AN APPROACH TO ESTABLISH RELATIONSHIP BETWEEN URBAN GROWTH AND HEAT ISLAND EFFECT TO UNDERSTAND THE FUTURE IMPACT OF PROPOSED GUWAHATI MASTER PLAN 2025

Dissertation submitted in partial fulfillment

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in

Remote Sensing and GIS Applications

by

ASHMITA JESSIE SEN

GI-2876

pursued in

NORTH EASTERN SPACE APPLICATIONS CENTRE

Under

Supervision of

Shri SANTANU DAS	**Prof. SHADAB KHURSHID**
(Supervisor)	**(Co-Supervisor)**
Scientist/ Engineer- SC	Chairman IDRS & GIS Applications
NESAC	A.M.U.

Interdisciplinary Department of Remote Sensing & GIS Applications

ALIGARH MUSLIM UNIVERSITY

Aligarh, U.P.

उत्तर-पूर्वीअंतरिक्षउपयोगकेंद्र
भारतसरकार, अंतरिक्षविभाग
उमियम - 793103, मेघालय
दूरभाष : 0364-2570140, 2570012, 25701411
फैक्स : 0364-2570139

NORTH EASTERN SPACE APPLICATIONS CENTRE
Government of India, Department of Space
Umiam - 793103, Meghalaya
Tele : 0364-2570140, 2570012, 2570141
Fax: 0364-2570139

CERTIFICATE

This is to certify that **Ms. Ashmita Jessie Sen** (Enrollment No.- GI-2876), Interdisciplinary Department of Remote Sensing & GIS Applications, Aligarh Muslim University, Aligarh has worked under my supervision and guidance at North Eastern Space Applications Centre, Department of Space, Government of India within a work-span ranging from 07th January 2019 to 15th April, 2019. She has successfully submitted the project entitled, **"An approach to establish relationship between Urban Growth and Heat Island Effect to understand the future impact of Proposed Guwahati Master Plan 2025"** in partial fulfillment of the requirement for the award of Degree of Masters in Remote Sensing & GIS Applications by Aligarh Muslim University, Aligarh 2017-2019.

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Shri Santanu Das

External Supervisor
Scientist/Engineer-SC
North Eastern Space Applications Centre
Dept. of Space, Govt. of India
Umiam (Meghalaya)

Prof. Shadab Khurshid
Chairperson

Interdisciplinary Department of Remote Sensing and GIS Applications
ALIGARH MUSLIM UNIVERSITY
ALIGARH- 202 002
Email ID: khurshidshadab@yahoo.com
Phone No: +91- 9897048619

CERTIFICATE

This is to certify that Miss Ashmita Jessie Sen has been carried out the M. Sc. Dissertation work entitled "***An approach to Establish Relationship Between Urban Growth and Heat Island Effect to Understand the Future Impact of Proposed Guwahati Master Plan 2025*"** under my co-supervision for the partial fulfilment of master of Science Degree in Remote Sensing and GIS Applications from Aligarh Muslim University.

She has completed the dissertation in the North Eastern Space Application Centre (NESAC) Umiam, Shillong with effect from 07.01.2019 to 15.04.2019.

I wish her all the success in future life.

Professor Shadab Khurshid
(Co-supervisor)
Chairman, Interdisciplinary
Department of Remote Sensing
and GIS Applications
AMU

Bonafide Certificate

This is to certify that the project report entitled "An approach to establish relationship between urban growth and heat island effect to understand the future impact of proposed Guwahati Master Plan 2025" submitted by Ashmita Jessie Sen to the North Eastern Space Applications Centre, Umiam, Shillong and Aligarh Muslim University, in partial fulfillment for the award of the degree M.Sc. in Remote Sensing & GIS Applications, is a bonafide record of the project work carried out by her under my supervision from 05/01/2019 to 15/04/2019.

Shri Santanu Das
Scientist/ Engineer (SC)
Remote Sensing & GIS
North Eastern Space Applications Centre
Umiam, Shillong

Place: Umiam, Shillong

April, 2019

DECLARATION BY AUTHOR

This is to declare that this report entitled **" An approach to establish relationship between Urban Growth and Heat Island Effect to understand the future impact of proposed Guwahati Master Plan 2025"** is written by me. No part of the report is plagiarized from other sources. All information included from other sources has been duly acknowledged and I affirm that if any part of the report is found to be plagiarized, I shall take full responsibility for it.

ASHMITA JESSIE SEN
GI-2876
M.Sc in Remote Sensing and GIS Applications
Aligarh Muslim University

Place: Umiam, Shillong
Date: 15/04/2019

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ABSTRACT

In today's fast life, we have forgotten what it really means to make the world a better place to live in. With the advancements in technology and development, it takes a great cost to our loss i.e., our planet. The increasing of Earth's temperature remains an important concern. This study is about linking urban growth with the heat island effect to understand the future impact of proposed Guwahati Master Plan 2025 in the city of Guwahati, Assam. This linking has been done by using growth trend analysis (GTA). In ArcGIS software, after the calculation of NDVI, NDBI and LST of the satellite imageries of 20 years of time period with 5 year interval, the built-up area and dense vegetation area has been extracted followed by the growth trend analysis of all those and has been used to predict the need of reducing heat island effect with the increasing built-up area by increasing greenery. So as to maintain the ratio between Built-up and dense Vegetation of 3:1 and to attain the temperature in 2004 i.e., 11.7 ˚C, the dense vegetation required to tackle the UHI effect in Guwahati master plan 2025 came out approximately to be 57.13km^2 and this required dense vegetation can be attained by green roofs, parks, reserves and green belts.

Keywords: Urban heat island effect, Urban growth, Guwahati Master Plan 2025, Growth trend analysis, Land surface temperature

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LIST OF ABBREVIATIONS

UHI	Urban Heat Islands
ET	Evapotranspiration
CLHI	Canopy Layer Heat Island
BLHI	Boundary Layer Heat Island
SHI	Surface Heat Island
UHII	Urban Heat Island Intensity
BU	Built-up
DV	Dense Vegetation
BT	Brightness Temperature
LST	Land Surface Temperature
NDVI	Normalised Difference Vegetation Index
NDBI	Normalised Difference Built-up Index
PV	Proportion Vegetation
USGS	United States Geological Survey
UCL	Urban Canopy Layer
CBD	Central Business District
AHS	Average Heat Signature

Chapter-1

1. INTRODUCTION

1.1. Phenomenon of UHI

The increasing urbanization is one of the greatest anthropogenic processes responsible for abnormal behaviour of our environment. The heat is created by energy from dense population, vehicular emissions and many more, and the buildings made of concrete or asphalt are impermeable which makes the evapotranspiration to get to the minimum possible rate with trapping all the heat produced making a place warmer than its surroundings. *Therefore, **UHIs** or **Urban Heat Islands** can simply be called as the urban area which is comparatively warmer than the surrounding fringe or rural areas.*

UHIs can be studied using remote sensing. Thermal remote sensing is a type of passive remote sensing since it detects naturally emitted radiation. Most thermal remote sensing in conducted in the 3-5 μm and 8-14 μm wavelengths. Remote sensing let us map the pattern of UHIs for an entire region. Infra-red imagery of a geographical location is provided by satellites such as LANDSAT, or by images captures from thermal cameras mounted on aircrafts made to fly over the given city. Thermal remote sensing is a type of passive remote sensing since it detects naturally emitted radiation. Most thermal remote sensing in conducted in the 3-5 μm and 8-14 μm wavelengths.

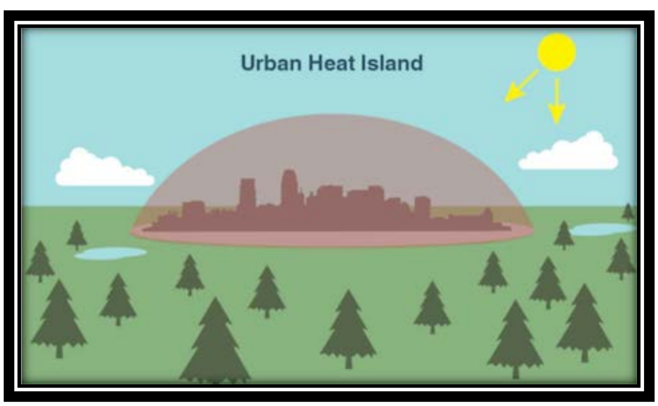


Fig. 1: Urban Heat Island Phenomenon

1.2. Factors affecting UHIs

- *Geographic location:* Climate, Topography, Rural Surrounding.
- *Time:* Day, Season.
- *Synoptic Weather:* Wind, Cloud.
- *City Form:* Materials, Geometry, Greenspace.
- *City Function:* Energy use, Water use, Pollution.

1.3. Causes

1.3.1. Dark surfaces like roads and roofs made of concrete and asphalt: When vegetated surfaces with moist soil underneath are exposed to direct sunlight, the temperature of the heat absorbed is only around 18°C (Gartland, 2012). However, the temperatures absorbed by dark and dry surfaces exposed to the same conditions can reach up to 52°C (Ibrahim et al., 2014).

E.g.- We prefer to wear a white T-shirt in summers than a black one because black is absorbent while white reflects. In the same way, our atmosphere reacts to man-made buildings.

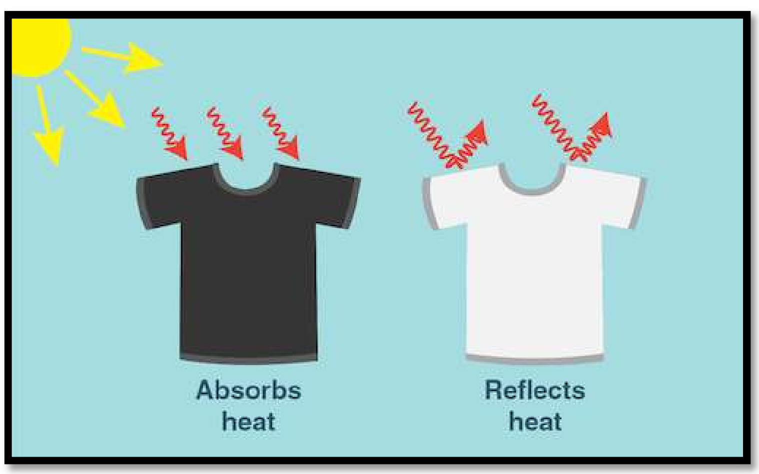


Fig. 2: Difference between black and white materials

1.3.2. Waste heat: (The unused heat given to the surrounding environment) Waste heat from human activity exacerbates this phenomenon. Some of the most notable sources of waste heat are air conditioners and emissions from vehicle engines.

Fig. 3: Some examples of waste heat

1.3.3. Lack of evapotranspiration: Theoretically, vegetation ET consumes large amounts of heat in the form of latent heat and can effectively reduce urban temperatures. Therefore, when the moist and permeable turns into dry and impermeable surface, it leads to formation of UHIs.

1.3.4. Increasing pollution level: High levels of pollution in urban areas can also increase the UHI, as many forms of pollution change the radiative properties of the atmosphere.

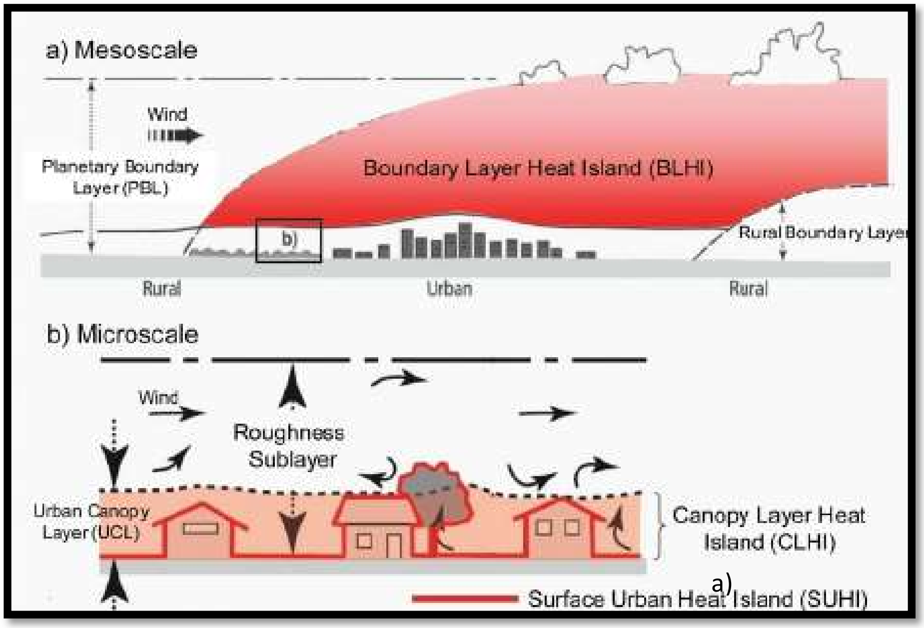
Fig. 4: Pollution destroying EARTH

1.4. Types of UHIs

1.4.1. Canopy layer heat island (CLHI): The UHI is typically presented as a temperature difference between the air within the UCL and that measured in a rural area outside the settlement. Research strategies have examined the temporal and spatial characteristics of UHI by using observations at fixed sites (representing urban and rural locations) and measurements made on mobile platforms (using cars and bicycles). In both cases, the selection of sites and routes is critical to establishing the form and behaviour of the UHI. Moreover, the choice of the non-urban, rural, sites is crucial.

