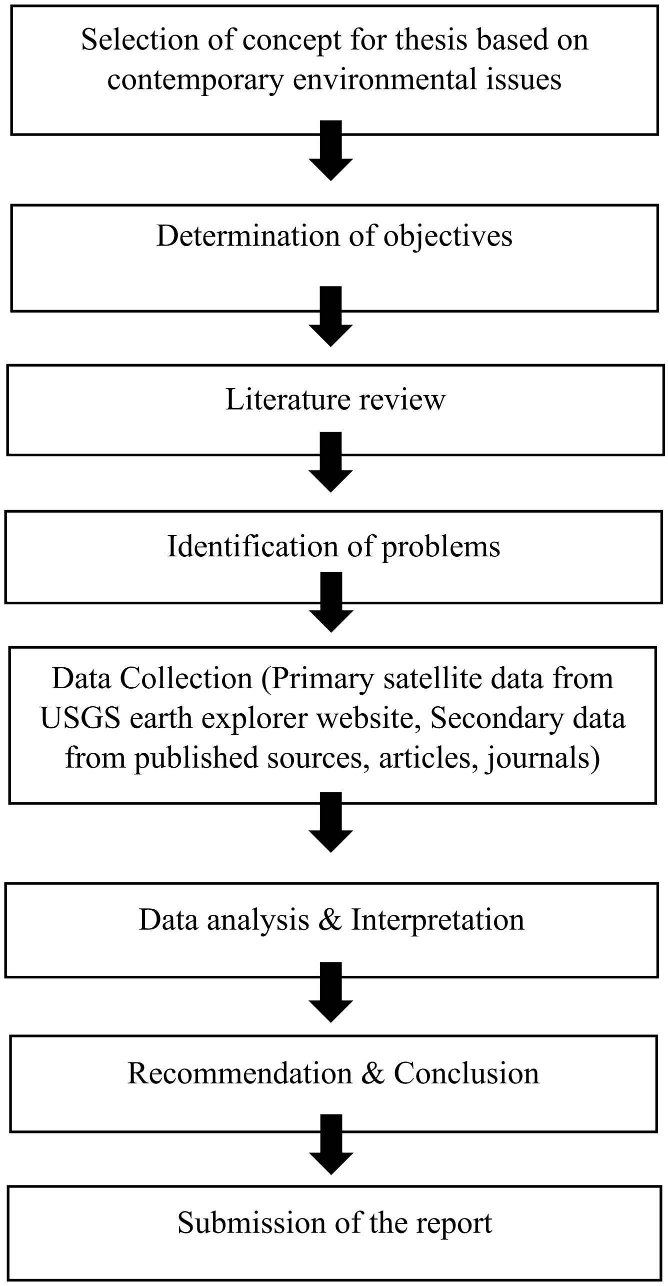
• There is a lack of comprehensive research exploring the actual percentage of land cover change in Dhaka city.

• There is a lack of research specifically pinpointing UHI effect of Dhaka city and the temperature change here.

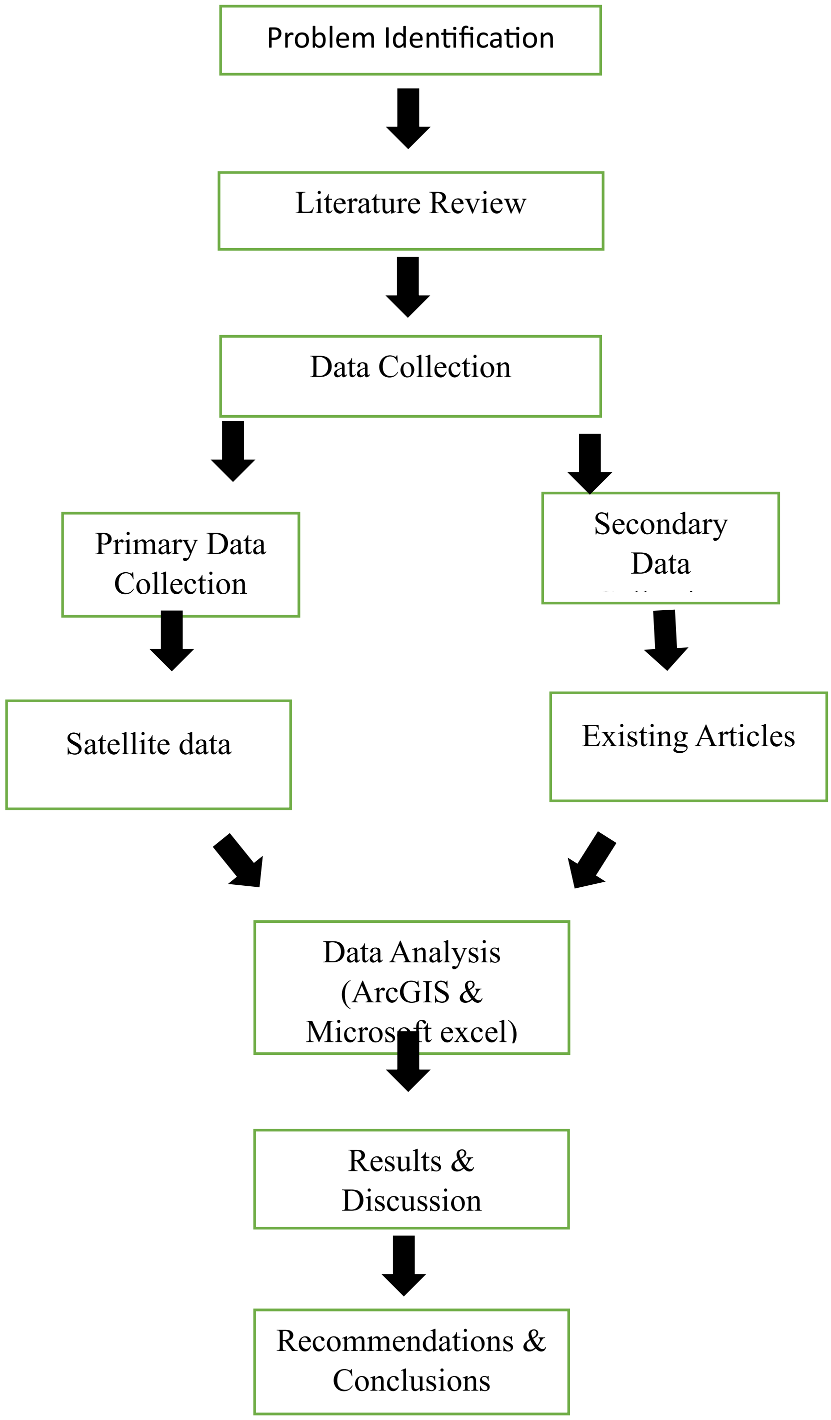
• There is no extensive analysis on how much the land cover change over years is affecting on the land surface temperature change and contributing to UHI effect.

Chapter 3

3.1 Conceptual framework:



3.2 Research Work Flow:



3.4 Study area:

For the analysis of Urban Heat Island effect Dhaka city was selected. The latitude of Dhaka, Bangladesh is 23.777176, and the longitude is 90.399452. With the GPS coordinates of 23° 46' 37.8336" N and 90° 23' 58.0272" E.