1.4.2. Boundary layer heat island (BLHI): The urban warmth extends into the UBL (above the RSL) through convergence of sensible heat plumes from local scale areas (bottom-up) and the entrainment of warmer air from above the UBL (top-down) to create the boundary-layer UHI. Radiative interactions through the polluted boundary layer may also be important. A few airplane, helicopter, remote sensing, balloon, and tower studies despite having experimental difficulties have been conducted since the 1960s in a wide range of cities.

1.4.3. Surface heat island (SHI): The surface UHI is defined by the temperature of the surface that extends over the entire 3-D envelope of the surface. Urban surface temperatures contain strong microscale patterns that are sensitive to the relative orientation of the surface components to the sun by day and the sky at night, as well as to their thermal (e.g., heat capacity, thermal admittance) and radiative (e.g., reflectivity or albedo) properties. The magnitude and temporal variation of the surface heat island are well known. It is strongest during daytime when solar heating creates large differences between dry/wet and vegetated surfaces and the response is dominated by exposed, horizontal surfaces such as roofs and pavements. During daytime, the warmest surfaces are measured in industrial–commercial zones, especially those with large, flat-topped buildings or extensive open areas of pavement (e.g., airport, shopping malls, and major highway intersections) rather than in the CBD where buildings are tall and roofs are not the principal surface.



c)

Fig. 5: Types of Urban Heat islands

a) Canopy Layer Heat Island

b) Boundary Layer Heat Island

c) Surface Urban Heat Island

NOTE: Out of these three, what we are concerned about are the SHIs.

1.5. Impact of the Urban Heat Island

Some positive impacts could result from UHI, such as reductions in energy required for heating, the melting of ice on roads during the winter and lengthening the growing season in the city. But meddling with the cycles of nature can result in more negative effects than the positive ones. Hence, the most frequent negative impacts in urban areas are:

1.5.1. Increased Energy Consumption

As we see today, the energy demand for cooling increases in summertime temperatures in cities and which eventually applies pressure to the electricity demand which increases by 1.5–2.0% for every 1°F (0.6°C) increase in air temperatures, suggesting that 5–10% of community-wide demand for electricity is used to compensate for the heat island effect.

During extreme heat events, which are exacerbated by urban heat islands, the resulting demand for cooling can overload systems and require a utility to institute controlled, rolling brownouts or blackouts to avoid power outages.

1.5.2. Fossil Elevated Emissions of Air Pollutants and Greenhouse Gases

Now, we know that the electricity supplied to us need fossil fuels to be made by power plants and which results in increase in air pollutants and greenhouse gases. The primary pollutants from power plants can be Sulphur dioxide (SO_2), Nitrogen oxides (NO_x), Particulate matter (PM), Carbon monoxide (CO), Mercury (Hg), etc.

These pollutants tend to mean harm to human health causing diseases like asthma, cancer, heart and lung ailments, neurological problems. Also, lead to air quality problems like acid rain, global warming, ground-level ozone (smog), etc.

Ground-level ozone is formed when NO_x and volatile organic compounds (VOCs) react in the presence of sunlight and hot weather. If all other variables are equal, such as the level of precursor emissions in the air and wind speed and direction, more ground-level ozone will form as the environment becomes sunnier and hotter.

1.5.3. Compromised Human Health and comfort

Human health can be affected by increasing heat island effect causing discomfort, respiratory difficulties, heat cramps and exhaustion, non-fatal heat stroke, and heat-related mortality. They can also exacerbate the impact of heat waves, which are periods of abnormally hot, and often humid, weather which can be harmful for infants and old aged people.

Excessive heat events can result in above-average rates of mortality. The Centres for Disease Control and Prevention estimates that from 1979–2003, excessive heat exposure contributed to more than 8,000 premature deaths in the United States. This figure came out to exceed the number of mortalities resulting from hurricanes, lightning, tornadoes, floods, and earthquakes combined.

1.5.4. Impaired Water Quality

High pavement and rooftop surface temperatures can heat stormwater runoff. Tests have shown that pavements that are 100ºF (38°C) can elevate initial rainwater temperature from roughly 70ºF (21ºC) to over 95ºF (35ºC). This heated stormwater is released into streams, rivers, ponds, and lakes.

Rapid temperature changes in aquatic ecosystems resulting from warm stormwater runoff can cause stress or even be fatal to aquatic life.

1.6. Aim

- To find a link between land use change and urban heat islands and find out some measures to combat the increasing heat accordingly.

1.7. Objectives

- Thorough study of Guwahati and its land surface temperature.
- To find how the population and increasing built up land affect the land surface temperature.
- To analyse the Master plan 2025 of the city with perspective of heat islands.
- To minimise the impact of urban heat islands through implementation of urban forestry.

1.8. Future Scope

- The work done can be the base for 2025 Guwahati Master Plan to efficiently increase built up land without much increase in daily temperature.
- The place can experience increment in tourism making it economically beneficial for state and national level both.

Chapter-2

2. STUDY AREA

2.1. Location

- Guwahati is located at 26.1445˚ N, 91.7362˚ E in Assam, India.
- It is spread within the area of 328 km^2 with a population of 9.57 lakhs according to 2011 census.
- It has an altitude of 55 metres above sea level situated on the banks of the mighty Brahmaputra.
- Guwahati is the junction of three important roads- National highways 31, 37 and 40.

2.2. Guwahati and its climate

The climate in Guwahati is warm and temperate. When compared with winter, the summers have much more rainfall. The average annual rainfall is 1698 mm with the Köppen-Geiger climate classification of Cwa. The average annual temperature in Guwahati is 24.6°C.

Guwahati, gifted with beautiful places to visit leaves it as the centre of attraction for tourists which subsumes having temples, national park, diverse wildlife and many more.

But besides the social life, with increasing built-up land, main concern becomes the increasing heat in the city in comparison to the nearby regions due to anthropogenic activities which is commonly referred to as **URBAN HEAT ISLANDS**.

In context to the Guwahati Master Plan 2025, govt is already working hard to overcome the possible increase in temperature but with increase in built up land, more effective measures need to be taken.

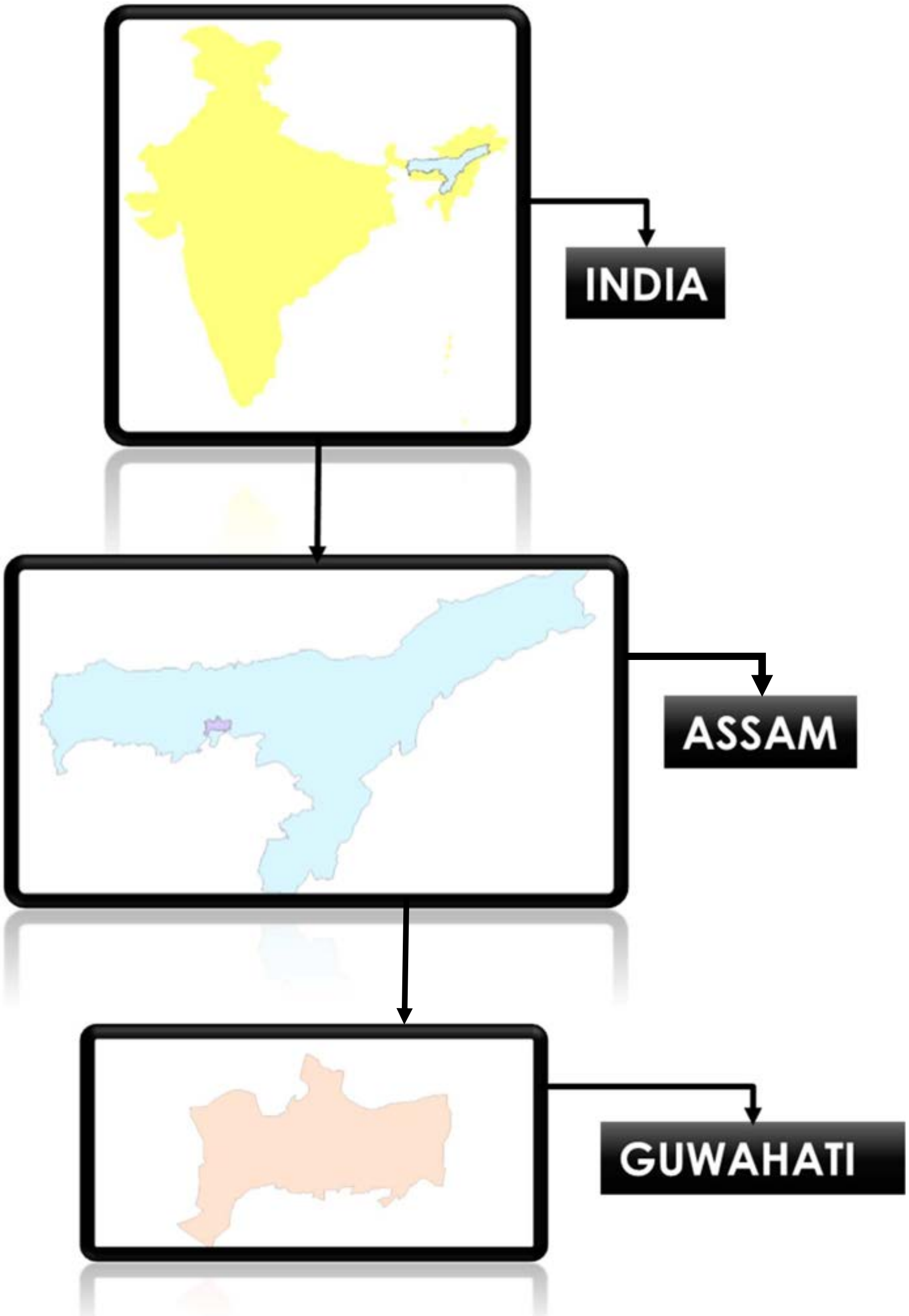


Fig. 6: Study area- Location

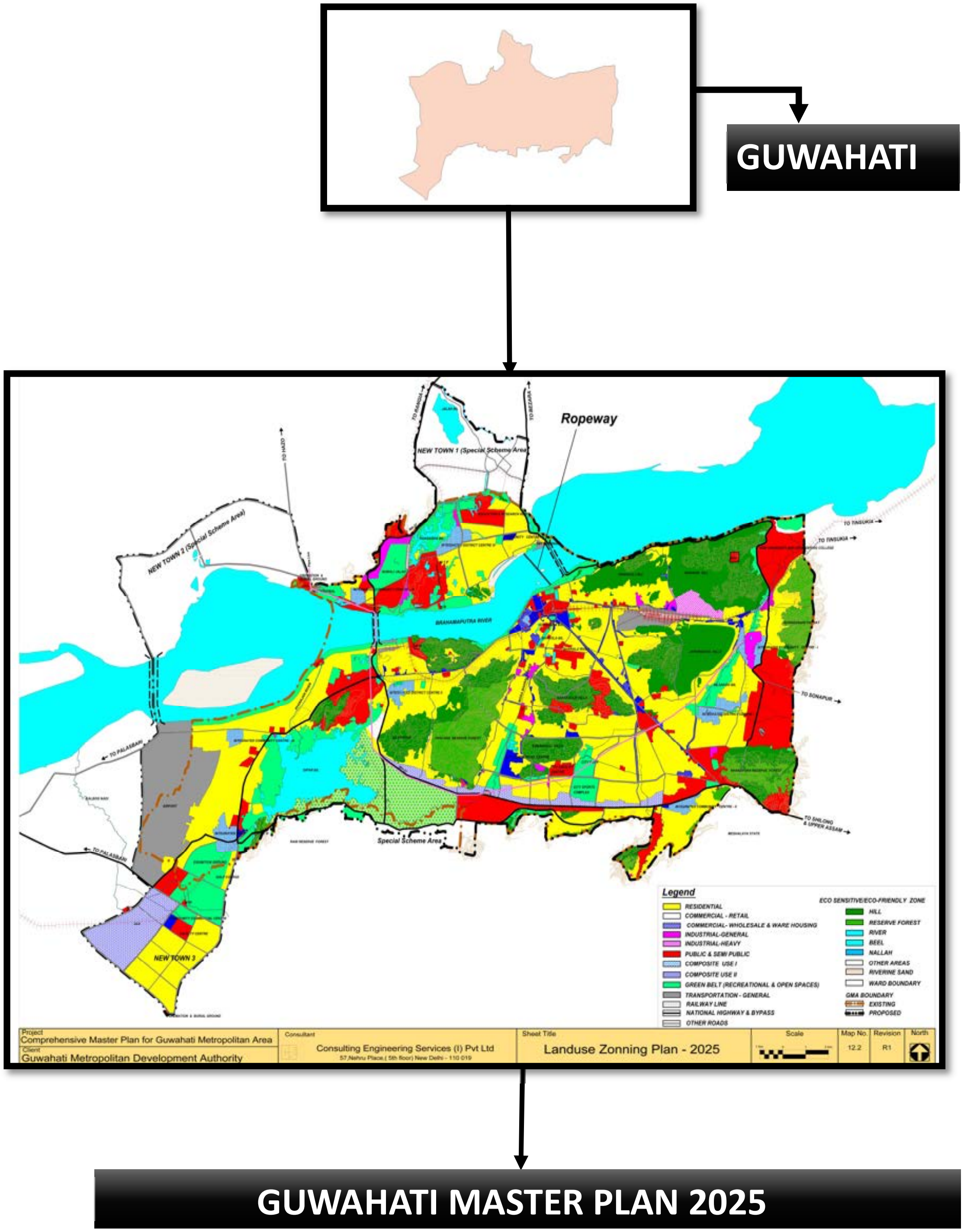


Fig. 7: Guwahati Master Plan

Chapter-3

3. LITERATURE REVIEW

Luke Howard in 1833 started work on UHIs with study area as London. He concluded that the temperature of the city was not its climate, rather it has some additional warmth and which was because of the structure of the city, the large population and usage of fossil fuels. His analysis was based on temperature records at three different sites outside London namely Plaistow, Tottenham and Stratford and one site (Royal Society) within London.