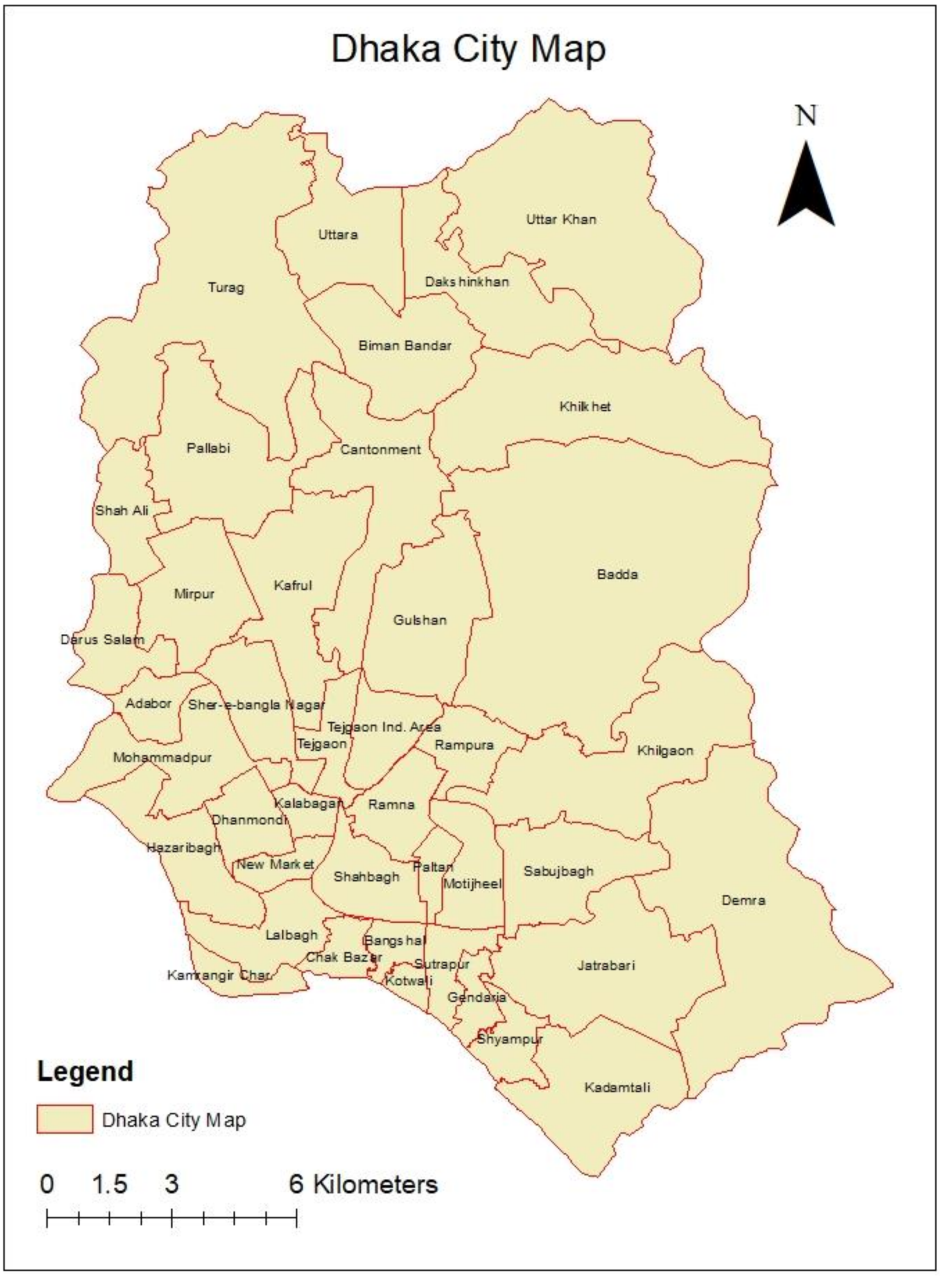


Figure 01: Dhaka city map

3.5 Source of data collection:

• For spatial data: satellite imagery has been used to analyze LST, land cover classification & change detection.

• Satellite images were downloaded from (https://earthexplorer.usgs.gov/) website.

3.6 Data collection and data processing:

Satellite imagery have been used in this research for land use land cover classification, LST calculation and change detection. The Landsat TM for 2001 and 2011 and Landsat 8 TIRAS/OLI for 2023 were collected from USGS earth explorer website with less than 10% cloud coverage.

Table. 1- specification for Landsat images:

Satellite	Sensors	Acquisition date	Path/Row	Number of bands	Radiometric resolution	Spatial resolution(m)
Landsat 5	TM	April 21, 2001	137/44	7	8 bits	30
Landsat 5	TM	March 11, 2011	137/44	7	8 bits	30
Landsat 8	OLI/TIRS	May 10, 2023	137/44	11	16 bits	30

All the images were carefully captured in summer season to avoid seasonal variation in thermal band. Before doing LULC of each Imagery Landsat TM & TIRS/OLI data was combined in a single composite band. Then my study area that means Dhaka city was clipped from BD admin data and was made a shape file of that. And my study area was extracted from the composite band for further analysis. All the data were collected carefully by monitoring the cloud cover to be under 10%

3.7 Data Analysis:

Data was analyzed by using ArcGIS 10.8.2. Latest version of Microsoft Excel has also been used.

Our two primary areas of analysis in this study were the classification of land cover with change detection and the estimation of land surface temperature and its link to changes in land cover.

3.7.1 Classification of Land Cover:

The primary goal of this study is to determine the link between LULC and LST of Dhaka city for a time period. Four categories were identified from the Landsat imagery between the land cover and LST, which are as follows: built-up area, barren land, water, and vegetation. Built-up area was indicated as residential, commercial, industrial, settlements and physical infrastructures; barren land as open space, bare lands, bare soil; vegetation as crop fields, trees, grasslands; waterbody as river, pond etc.

Regarding land cover classification, with the use of supervised techniques. Mostly, support vector machine (SVM) was used cause SVM classifier is less susceptible to noise, and correlated bands also its accuracy is more than maximum likelihood classification. After doing the SVM classification the percentage of area occupied by each category was calculated using excel. And for accuracy assessment of the classification kappa coefficient was determined using ArcGIS and google earth pro.

3.7.2 Calculation of LST:

The land surface temperature of the research area was obtained using the thermal band of Landsat TM and TIRS (Sobrino et al., 2004). The wavelength of band 6 (10.40–12.50 µm) in the Landsat 5 TM data is classified as the thermal area. Bands 10 and 11 (11.50 – 11.19 µm) have different wavelengths. – 12.51 m) of the Landsat 8 TIRS data is classified as thermal. However, because of a greater calibre Because of the uncertainties surrounding band 11 (USGS, 2014), retrieving LST is not advised. Rather, Compared to band 11, band 10 had better accuracy in LST retrieval (Jimenez-Munoz et al., 2014). For this reason, in order to retrieve LST for Landsat 8 TIRS data for the research area in 2023, band 10 of the data was utilized. And band 6 images of the Landsat 5 for the year 2001 and 2011 was utilized.

For Landsat 8 data:

Land Surface Temperature,

Using Landsat 8 Satellite Top of Atmosphere (TOA) radiance was calculated.

Using the radiance rescaling factor, Thermal Infra-Red Digital Numbers was converted to TOA spectral radiance.

$$L\lambda = ML * Qcal + AL$$

Where:

$L\lambda$ = TOA spectral radiance (Watts/ (m2 * sr * µm))

ML = Radiance multiplicative Band (No.)

AL = Radiance Add Band (No.)

Qcal = Quantized and calibrated standard product pixel values (DN)

ii. Top of Atmosphere (TOA) Brightness Temperature:

Spectral radiance data were then converted to top of atmosphere brightness temperature using the thermal constant Values in Meta data file.

$$BT = K2 / In (k1 / LX + 1)-273.15$$

Where:

BT = Top of atmosphere brightness temperature (°C)

$L\lambda$ = TOA spectral radiance (Watts/(m2 * sr * µm))

K1 = K1 Constant Band (No.)