Jones et al. determined that the impact of urbanization on the temperature time series has been 0.05°C/100 years for a large part of the northern hemisphere. This result was based on the work of **Karl et al.** for the United States which showed an urban influence of 0.15°C over the period 1901-1984, extended with further analysis of European parts of the Soviet Union, eastern Australia and eastern China.

Gallo et al. looked at clusters of 1221 weather observation stations that composed the US Historical Climatology Network and designated as urban, suburban, or rural, based on data from the Defence Meteorological Satellite Program Operational Linescan System. They concluded that the general (urban, suburban or rural) land use/land cover was associated with surface observation stations and may influence the trends observed in temperature. Their study found an average of 0.3°C of more warmth during the summer months than others.

Hansen et al. compared the United States and global surface air temperature changes of the past century using the current Goddard Institute for Space Studies (GISS) based on data of the Global Historical Climatology Network (GHCN) for determining long-term trends. Evidence of local human effects (urban warming) even in suburban and small-town surface air temperature records were found. They found a decline of about 0.5°C in the U.S. mean temperature between the early 1930s and the late 1970s, with the greatest cooling in the South-Eastern U.S., while the global temperature declined only about 0.1°C.

Stone studied temperature data from urban and rural stations for 50 large US metropolitan areas and analysed the mean decadal rate of change in urban temperatures, rural temperatures and heat island intensity of large US cities over five decades (1951-2000). The mean rate of UHII for cities experiencing growth in heat island intensity over time was found to be about four times greater (almost 0.2°C/decade) than the mean for all cities.

Santamouris examined the UHI phenomenon in 100 Asian and Australian cities and regions, reviewing 88 scientific articles. In most of the cities the maximum UHII was observed during the late afternoon, night or early morning period. However, in many Asian cities the maximum intensity was the measured UHII in Asia and Australian cities was quite significant and varied from 0.4-11°C. The average UHII was 4.1-5°C (mobile and non-standard stations). In standard measuring stations, the UHII was 1°C annually and the average maximum 3.1°C.

Wang et al. used 42 pairs of urban-rural stations in China from 1954-1983. They found an average UHII of 0.23°C over this 30-year period and an increase of about 0.1°C. The UHI was found to have seasonal dependence and varied across the country. Seasonal variations were found and UHII varied annually from 0.15-0.26°C where it was found that the annually maximum was 0.28-0.33°C in spring and minimum annually 0.06-0.10°C in summer and autumn. The mean annual urban warm bias increased 0.19°C during these 30 years.

Jiahua and Fengmei investigated the UHI in Beijing (China) using MODIS data and concluded that the land surface temperature difference is approximately 4-6°C between the city of Beijing and suburban areas and 8-10°C between the city center and north-western far (outer) suburbs in the summer time (evening or late night). This big difference between the city and suburban areas is attributed to surface absorption and deposition of heat. **Cai et al.** also detected the UHII in Beijing from 2002 to 2006 with a combination of Advanced Spaceborne Thermal Emission, Reflection Radiometer (ASTER) and Thematic Mapper (TM) data. Their results showed that the UHI effect has not been proportional to urbanization over time. Most areas in Beijing have a high UHI effect, especially in industrial areas with iron and steel factories, thermo-electric plant, foundry and many other factories. Higher temperature accrued by the high density of factories, which consume large amounts of heat. Moreover, industrial workshops and airport also have a strong UHII as well as areas with higher density of buildings, roads, transportation systems and residents.

Giridharan et al. investigated the impact of design-related variables on heat island effect in residential developments of Hong Kong. They dealt with the UHI within and between estates as well as with the influence of design variables on it. The UHII was found equal to 1.5°C (maximum during the day of the summer) within three large housing estates in Hong Kong and 1°C between estates. The most important variables were found to be surface albedo, sky view factor, height to total floor area ratio and altitude.

Kim and Baik investigated the UHII in Seoul, Korea using near-surface temperature data measured at 31 automatic weather stations for 1-year period (2001-2002) and studies UHI and its effects. The UHI in Seoul was stronger in the night-time than in the daytime and decreased with wind speed and cloud cover. Moreover, it was least developed in summer. The average maximum UHII was 2.2°C. It is found to be stronger on weekdays than weekends.

Sharma and Joshi used Landsat TM data and analysed the seasonal variation of the UHII in the Delhi territory (India). They found that the largest UHII (16.7°C) was recorded during the summer when solar radiation is high and most of the agricultural fields are fallow. The UHII in winter was lower (7.4°C) as this is the season when incoming solar radiation is low while the agricultural land is covered with crops and is rich in moisture. The Monsoon season exhibited the second highest UHII (13.8°C).

Borbora and Das conducted a study in Guwahati, a small but rapidly growing city of the Assam state in North-Eastern India, half-hourly temperature data measured at four fixed observation sites (two in the urban and the others at the periphery). The in-situ measurements were conducted using stationary loggers. Moreover, mobile measurements were carried out during summer of 2013 (June, July and August) to bring out the intra-city temperature variation. The authors established the existence of an UHII over 2°C. The highest magnitude of the daytime UHII for the entire period of study was 2.12°C while the highest night time UHII was 2.29°C. Observations corroborated to the conclusion the UHII was increased during warm periods.

Chapter-4

4. DATA AND METHODOLOGY

4.1. DATA

The data used for the project is secondary data. The level-1 data was downloaded from **USGS Earth Explorer** of the satellites and their resolutions mentioned below. Besides this data, the proposed Guwahati Master Plan 2025 was downloaded from **Guwahati Development Department** website.

DD/MM/YYYY	Datasets	Resolution	Projection
02/03/2004	LANDSAT 4-5	Spatial-30m Thermal-120m Pan-30m	WGS_1984_UTM_ZONE_46N
29/02/2009	LANDSAT 4-5		WGS_1984_UTM_ZONE_46N
26/02/2014	LANDSAT 8	Spatial-30m Thermal-100m Pan-15m	WGS_1984_UTM_ZONE_46N
24/02/2019	LANDSAT 8		WGS_1984_UTM_ZONE_46N

Software used:

- **Arc GIS 10.3:** The NDVI, NDBI, Dense Vegetation and the digitisation including the LST of the downloaded data was estimated through this software.
- **ERDAS IMAGINE 2015:** The average of LST derived from LANDSAT images were estimated using this software.
- **Microsoft Excel 2016:** This software was used for plotting graphs.

4.2. METHODOLOGY

4.2.1. GMP 2025

- **Geo-referencing:** Geo-referencing is simply relating the internal coordinate system of a map with ground system of geographic coordinates.
- The proposed land-use map of Guwahati master plan 2025 was processed as:
    1. Georeferencing the map
    2. Digitisation of the map
    3. Extracting the Built-up Land

- The Geographic coordinate system which has been used is **GCS_WGS_1984** whereas the Projected Coordinate System was **WGS_1984_UTM_ZONE_46N**

4.2.2. LANDSAT Imagery

- The project is about linking the urban built up atmosphere with the urban climate, so, as far as urban heat islands are concerned, the most important part is the availability of thermal data for which the most suitable one was the LANDSAT satellite- LANDSAT 8 and LANDSAT 4-5.

  The data i.e., the LANDSAT level-1 images were downloaded from USGS Earth Explorer, keeping in mind the dates after 5 years on interval.

  - **E.g**.- If the data from 2004 was downloaded of the date 02/03/2004, it was made sure that the data of 2009 must be of the same date i.e., 02/03/2009 and if not available the date can range within 2 to 3 days of the actual date.

- After the data was downloaded, it needed to be processed and the process began with eliminating the **NO VALUE DATA** by the following steps:

1) To the *Layerstacked* image, apply the formula using raster calculator:

Con (“image”, 1, 0)

2) Change values in “*Reclassify*” menu as:

From	0-1	to	0- Nodata
From	1-2	to	1-1

3) Using Raster calculator, apply the following formula:

“image” * “Reclassified image”

4) ***Export*** data
5) ***Clip*** the images with the help of shapefile of Guwahati Master Plan.

4.2.2.1. LANDSAT Imagery- STEP 1

- The next step remains the calculation of **NDVI** as:
  - For LANDSAT 8

NIR (Band 5- Band 4)/ NIR (Band 5+ Band 4)

  - For LANDSAT 4-5

NIR (Band 4- Band 3)/ NIR (Band 4+ Band 3)

- ***After the NDVI was calculated, the Dense Vegetation was extracted from each of the images via digitisation to calculate its area for further usage.***

- The next thing to be calculated was the **LST**, with the following steps:

1. Top of atmosphere (TOA)

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

- $L_{\lambda=}$ TOA spectral radiance (Watts/ (m^2 * srad * μm))
- $M_{L=}$ Band-specific multiplicative rescaling factor from the metadata (RADIANCE_MULT_BAND)
- $Q_{cal=}$ Quantized and calibrated standard product pixel values (DN)
- $A_{L=}$ Band-specific additive rescaling factor from the metadata (RADIANCE_ADD_BAND)

2. Brightness temperature (BT)

$$[K_2/\text{Ln }\{(774.89/ L_\lambda) +1\}]- 273.15$$

3. NDVI

NIR (Band 5- Band 4)/ NIR (Band 5+ Band 4)

4. Proportion Vegetation (PV)

$$\text{Square } (NDVI- NDVI_{min})\ (NDVI_{max}- NDVI_{min})$$

5. Emissivity (ε)

$$0.004*PV + 0.986$$

6. LST

$$[BT/ \{1+ (0.00115* BT/ 1.4388) * Ln(\varepsilon)\}]$$

4.2.2.2. LANDSAT Imagery- STEP 2

- The next step remains the calculation of **NDBI** as:
  - For LANDSAT 8

{SWIR (Band 6)- NIR(Band 5)}/ {SWIR (Band 6)+ NIR(Band 5)}

  - For LANDSAT 4-5

{SWIR (Band 5)- NIR(Band 4)}/{SWIR (Band 5)+ NIR(Band

- ***After the NDBI was calculated, the Built-up was extracted from each of the images via digitisation to calculate its area for further usage.***

- ***<u>To record considerable changes in built-up and vegetation, the interval of 5 years was taken.</u>***