K2 = K2 Constant Band (No.)

iii. Normalized Differential Vegetation Index (NDVI):

The Normalized Differential Vegetation Index (NDVI) is a standardized vegetation index which was Calculated using Near Infra-red (Band 5) and Red (Band 4) bands.

$$NDVI = (NIR - RED) / (NIR + RED)$$

Where:

RED= DN values from the RED band

NIR= DN values from Near-Infrared band

iv: Land Surface Emissivity (LSE):

Land surface emissivity (LSE) is the average emissivity of an element of the surface of the Earth which was calculated from NDVI values.

$$PV = [(NDVI - NDVI\ min) / (NDVI\ max + NDVI\ min)]^2$$

Where:

PV = Proportion of Vegetation

NDVI = DN values from NDVI Image

NDVI min = Minimum DN values from NDVI Image

NDVI max = Maximum DN values from NDVI Image

$$E = 0.004 * PV + 0.986$$

Where:

E = Land Surface Emissivity

PV = Proportion of Vegetation You sent

v: Land Surface Temperature (LST):

The Land Surface Temperature (LST) is the radiative temperature Which was calculated using Top of atmosphere brightness temperature, Wavelength of emitted radiance and Land Surface Emissivity.

LST = (BT/1)+W* (BT/14380) * In(E)

Where:

BT = Top of atmosphere brightness temperature (°C)

W = Wavelength of emitted radiance

E = Land Surface Emissivity

Table. 2- wavelength of emitted radiance for different satellite image

satellite	Band	W(µm)
Landsat 5	6	11.45
Landsat 8	10	10.8

For Landsat 5 data:

First of all, the conversion of DN to radiance was needed.

Conversion of DN to radiance:

$$L\lambda = \left(\frac{LMAX_\lambda - LMIN_\lambda}{QCALmax - QCALmin}\right)(\text{Qcal-Qcal min}) + LMIN_\lambda$$

Here in the formula ,

Lλ = At-sensor spectral radiance in [W/(m2 sr µm)]

Qcal = Landsat image (digital number DN)

Qcalmin = Minimum quantized calibrated pixel value corresponding to LMIN

Qcalmax = Maximum quantized calibrated pixel value corresponding to LMAX

LMINλ = Spectral -at sensor radiance that is scaled to Qcalmin [W/(m2 sr µm)]

LMAXλ = Spectral -at sensor radiance that is scaled to Qcalmax [W/(m2 sr µm)] Convert radiance to BT

Conversion of radiance to BT:

Conversion to At-Satellite Brightness Temperature TIRS band data can be converted from spectral radiance to brightness temperature using the thermal constants provided in the metadata file and the following equation:

$$T_{Sen} = \frac{k_2}{ln\left(\frac{k_1}{L_\lambda}\right) + 1}$$

Table. 3-Thermal Conversion Constants for Landsat images

Constant	Landsat 5 (band 6)	Landsat 8 (band 10)
K_1 (w/m^2/sr/µm)	607.76	774.89
K_2 (degree Kelvin)	1260.56	1231.08

Here,

Tsen = At-satellite brightness temperature (K)

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

K_1= Band-specific thermal conversion constant from the metadata

(K1_CONSTANT_BAND_x, where x is the thermal band number)

K2 = Band-specific thermal conversion constant from the metadata

(K2_CONSTANT_BAND_x, where x is the thermal band number)

Conversion of degree kelvin to degree Celsius:

C= K-273.15

Using these equations Land Surface Temperatures were calculated in the ArcGIS. Following the method described.

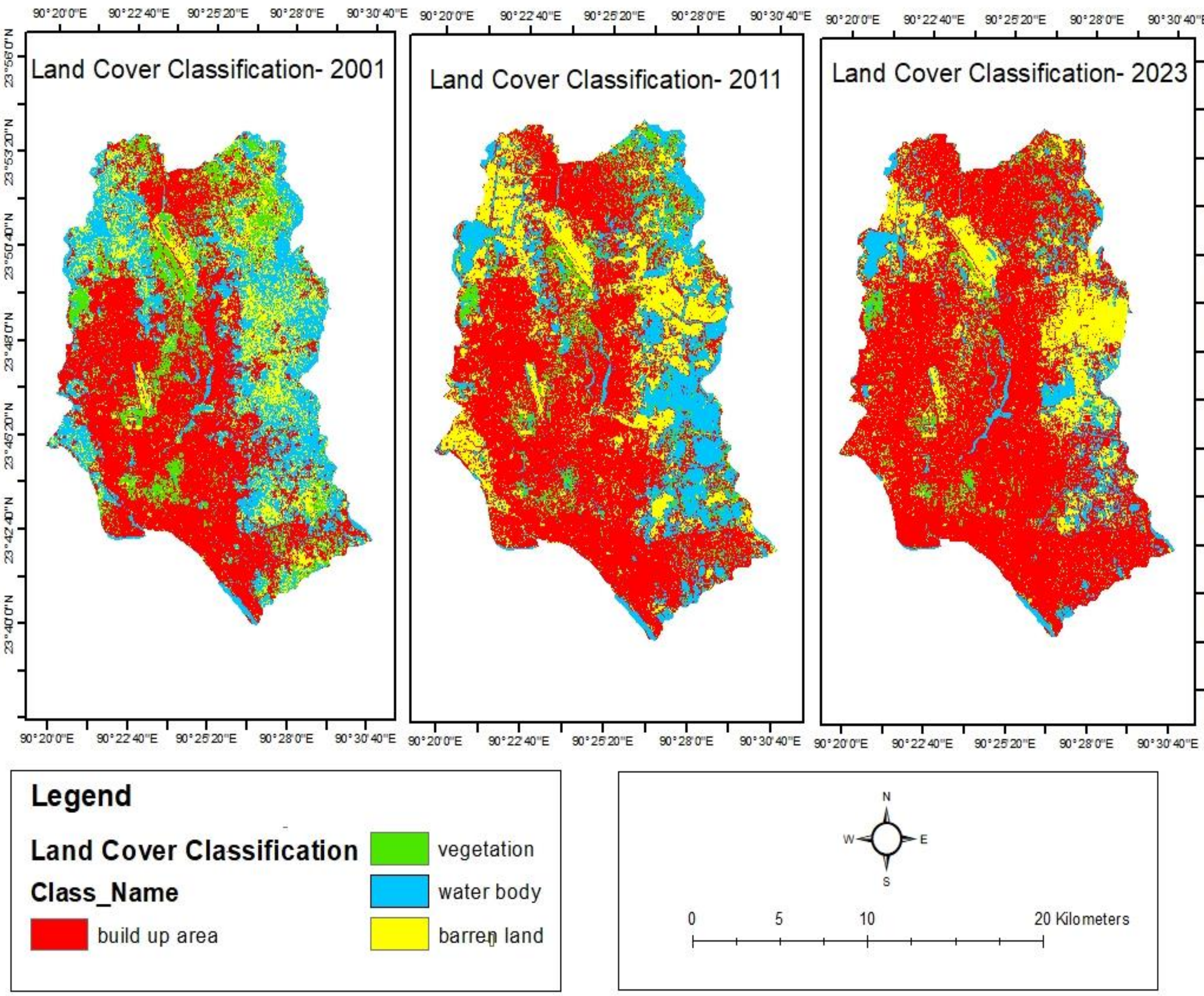
Chapter 4

Result and discussion:

4.1 Land cover classification:

The class determined the land cover area for the three years. From the Land Cover Classification maps of 2001, 2011 and 2023 we can clearly see that gradually the build-up area of Dhaka city is increasing and the vegetation cover is decreasing day by day. Land Cover percentage of each category shows that the build-up area of Dhaka city was 46% in 2001 and increases to 54% in 2011 and now in 2023 the build-up area has turned to 69% and it can be understood how rapidly the build-up area is increasing and the build-up area is increasing by replacing the water bodies and vegetation cover with the build-up area. And the decrease of vegetation cover in an area has huge impact on the surface area of that area. Besides the vegetation cover is decreasing from 2001 to 2023 gradually. It was 12% on 2001, became 7% on 2011 and its 2023 and the vegetation cover is 4% now. Which is very alarming. By observing the water bodies, we understand that the water body is also decreasing so the water bodies are turning into build-up areas. Waterbodies contribute in keeping the area cooler when the build-up area increases and water bodies decreases that also affects the temperature of that area. Which is shown in further analysis of Land Surface Temperature. The conversion of areas is also showed here, it is seen that the area of build-up area is continuously increasing.

Figure 2- Land cover classification maps for the years 2001,2011 and 2023



Here, the red color indicates the build-up area, green color indicates the vegetation cover, blue color indicates the water bodies and the yellow color shows the barren land of Dhaka city for the following years.

Below there the table-4 shows the amount of area each category occupies in square kilometer. And table-5 shows the percentage of build-up area, vegetation, water body and barren land for the following years. These values are calculated from these LULC maps.

Table. 4- Land cover area calculation for the years 2001,2011 and 2023

Class / Area in Sq.km	2001	2011	2023
Built-up	137.29	162.97	207.66
Barren land	47.81	55.48	49.58
Waterbody	80.78	61.64	32.13
Vegetation	35.0	20.79	11.52

Table. 5- Land cover percentage calculation for the years 2001,2011 and 2023

Class / Area in Sq.km	2001	2011	2023
Built-up	46%	54%	69%
Barren land	16%	18%	16%
Waterbody	27%	20%	11%
Vegetation	12%	7%	4%

4.2 Land cover change detection:

Land cover change detection was also performed in ArcGIS to understand and analyze the area change among the classes over the years.

According to table 6 – which is found from the change detection map of 2001-2011 and 2011-2023 it is seen that a major change occurred in barren land to build up are which proves that more area is being occupied by the build-up area. From the table it is seen that 12.8 km2 of land has converted to baren land to build up area. And in 2011-2023 29.4 km2 of land has transferred to build up area from barren land. Which is very clear that the barren land is transferring to build up area with time. Also, we can notice that the conversion of vegetation to build up is also noticeable. We can see the conversion from 2001-2011 is 15.7 km2 and from 2011-2023 it is 11.1 km2. Water body has also converted to build up area in these years. From the figure it is seen that from 2001-2011 water body has transformed to build up area 19.05 km2 and in 2011-2023 water body has converted to build up area 22.40 km2. This amount of conversion is also noticeable. The other conversions are also shown here from the change detection map ArcGIS.

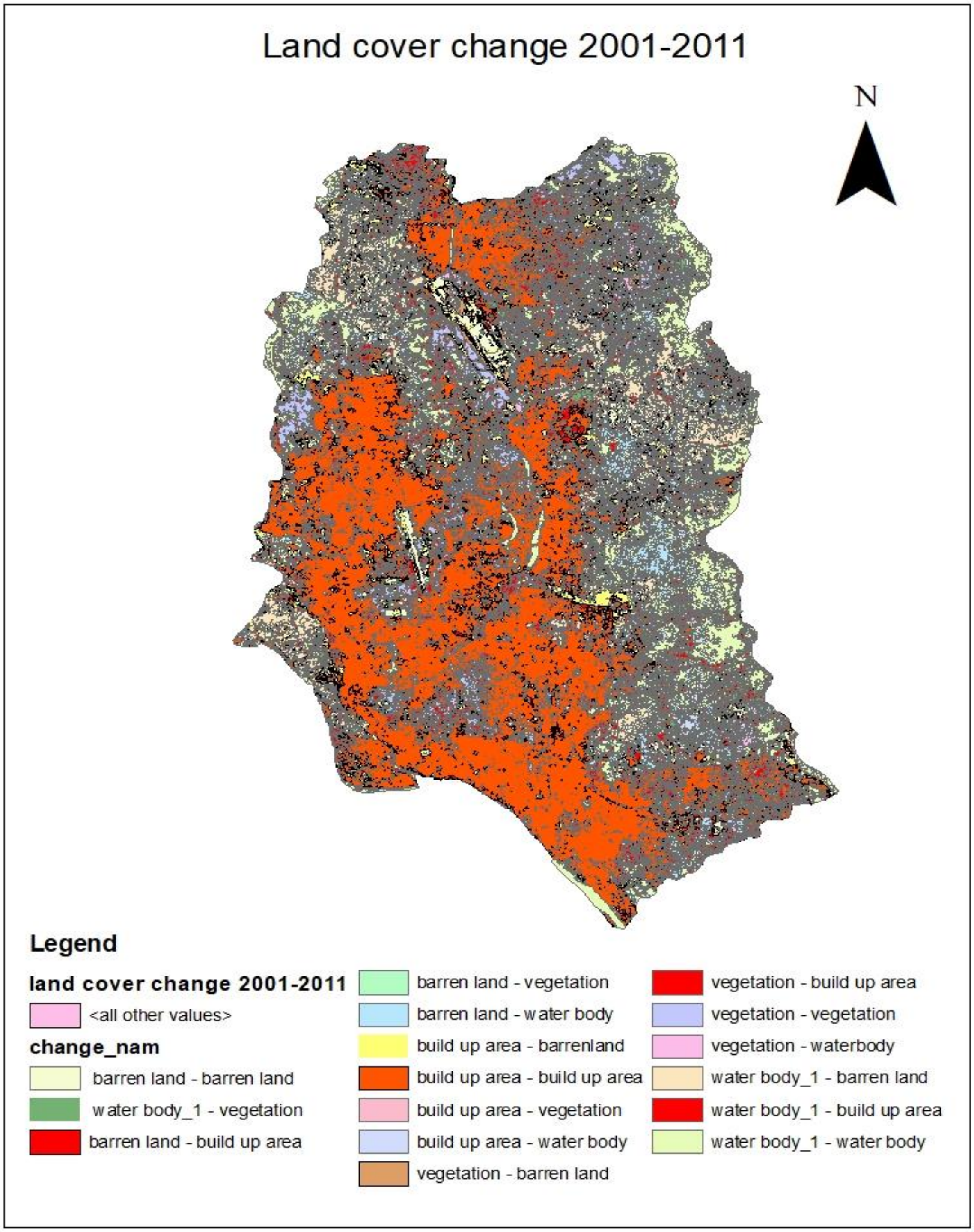
The changes of different type land cover show that there is a significant change in the land occupying the build up area. From the land cover map also, it is significant that other land types are converting to build up area from 2001 to 2023. Changes areas among 2001-2011 and 2011-2023 can be seen in the table below.

Table. 6- Area change detection from the years 2001-2011 and 2011-2023

Change	Area change - km2 (2001-2011)	Area change- km2 (2011-2023)
barren land - barren land	15.83	20.70
build up area – barren land	13.24	10.34
vegetation - barren land	4.08	2.17
water body - barren land	22.29	16.34
barren land - build up area	12.85	29.46
build up area - build up area	115.31	144.55
vegetation - build up area	15.70	11.13
water body - build up area	19.05	22.40
barren land - vegetation	3.27	1.50
build up area - vegetation	3.22	3.16
vegetation - vegetation	10.97	5.19
water body - vegetation	3.30	1.65
barren land - water body	15.82	3.76
build up area - water body	5.47	4.86
vegetation - waterbody	4.22	2.27
water body - water body	36.01	21.5
total change	300.70	300.70