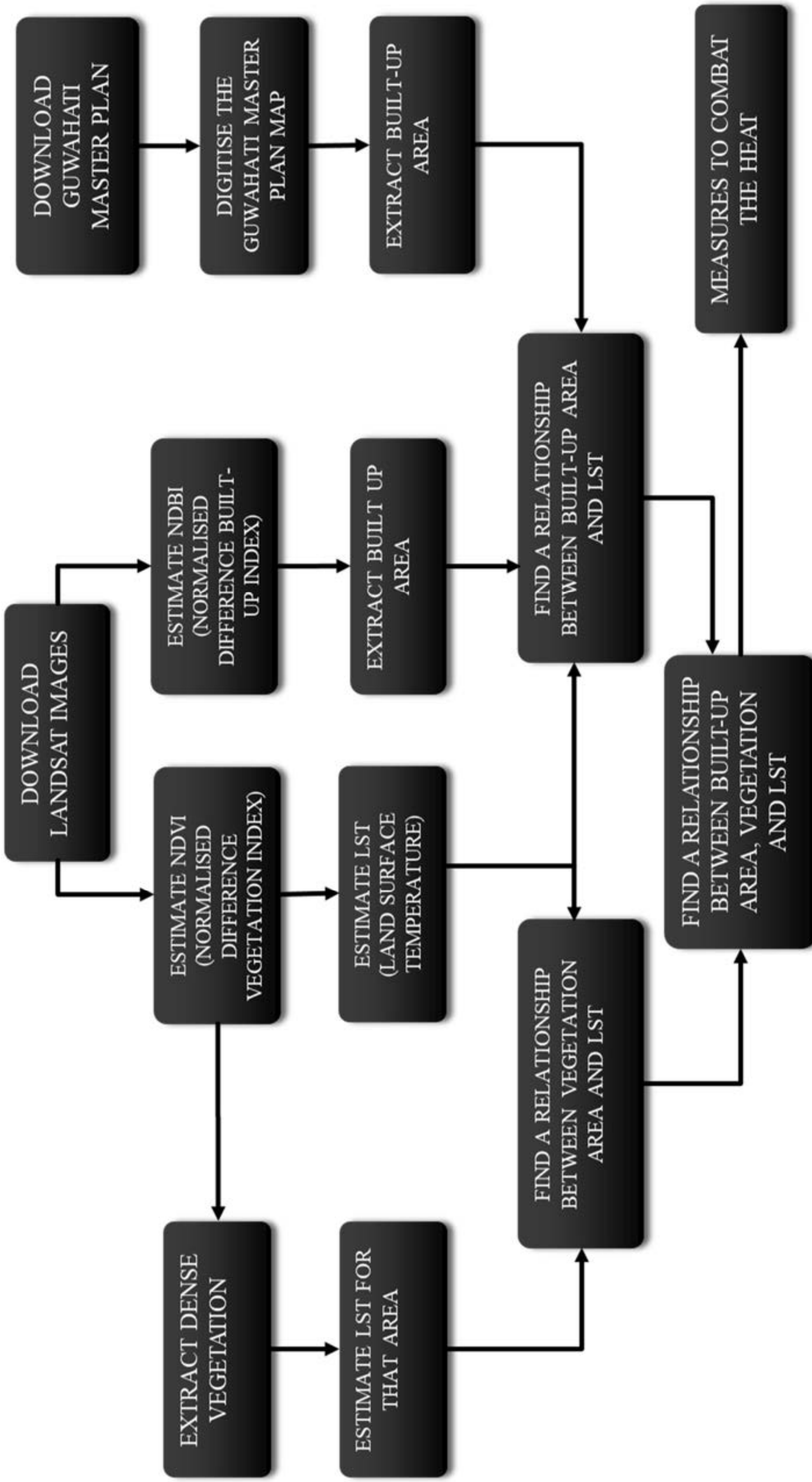


Fig. 8: FLOW CHART SHOWING METHODOLOGY (I)

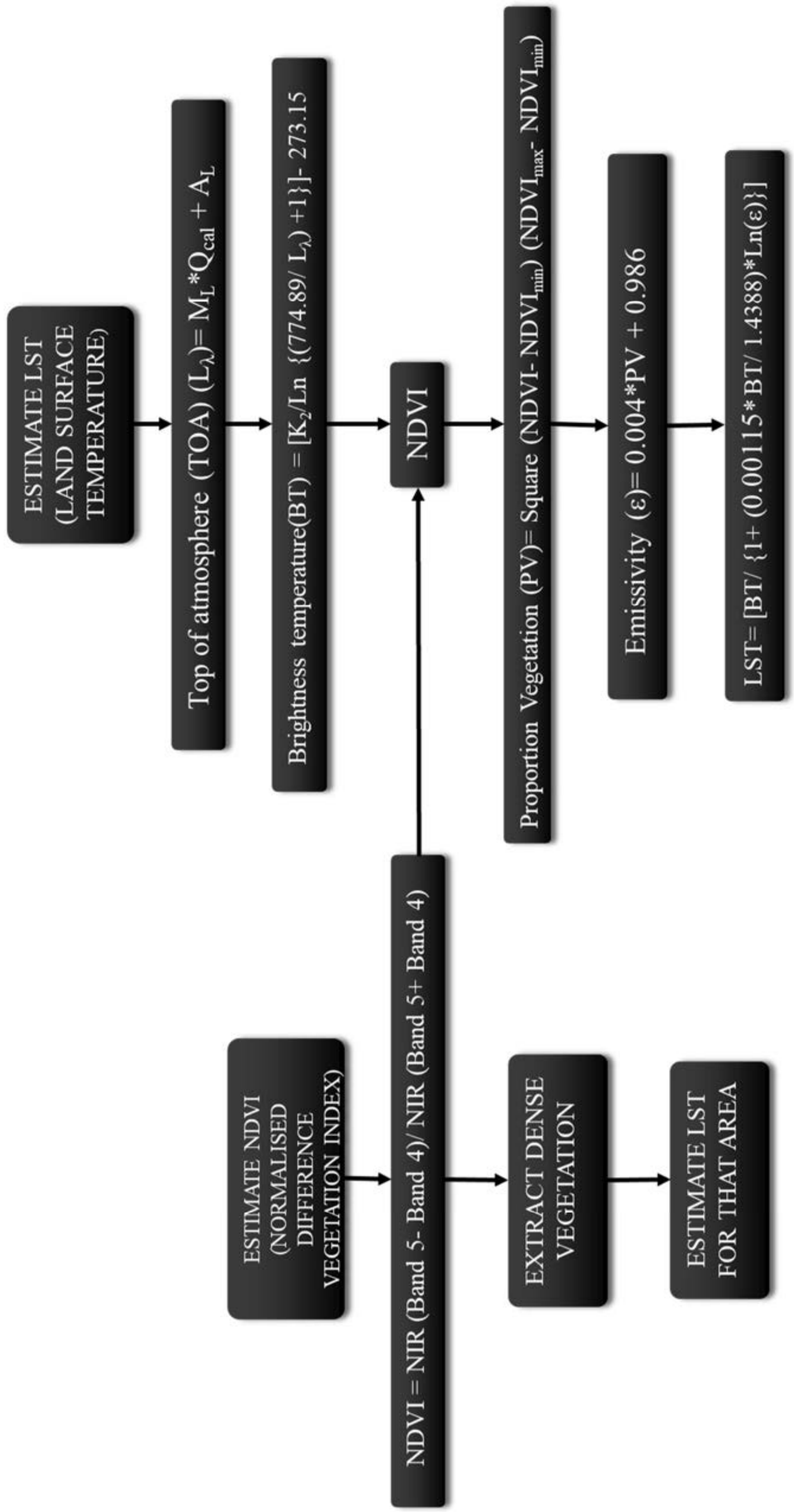


Fig. 9: FLOW CHART SHOWING METHODOLOGY (II)

RESULTS
&
DISCUSSIONS

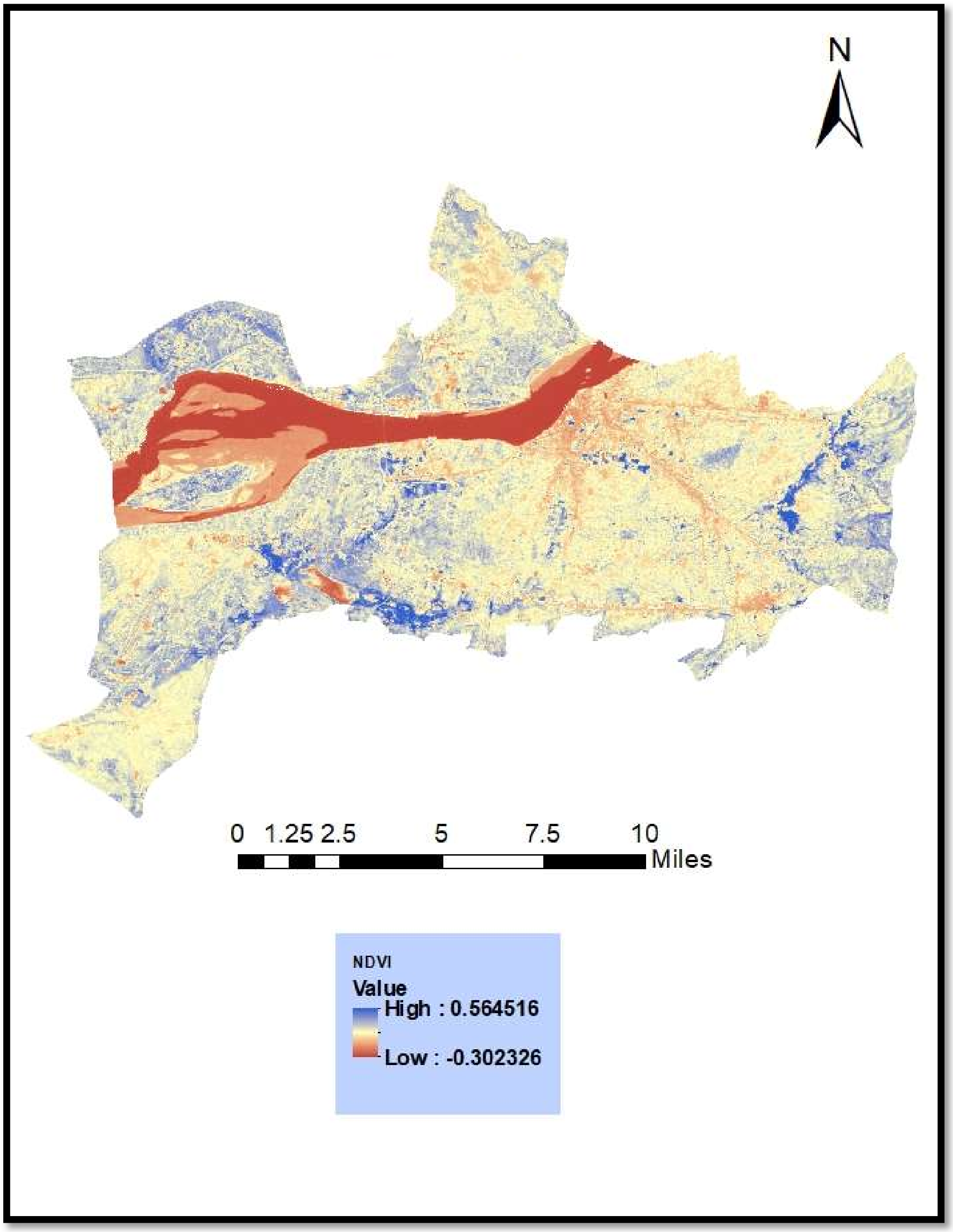


Fig 10: Map showing existing Vegetation quality (NDVI) in 2004 (Guwahati)

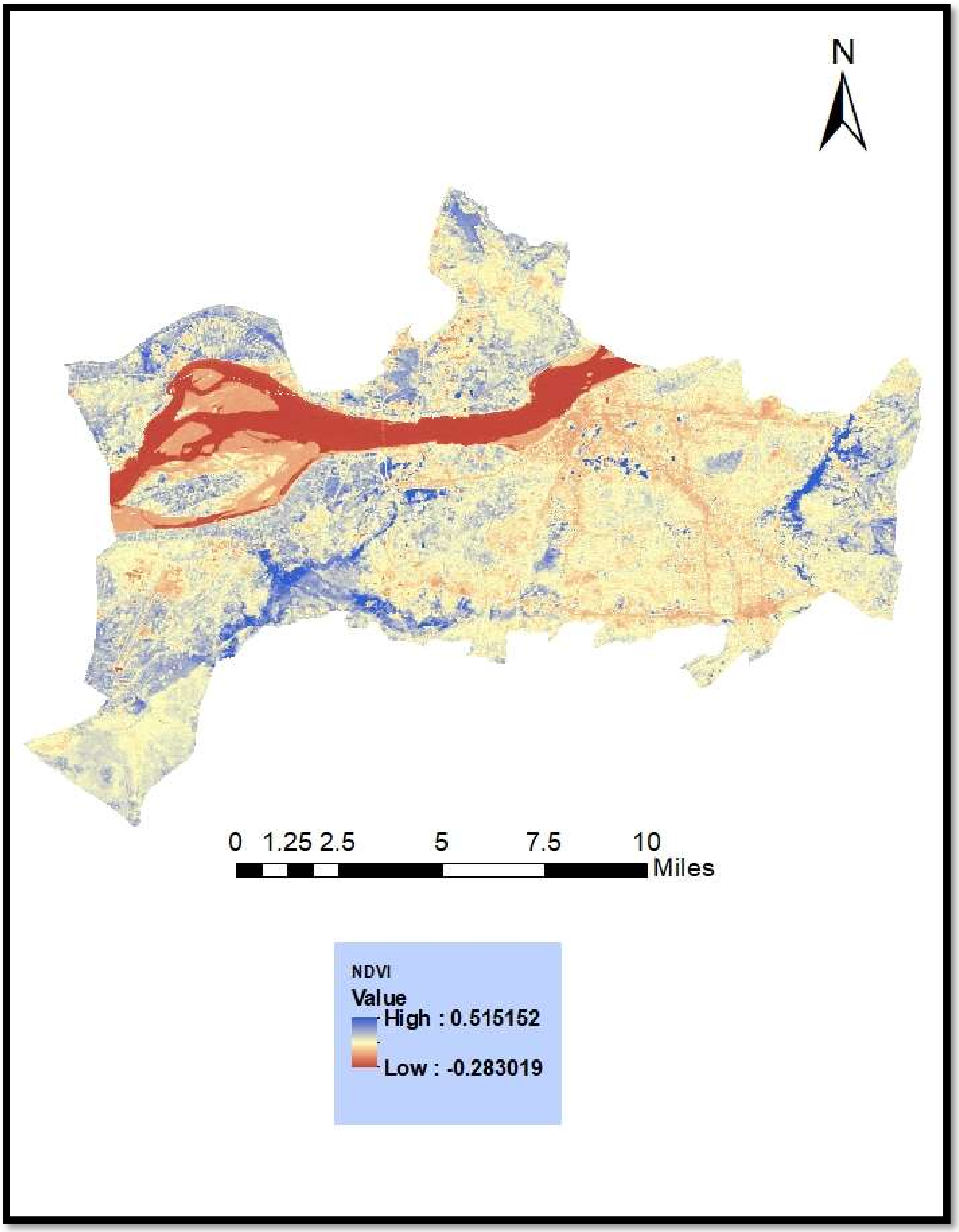


Fig 11: Map showing existing Vegetation quality (NDVI) in 2009 (Guwahati)