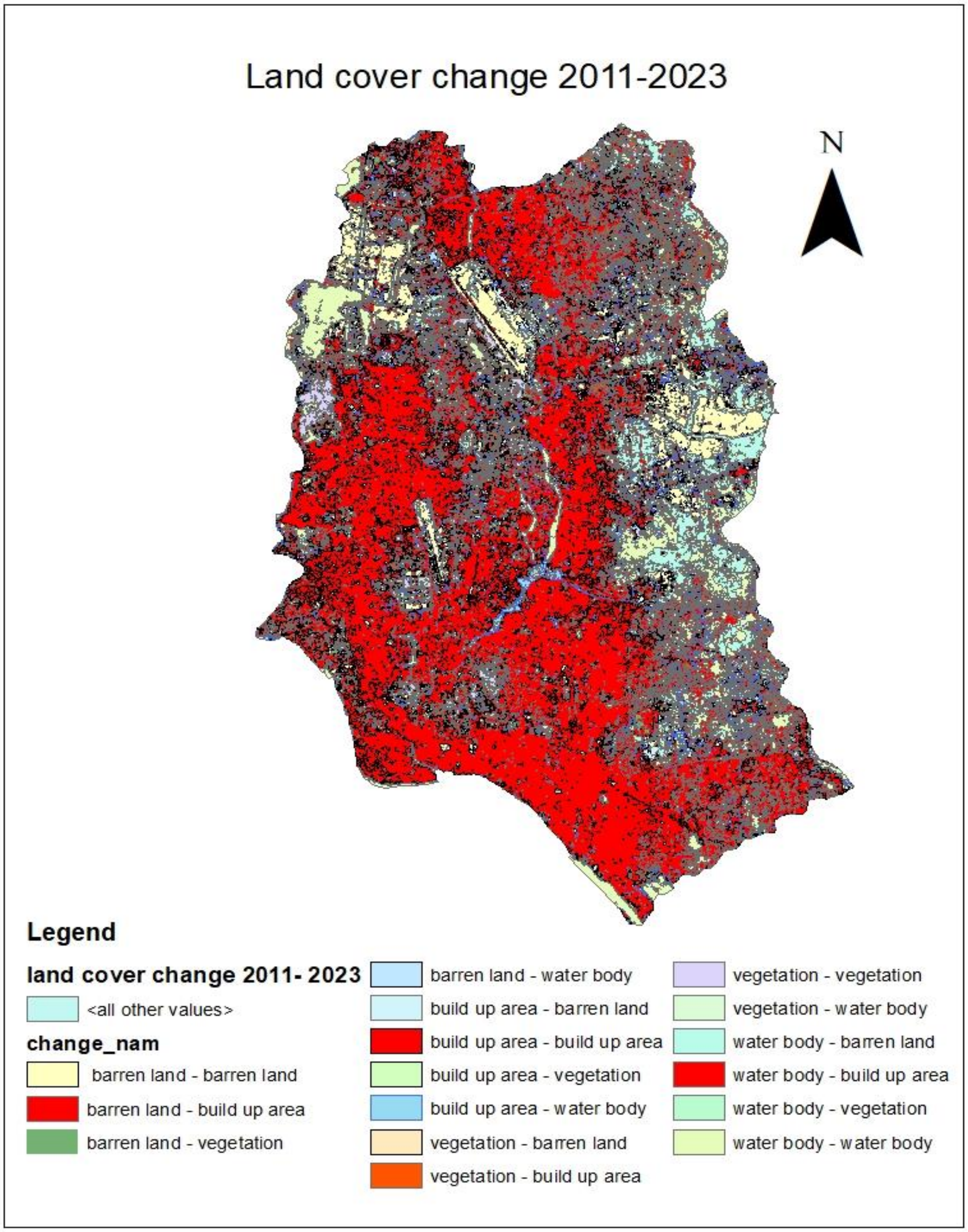
Here, in the Land Cover change map we can see different colors which indicate different land cover change over years.

Figure 3- Land cover change detection map from 2001-2011 of Dhaka city



Here the change detection between 2011-2023 can be seen below,

Figure 4- Land cover change detection map from 2011-2023 of Dhaka city.