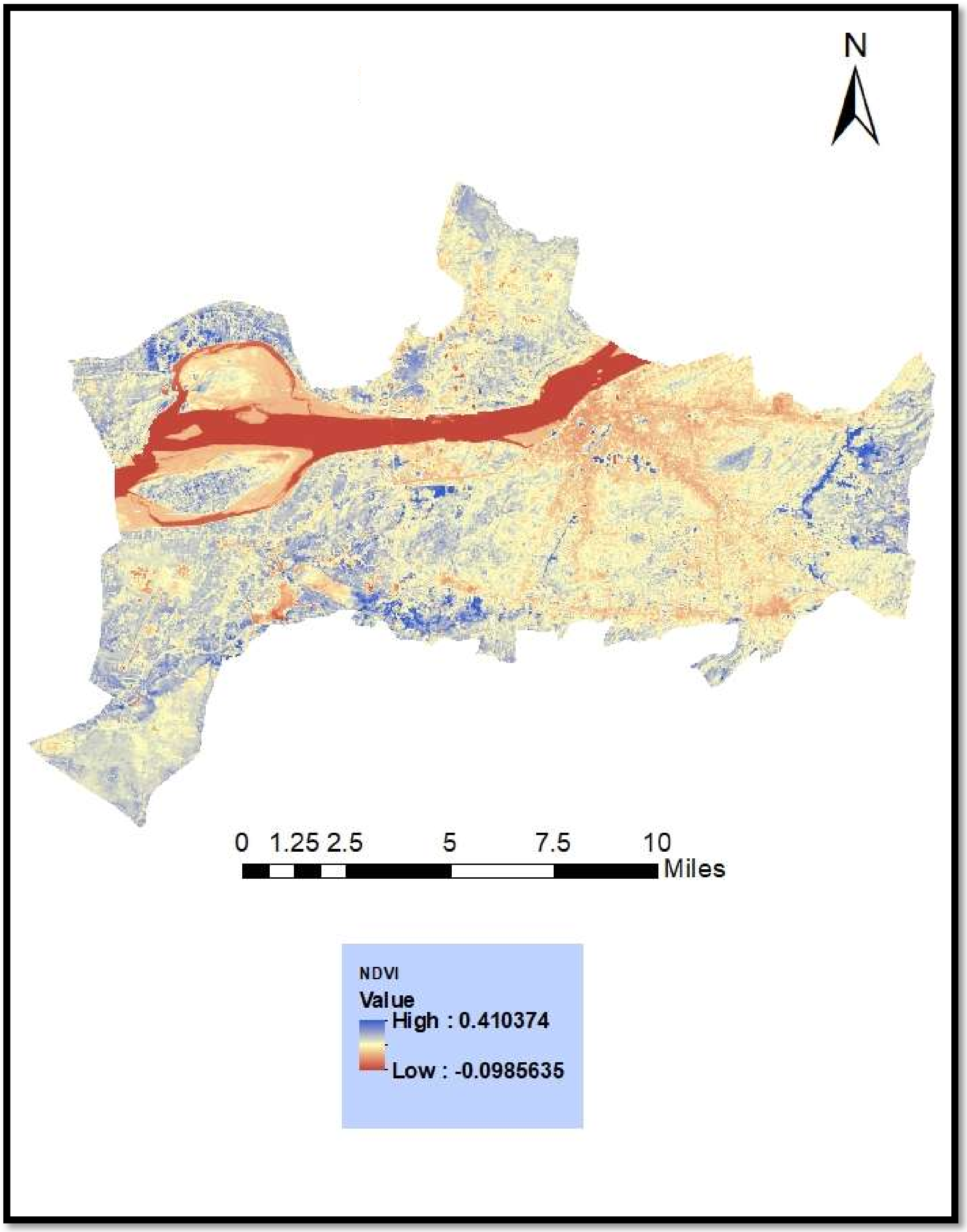


Fig 12: Map showing existing Vegetation quality (NDVI) in 2014 (Guwahati)

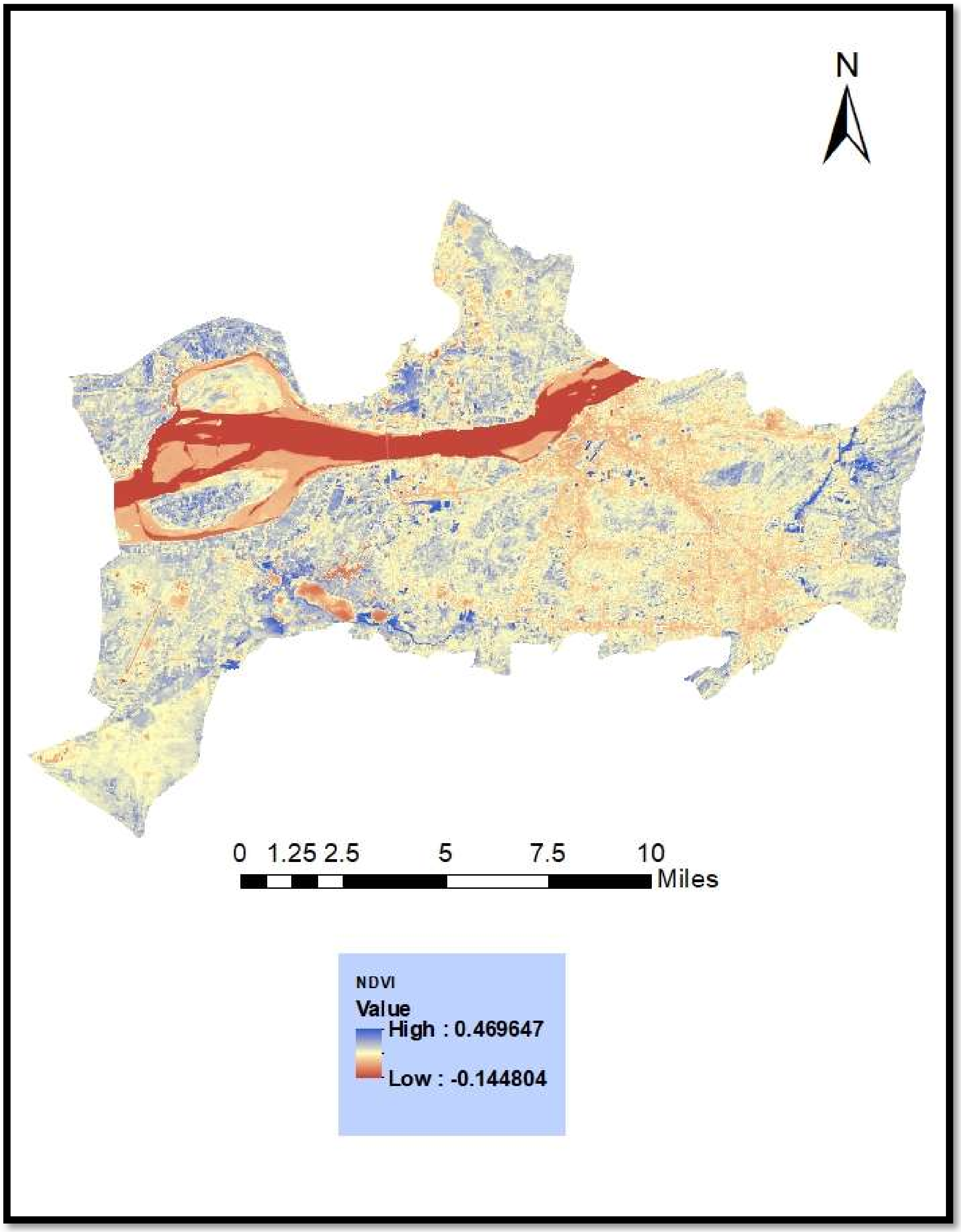


Fig 13: Map showing existing Vegetation quality (NDVI) in 2019 (Guwahati)

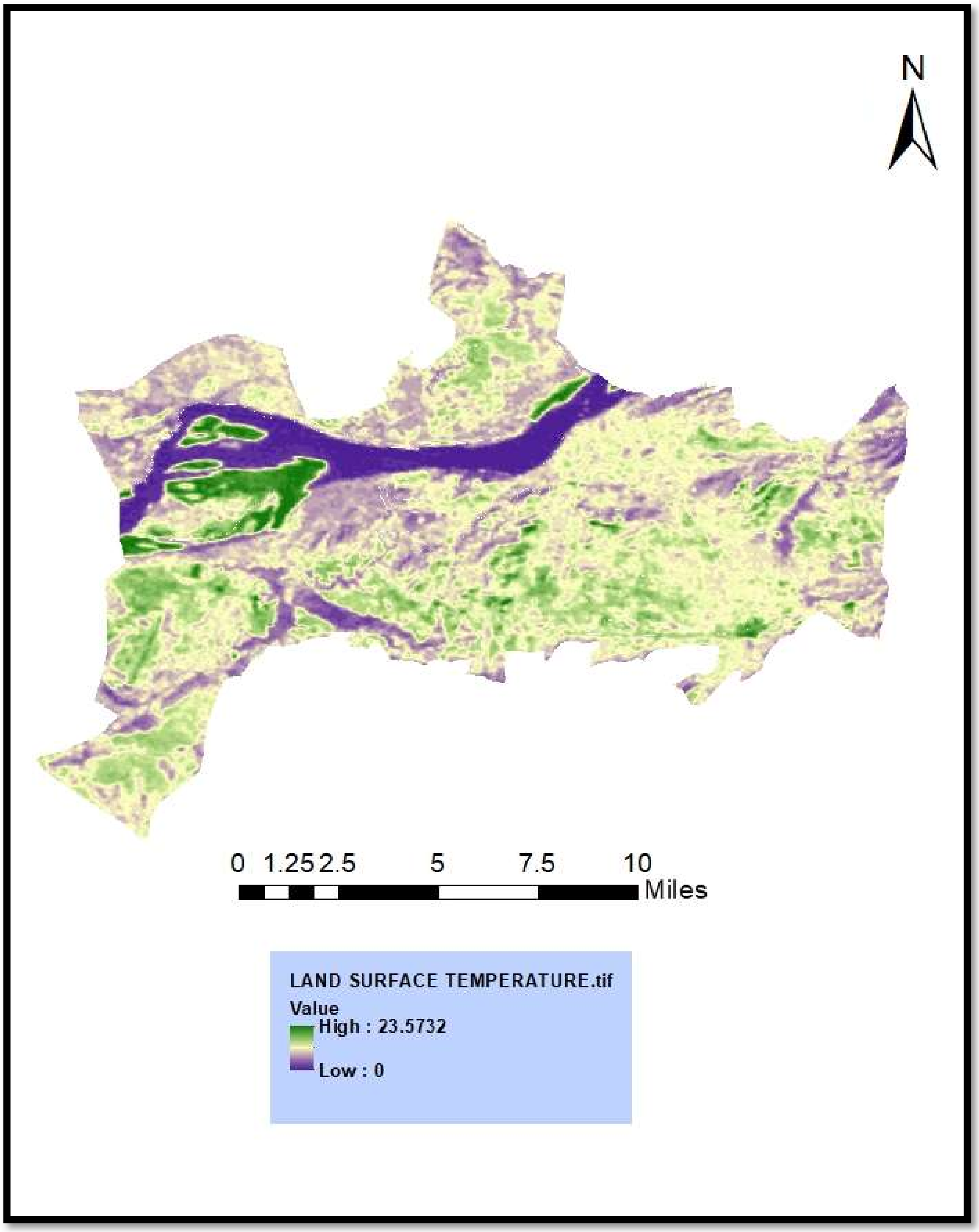


Fig 14: Map representing Land surface temperature in 2004 (Guwahati)

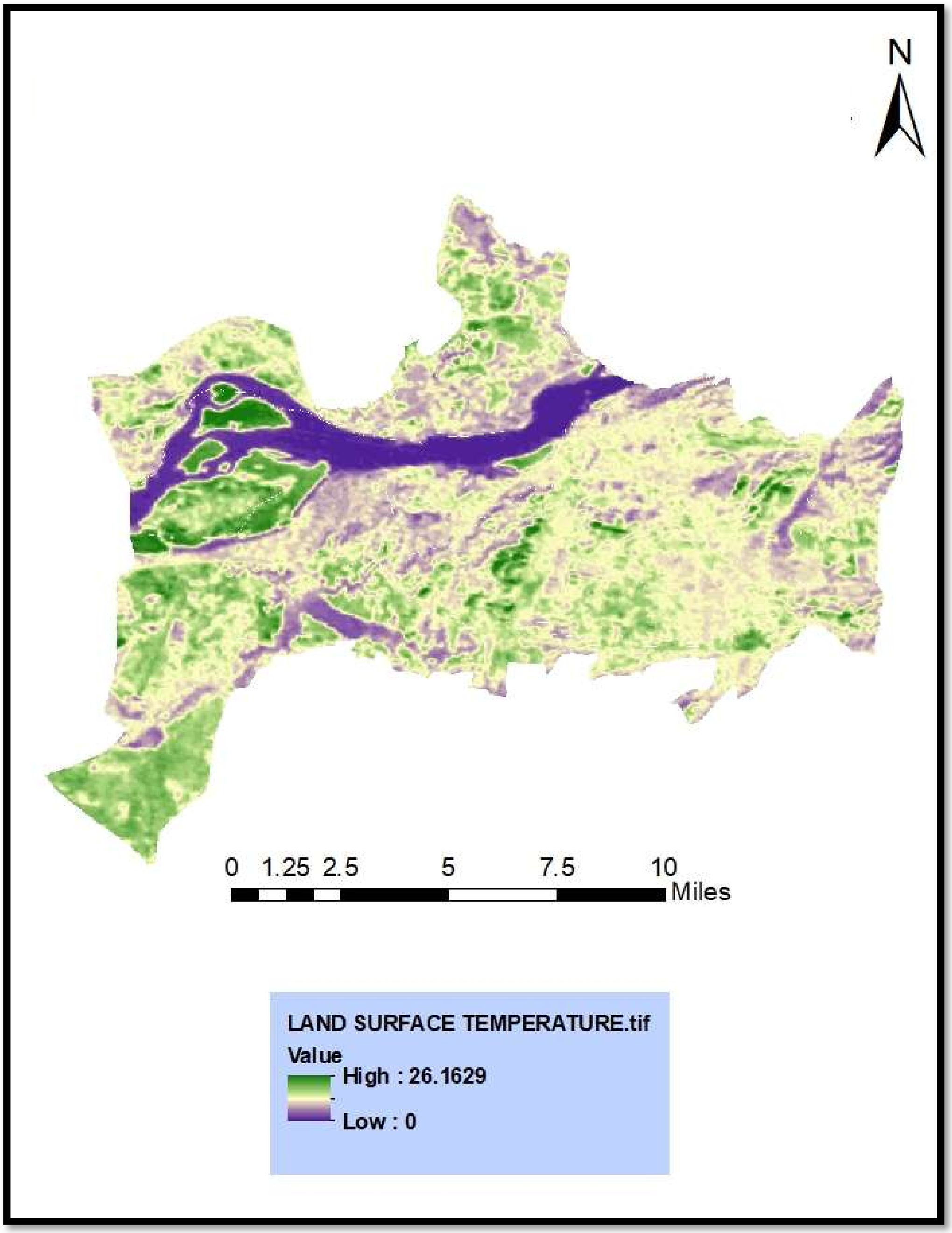


Fig 15: Map representing Land surface temperature in 2009 (Guwahati)

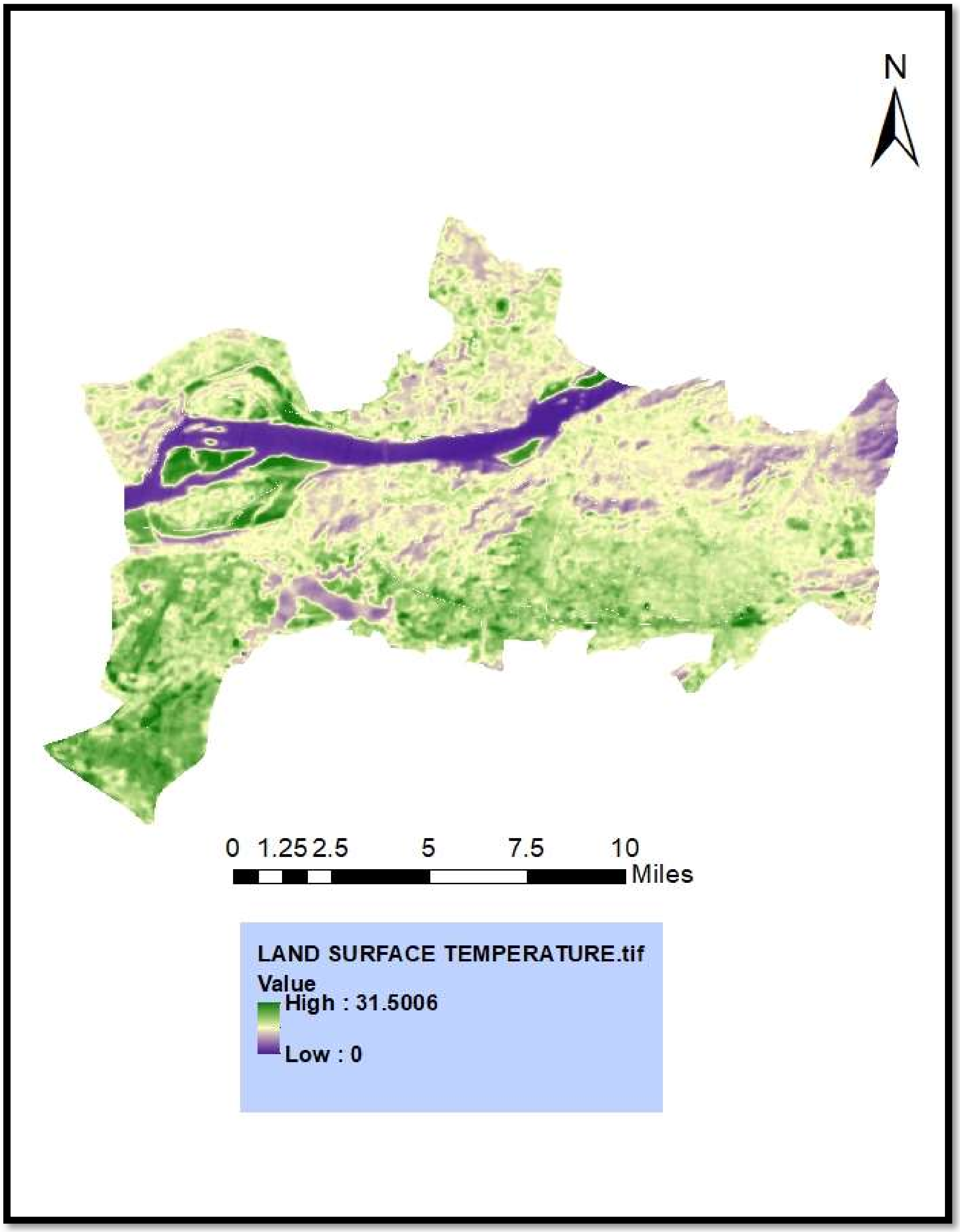


Fig 16: Map representing Land surface temperature in 2014 (Guwahati)

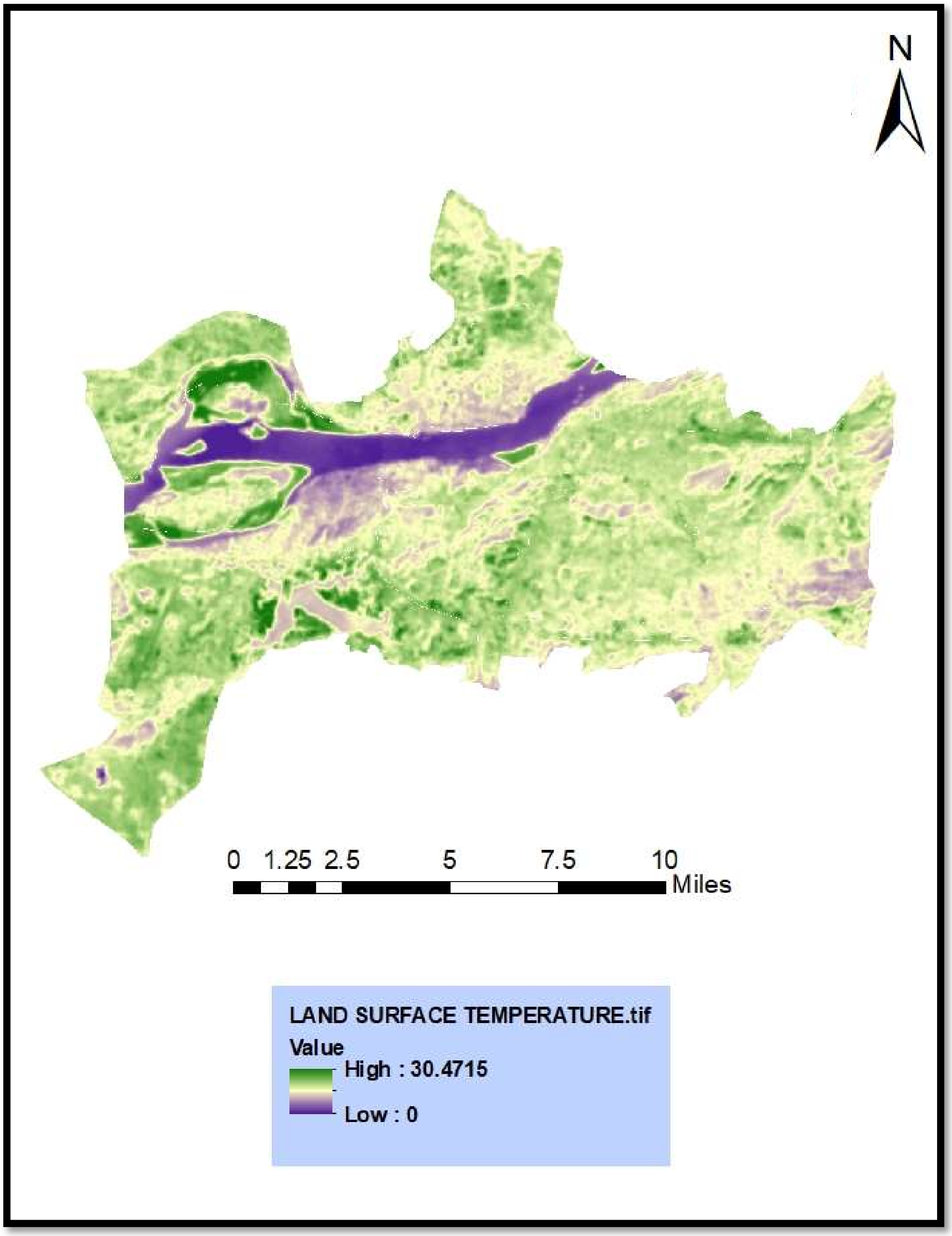


Fig 17: Map representing Land surface temperature in 2019 (Guwahati)