4.3 land surface temperature change detection

Figure 5- Land surface temperature detection map for 2001 of Dhaka city

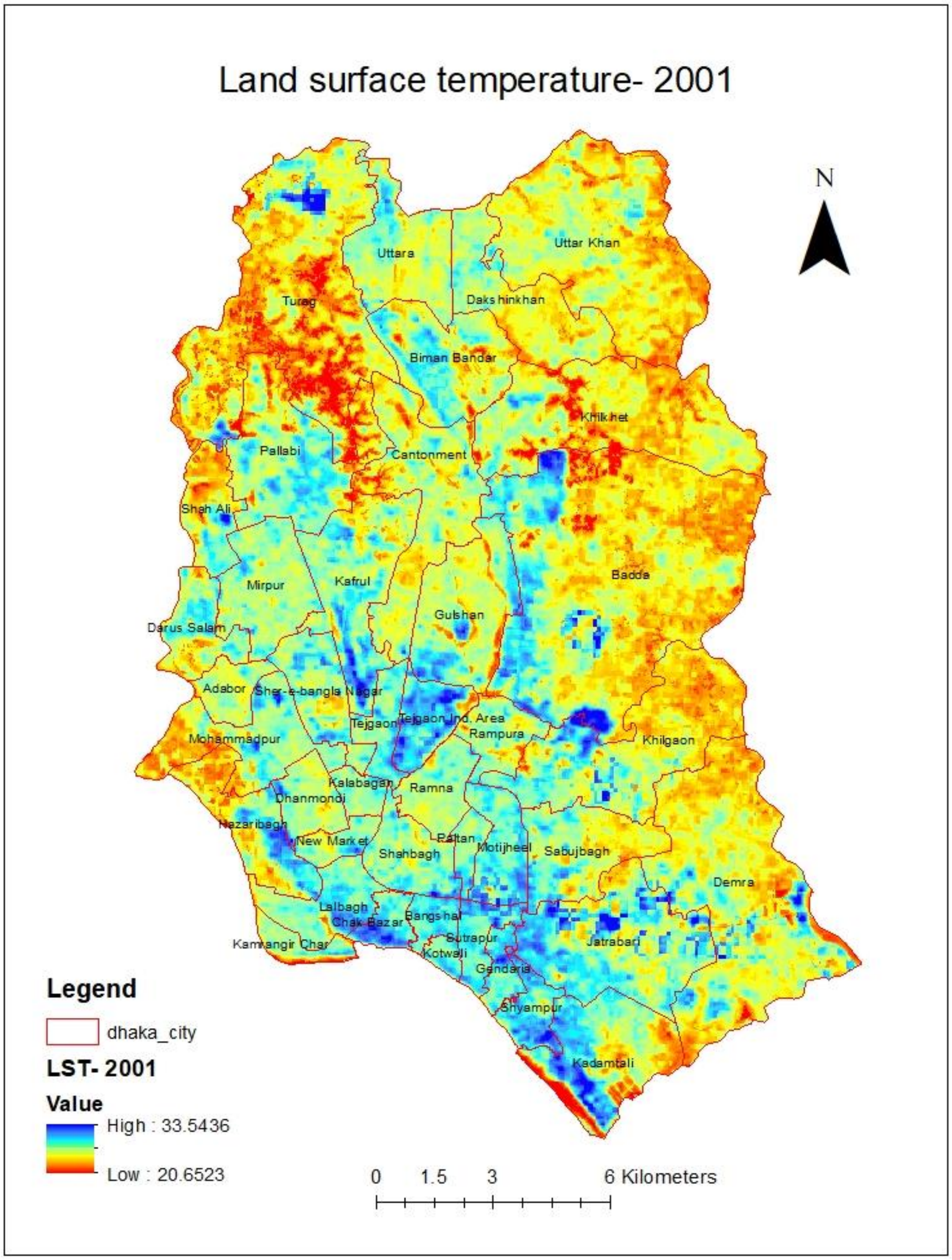


Figure 6- Land surface temperature detection map for 2011 of Dhaka city

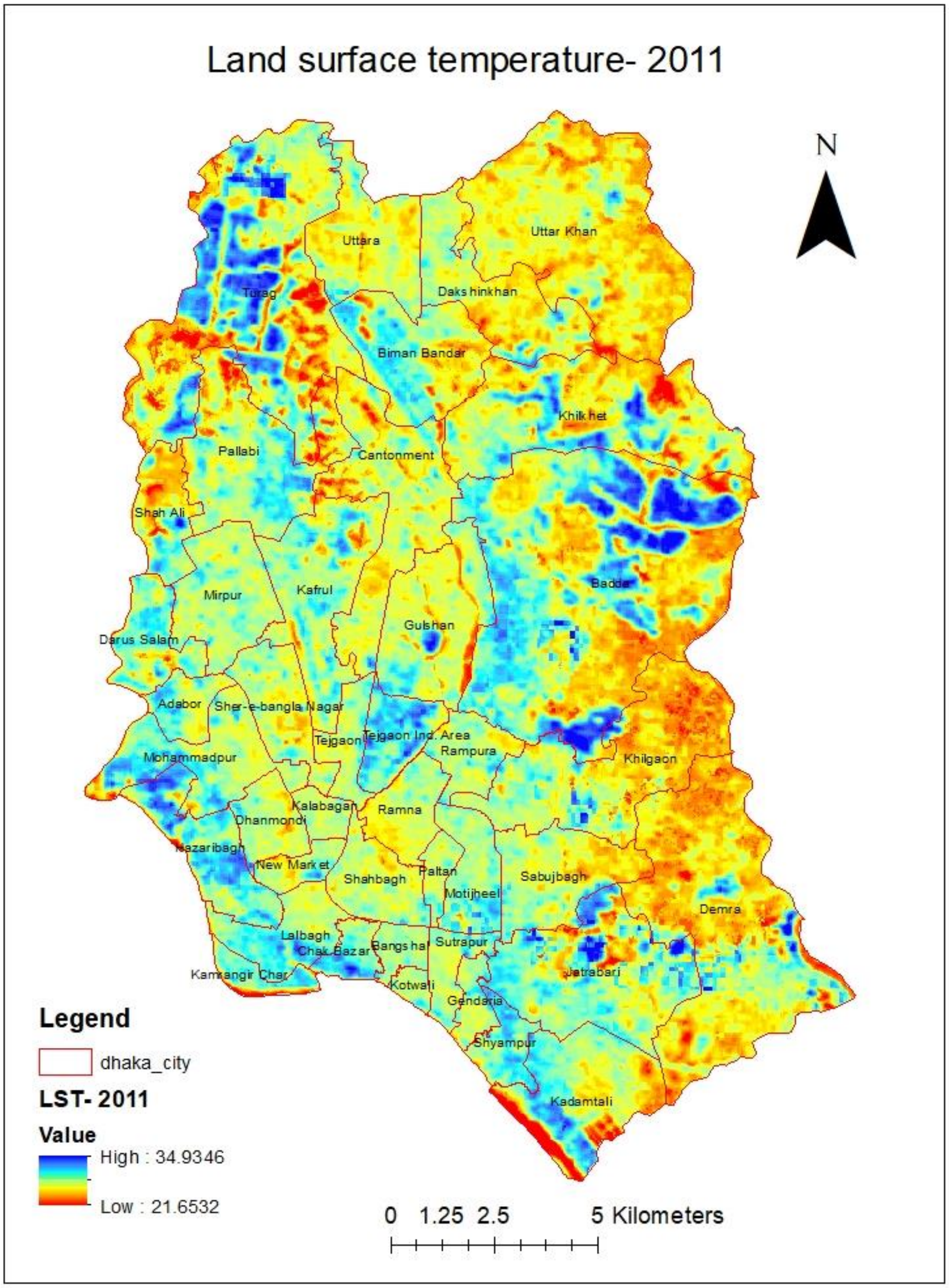
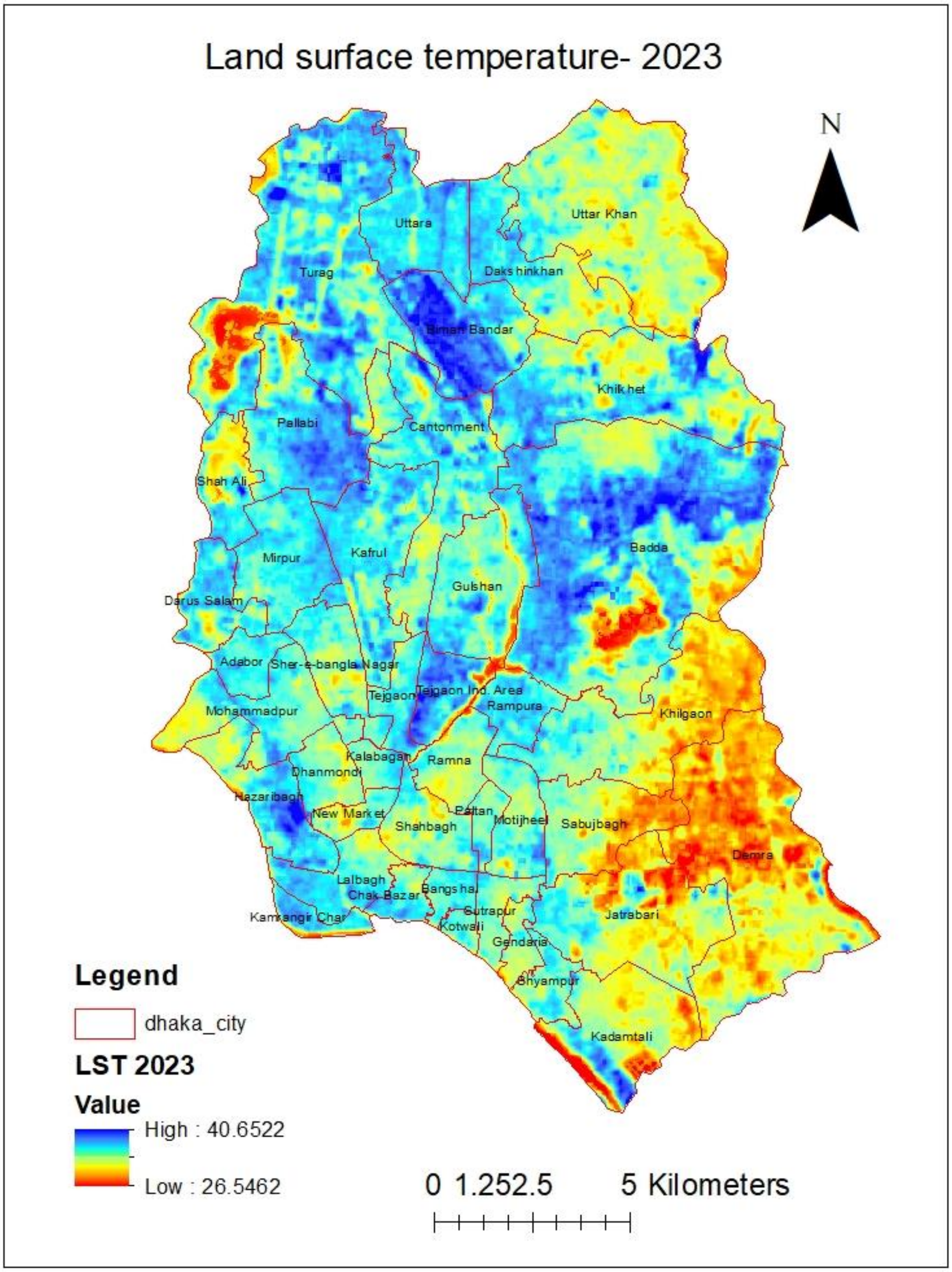


Figure 7- Land surface temperature detection map for 2023 of Dhaka city



4.4 Urban Heat Island effect analysis:

Land Surface Temperature maps of Dhaka city in these figures (figure 5, figure 6, figure 7) represent the maximum and minimum temperatures of the year 2001, 2011 and 2023. In the map the red colored areas show the minimum temperature and the blue colored areas show the maximum temperature. From different areas of the map. it is seen that the build-up areas are showing the high temperature, the temperature of the barren lands are also significantly higher than the vegetations and the water bodies and the water bodies are basically showing the low temperatures. We can see that the maximum temperature of 2001 was 33.5 and the minimum temperature was 20.65. and in 2011 the maximum temperature was 34.9 and minimum temperature was 21.65. but in 2023 the maximum temperature has become 40 and the minimum temperature has become 26.5. so, the lower temperature is increasing over years and the higher temperature is also increasing over years from 2001 to 2023. Which indicates the average temperature rise as well. All these pictures are taken in summer season. And from here we can understand that the Land Surface Temperature is increasing from 2001 gradually. So this temperature rise in the urban areas because of the increase of build-up area with urbanization is called the Urban Heat Island effect.

4.5 Urban Heat Island effect & Land cover change:

In figure 8, 9, 10, 11 the land surface temperature for different land cover type is showed. And maximum and minimum temperature of each category of land type is showed here. It is seen that in 2001 the minimum LST for build-up area was 22.04 ^{0} C and maximum LST for build-up area was 33.5 ^{0} C. and for water body the minimum LST was 20.6 ^{0} C and maximum LST was 25.1 ^{0} C. for vegetation cover the maximum and minimum LST was gradually 26.5 ^{0} C and 21.2 ^{0} C. for barren land the maximum and minimum LST was 32.6 ^{0} C and 21.9 ^{0} C. the Same way LST for different land types and for different years are showed here.

Figure.8,9,10,11 Land Surface Temperature detection map of 2001 for build-up area, vegetation, waterbody and barren land

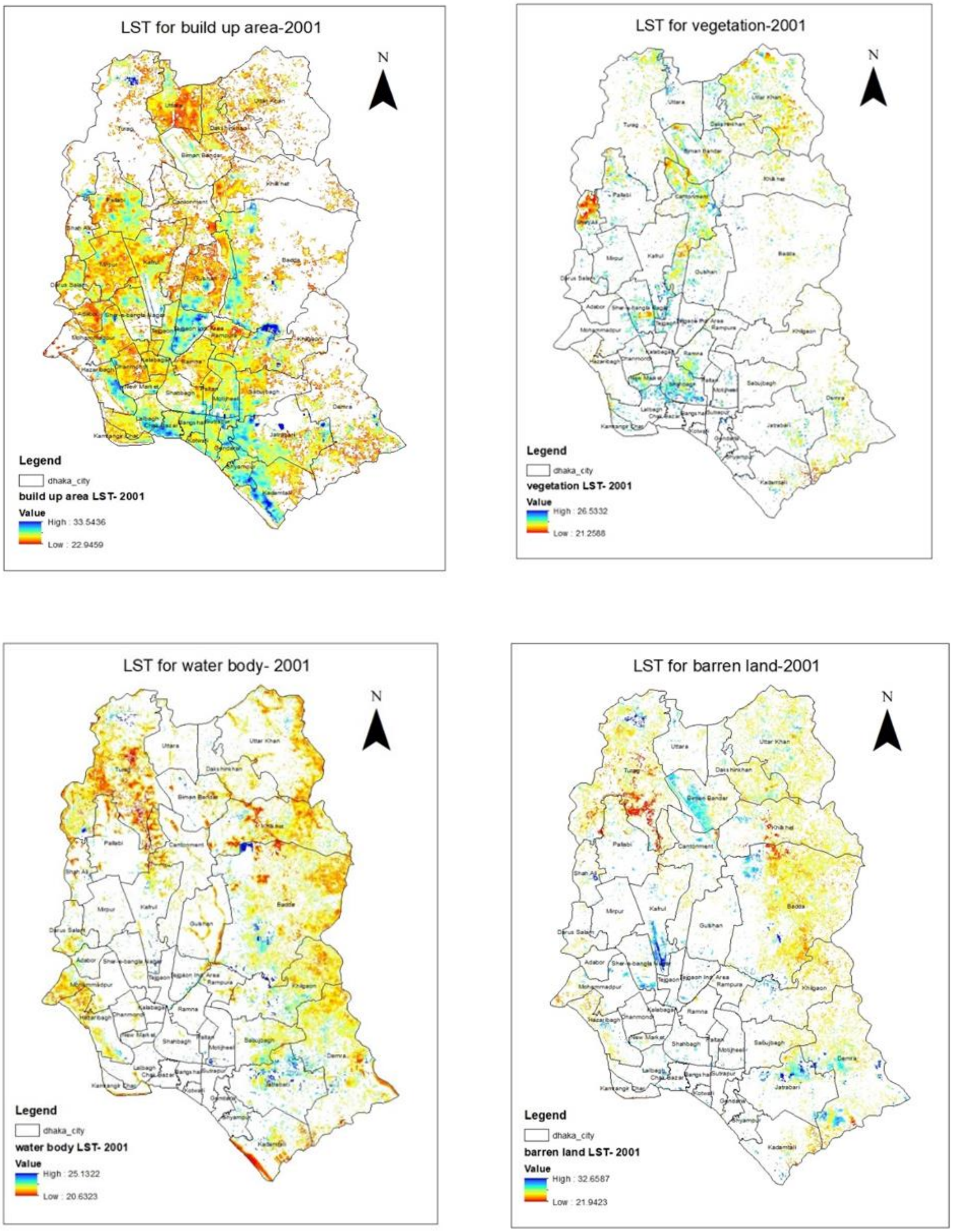


Figure. 12,13,14,15 - Land Surface Temperature detection map of 2011 for build-up area, vegetation ,water body and barren land