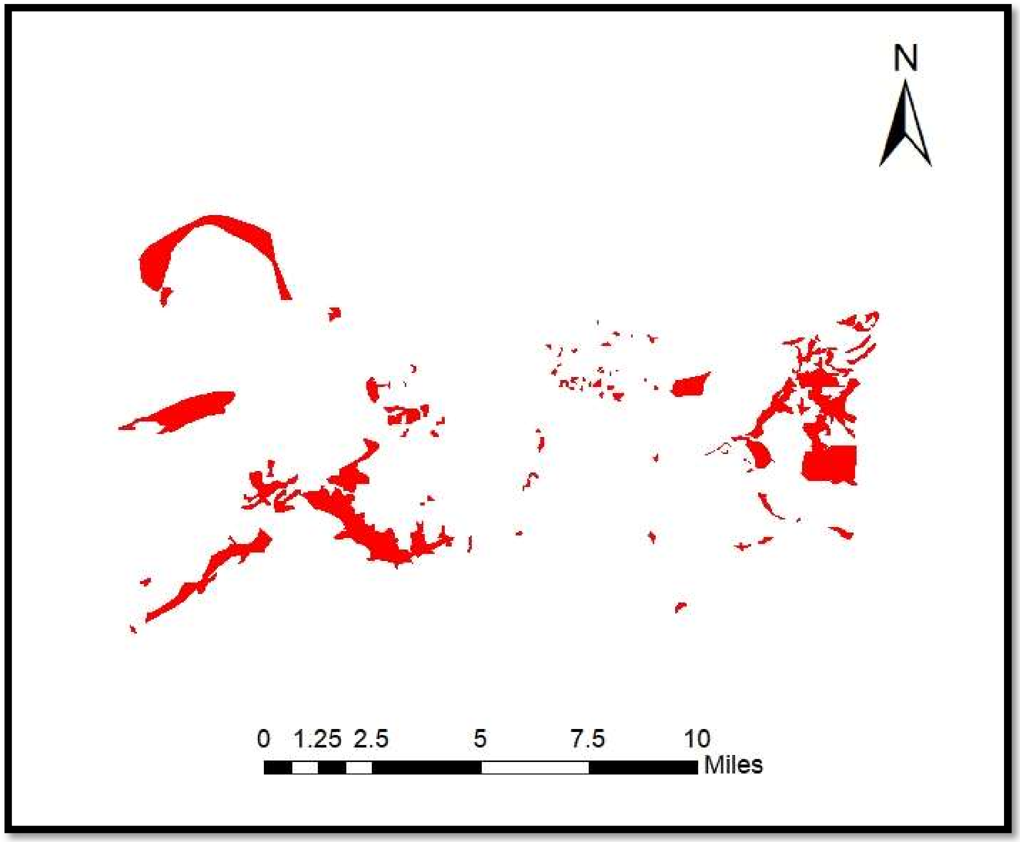


Fig 18: Map showing extracted Dense Vegetation in 2004 (Guwahati)

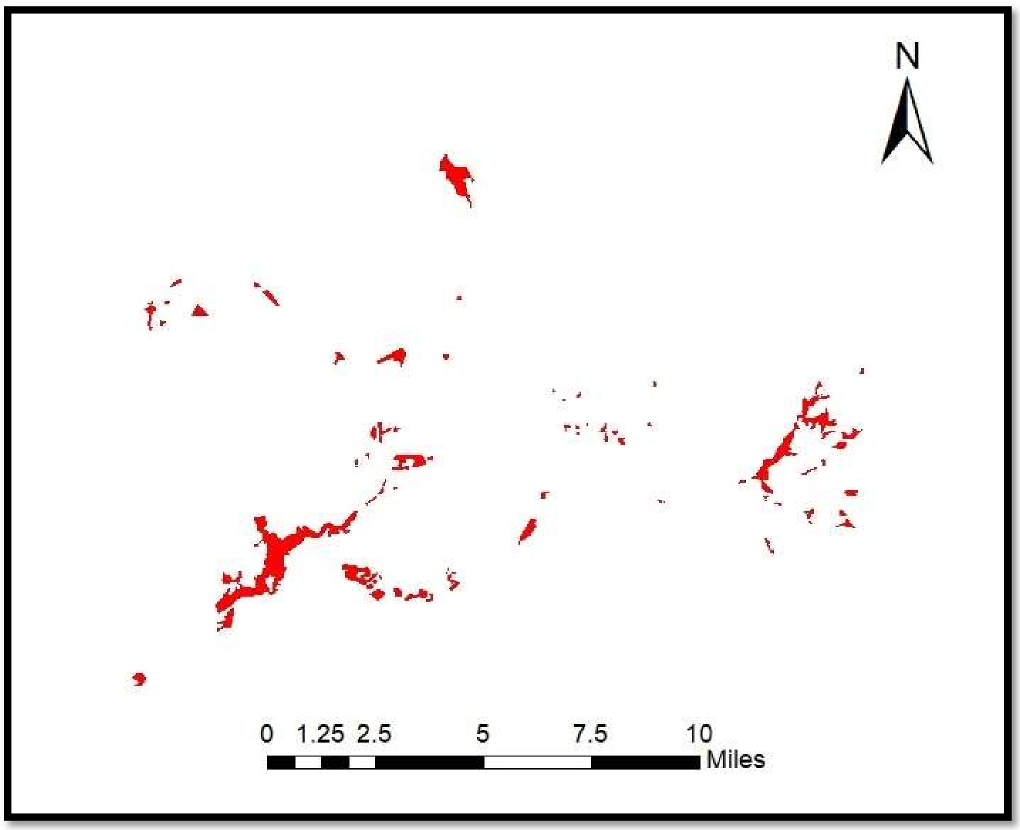


Fig 19: Map showing extracted Dense Vegetation in 2009 (Guwahati)

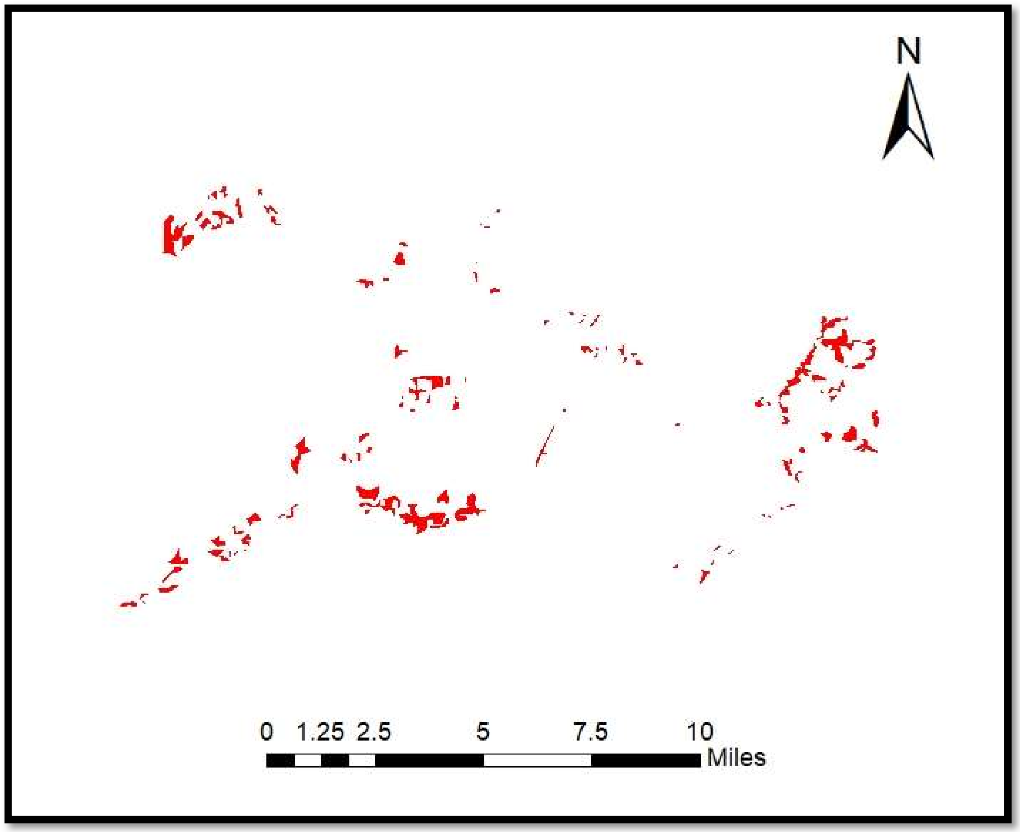


Fig 20: Map showing extracted Dense Vegetation in 2014 (Guwahati)

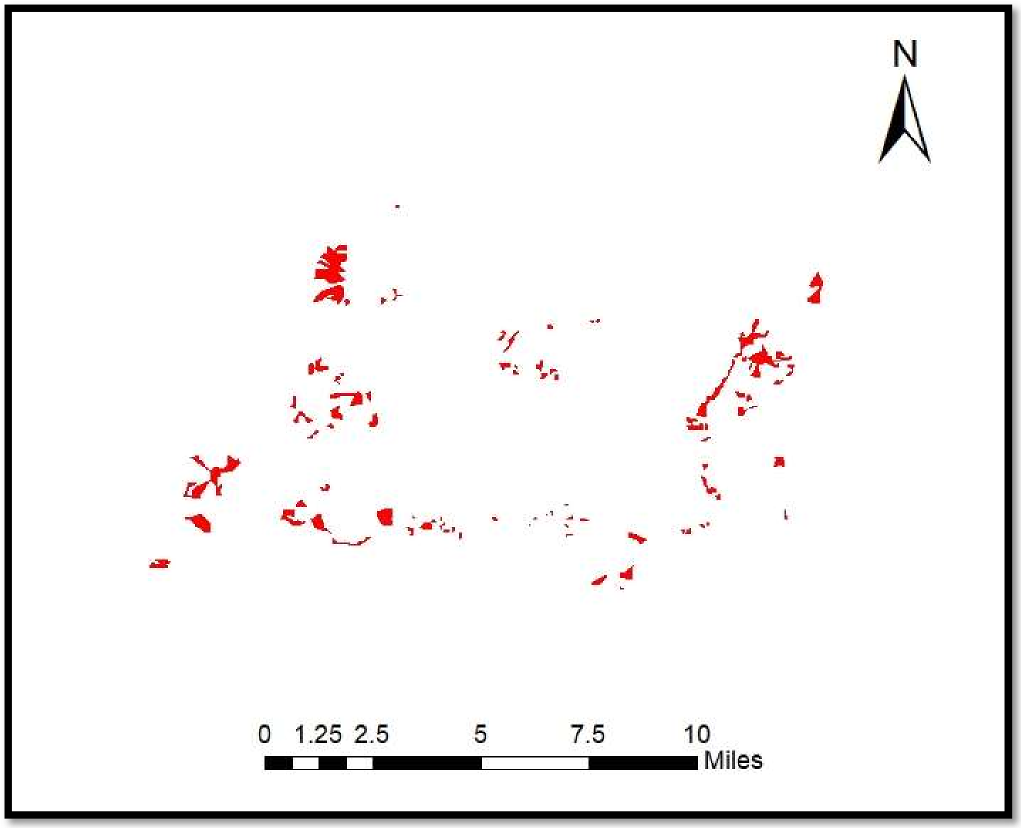


Fig 21: Map showing extracted Dense Vegetation in 2019 (Guwahati)

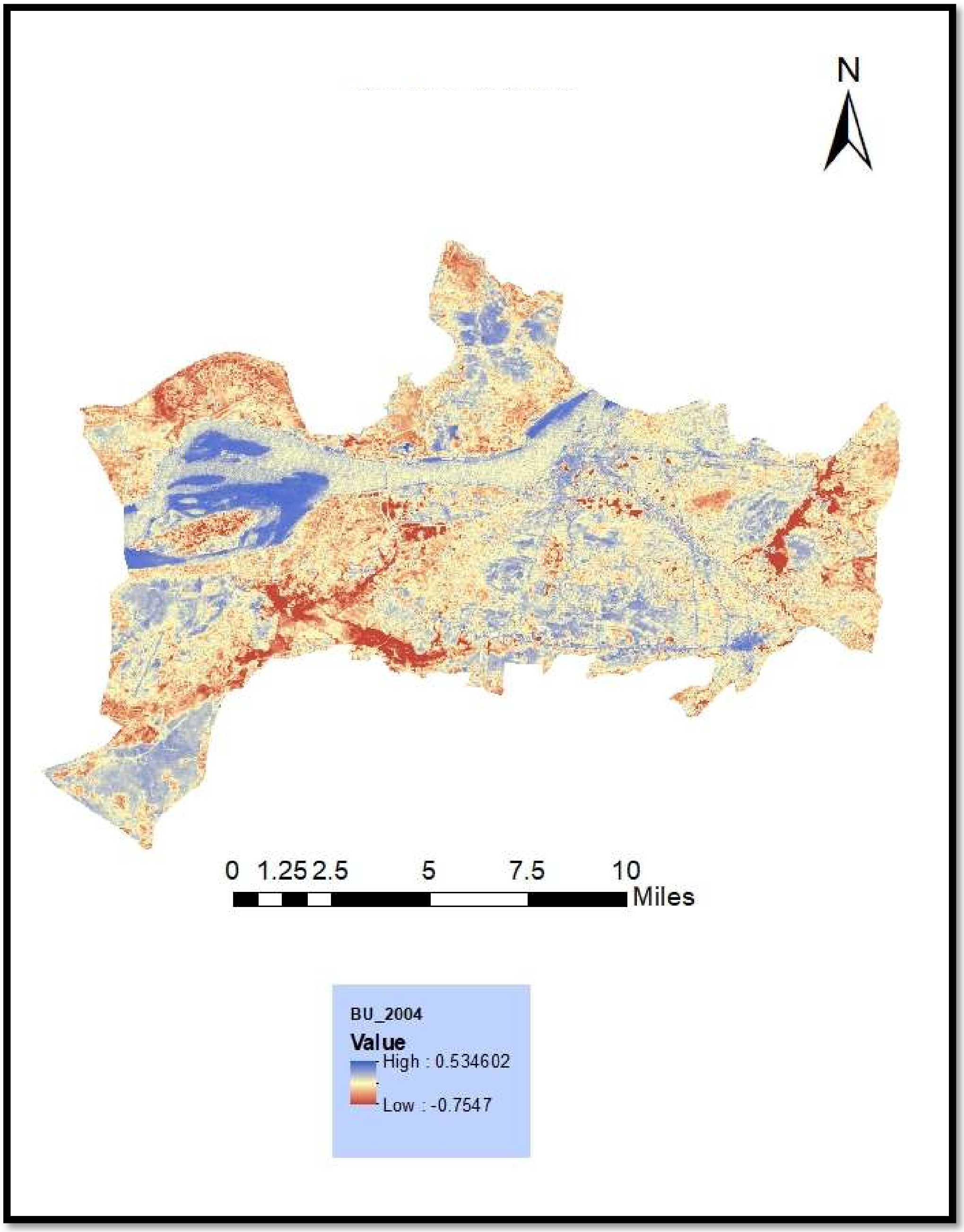


Fig 22: Map showing existing Built-up (NDBI) in 2004 (Guwahati)