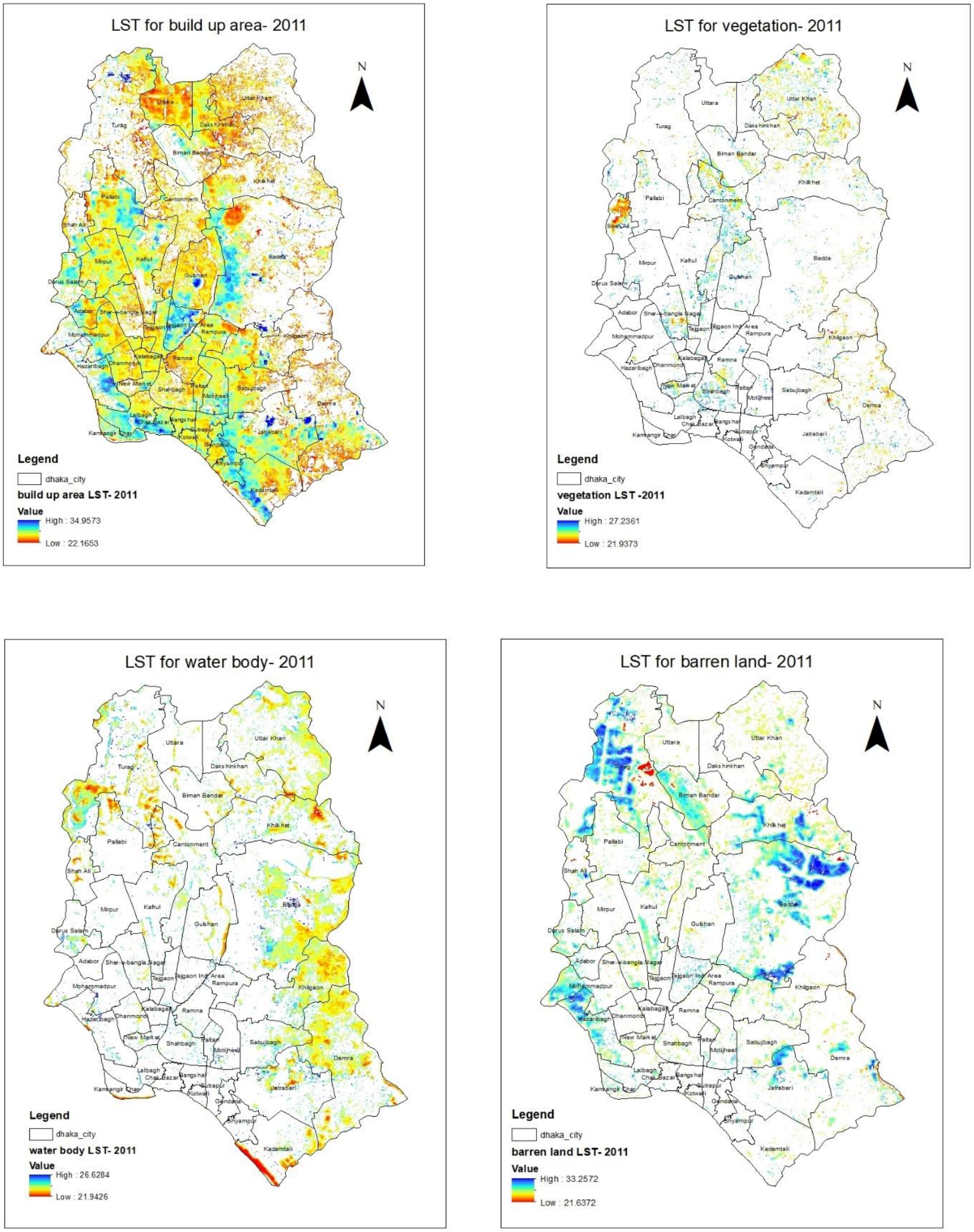
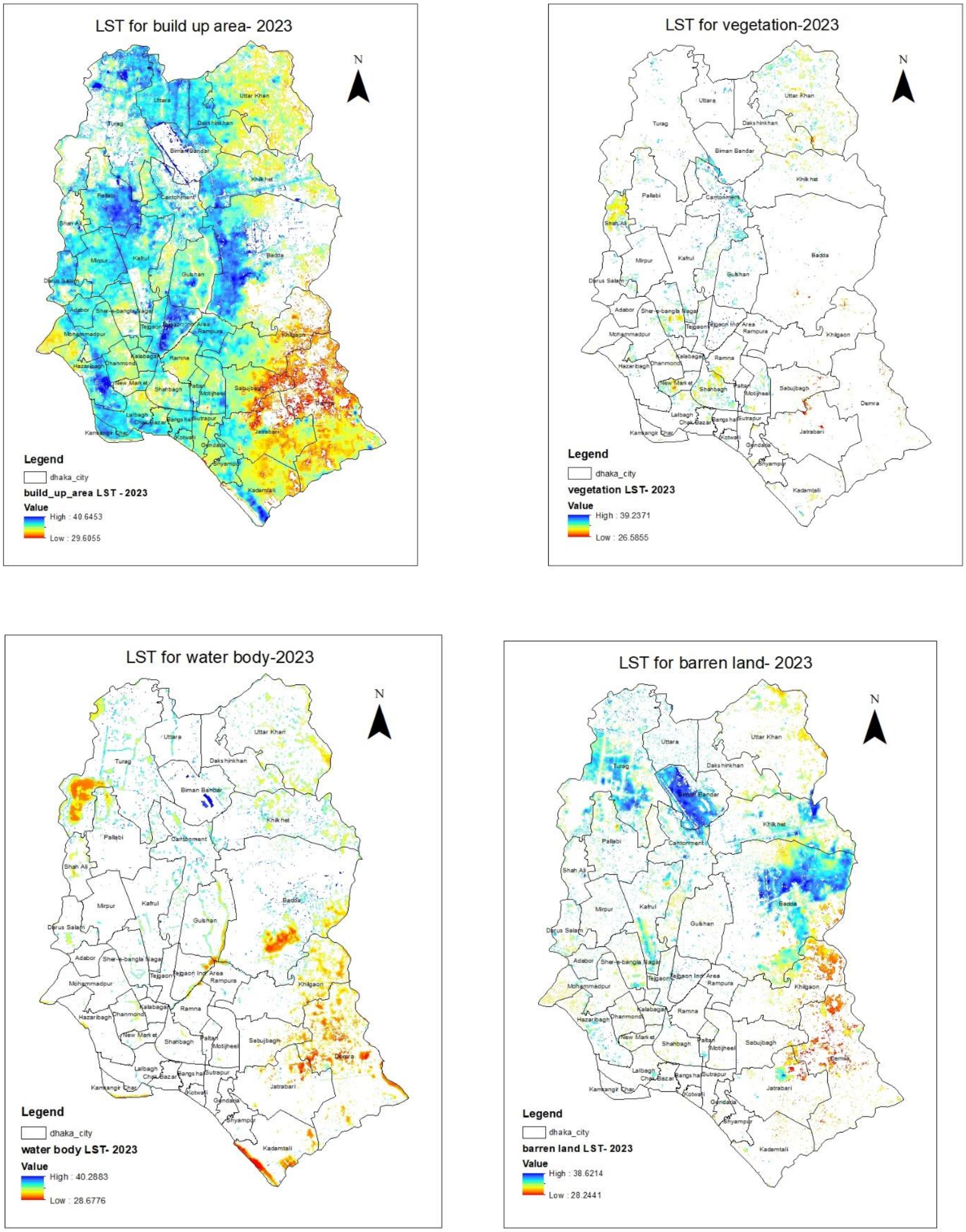


Figure. 16,17,18,19 - - Land Surface Temperature detection map of 2023 for build-up area, vegetation, water body and barren land



Land Cover change and Urban Heat Island effect:

Table.7- Land cover classes and their maximum, minimum and average LST

Class/LST(^{0}C)	2001			2011			2023		
	Avg.	Min	Max	Avg.	min	max	Avg.	Min	Max
Built-up	28.2	22.9	33.5	28.5	22.1	34.9	35.1	29.6	40.6
Barren land	27.3	21.9	32.6	27.4	21.6	33.2	33.4	28.2	38.6
Waterbody	23	20.6	25.1	24.2	21.9	26.5	34.4	28.6	40.2
Vegetation	23.8	21.2	26.5	24.5	21.9	27.2	32.8	26.5	39.2

In this table the minimum, maximum and average LST for each land cover types are shown from the map for the better realization of LST change over years in Dhaka city and from the table clear change of Land Surface Temperature over years are visible for different land type. In the map specifically the maximum and minimum temperature of specific land type for example barren land, water body, vegetation cover and build-up areas are showed for the years 2001 to 2023. And for each land time for the following years the maximum and minimum Land Surface Temperature are determined in ArcGIS and the values are showed in the table. The temperature has changed for each land types for the year of Significant temperature change in build-up area over years prove the visible heat island effect.

4.6 Limitation

- To show the temperature difference of Dhaka city with the nearest urban area, temperature data of nearest urban area was not found.
- For more precision of the study satellite image with 0% cloud cover was needed but for all the years summertime images with 0% cloud cover was not found in the website.
- Lack of the proper processing of the images can hamper the precision of the result.

Chapter 5

5.1Conclusion:

The identification of UHI effect for Dhaka city will help us to understand the extent of temperature rise and temperature difference between nearest rural area and the main city. Also, the impact on the micro climate will also be determined. Which will help us to understand the importance of greenness in the city and it will further help the government and urban planning sector to understand how to do the urban planning so that it doesn't stress the environment. In this research it has been found that the build-up area is increasing day by day. Build-up area was 46% on 2001 and it has become 69% on 2023. Also, it has been found that the LST is also increasing and the highest LST has been found for the build-up area. The highest LST is 40.6^0 C on 2023 which is found for build-up area and on 2001 the highest LST was 33.5^0 C which was also for build-up area. So, the build-up area is contributing to LST rise over time. From this research finding it can be understood that the increase of build-up area or urbanization is one of the important reasons for Urban Heat Island effect. It will also help the government to understand the recent situation and take measures to control the UHI effect in the city.

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