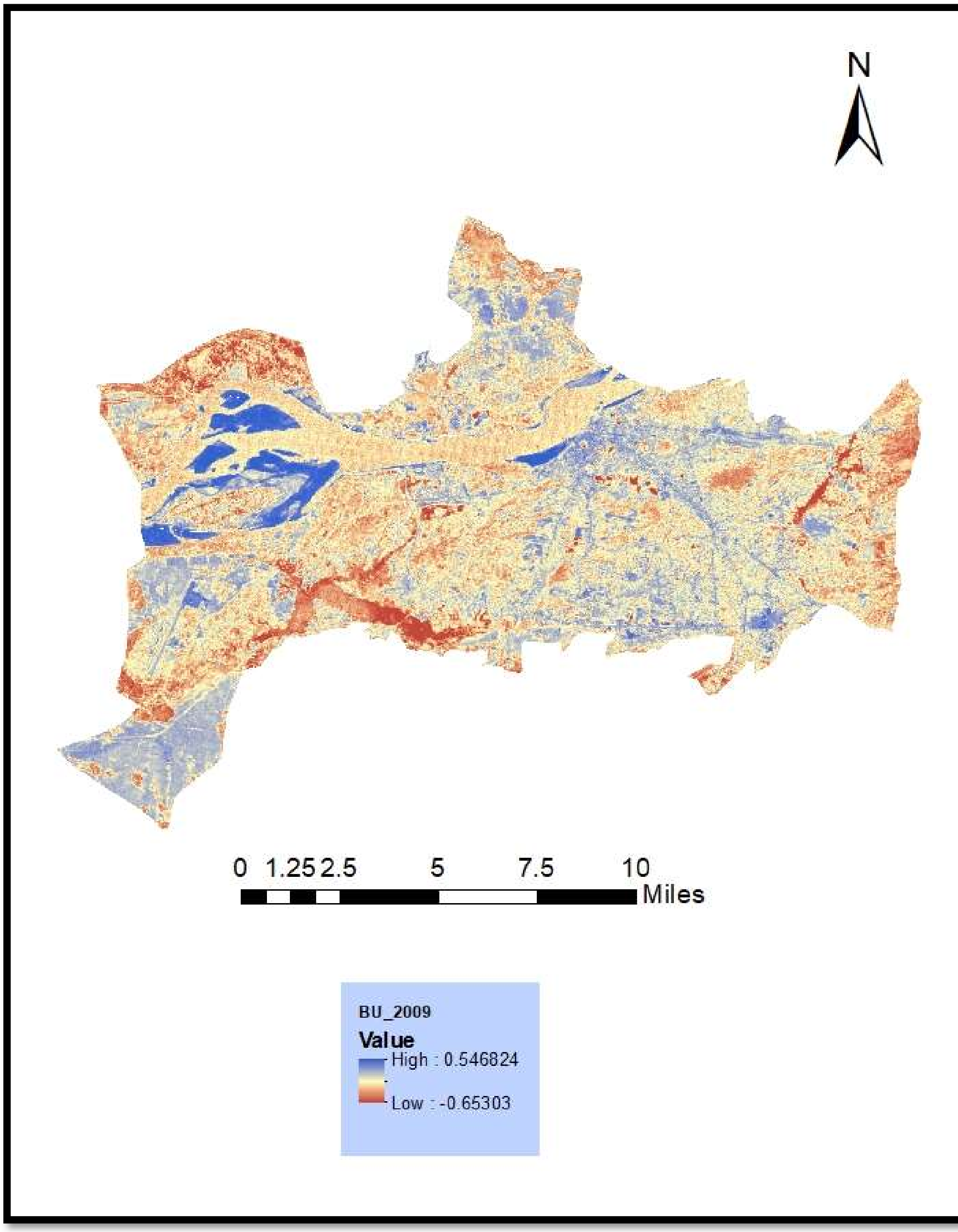


Fig 23: Map showing existing Built-up (NDBI) in 2009 (Guwahati)

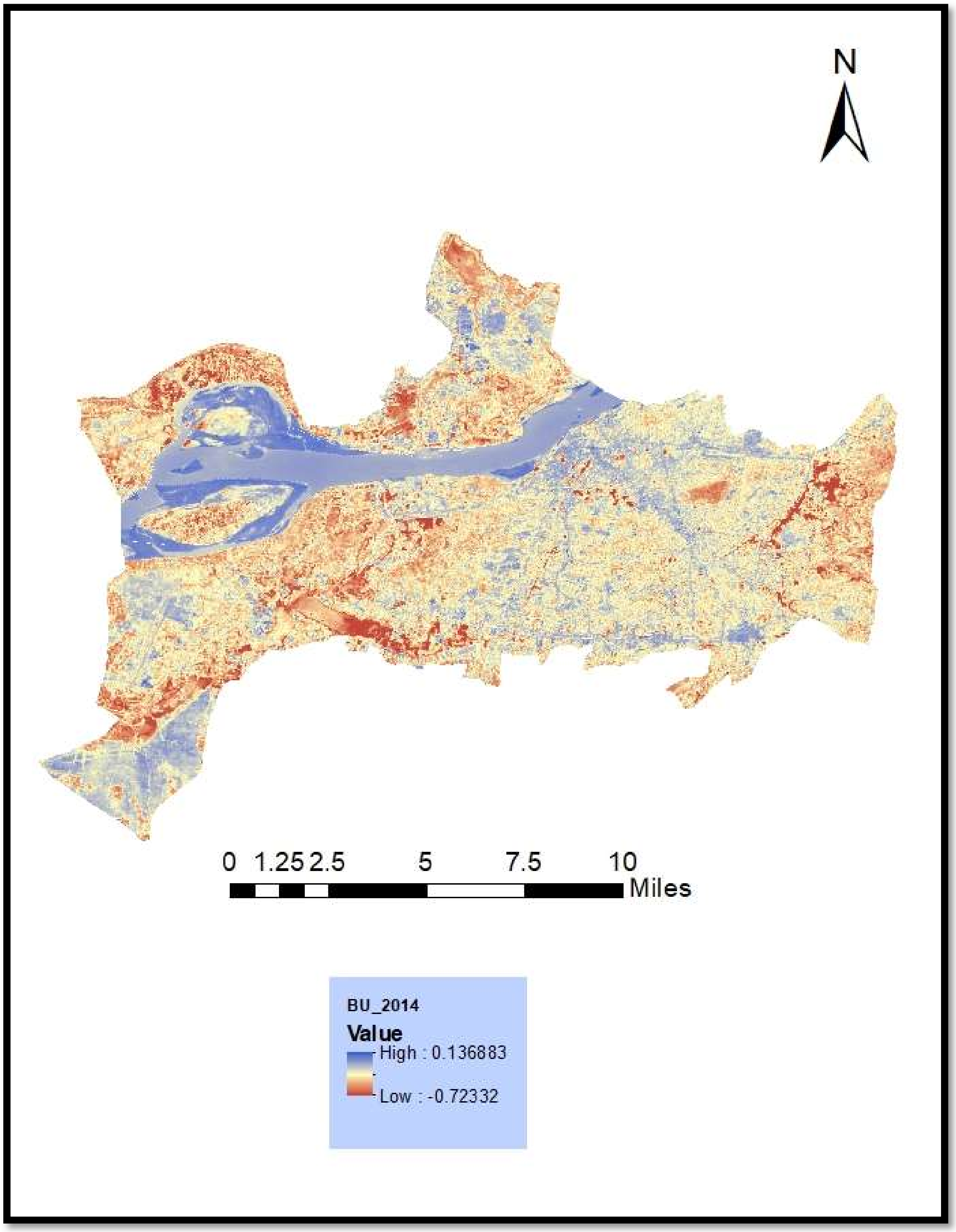


Fig 24: Map showing existing Built-up (NDBI) in 2014 (Guwahati)

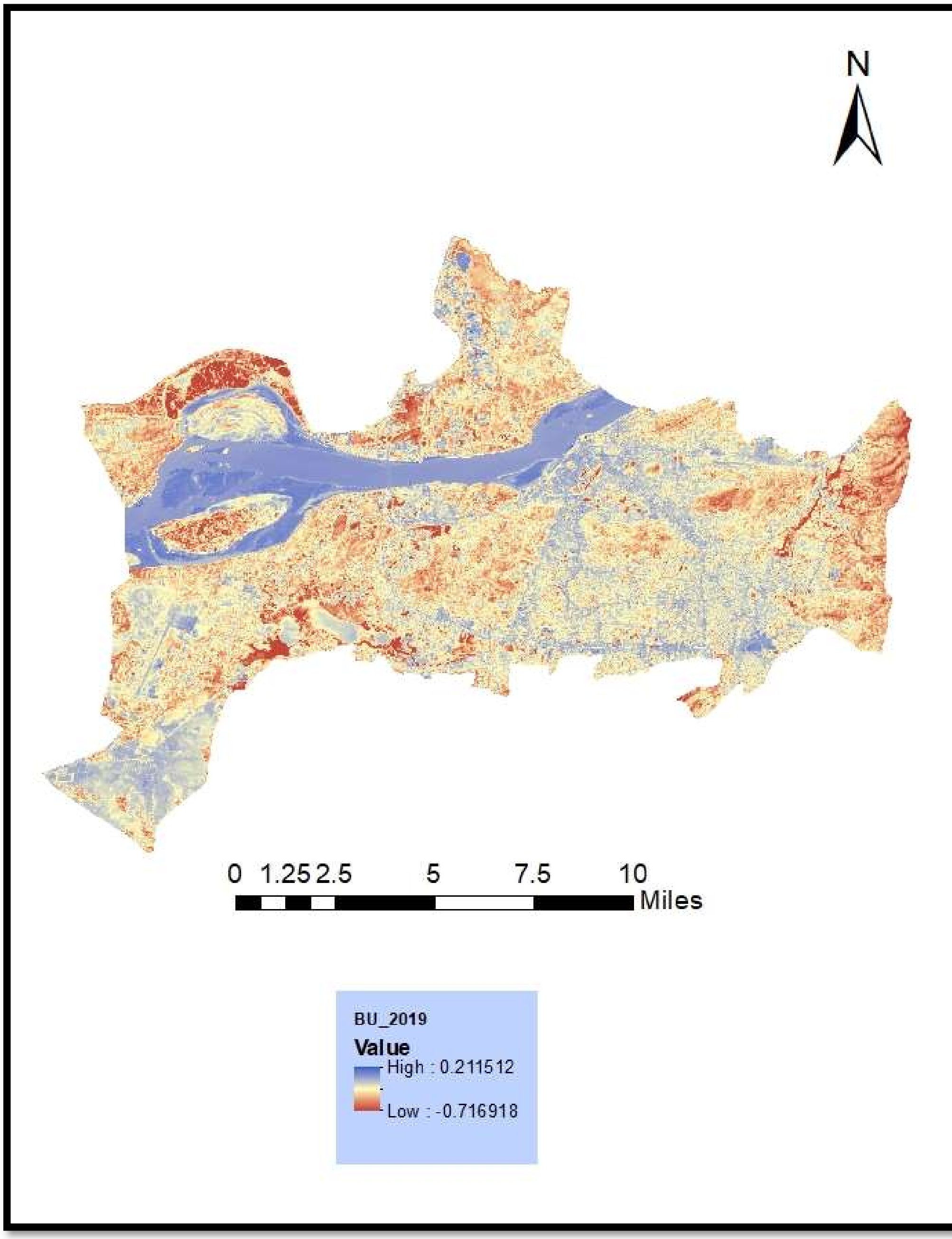


Fig 25: Map showing existing Built-up (NDBI) in 2019 (Guwahati)

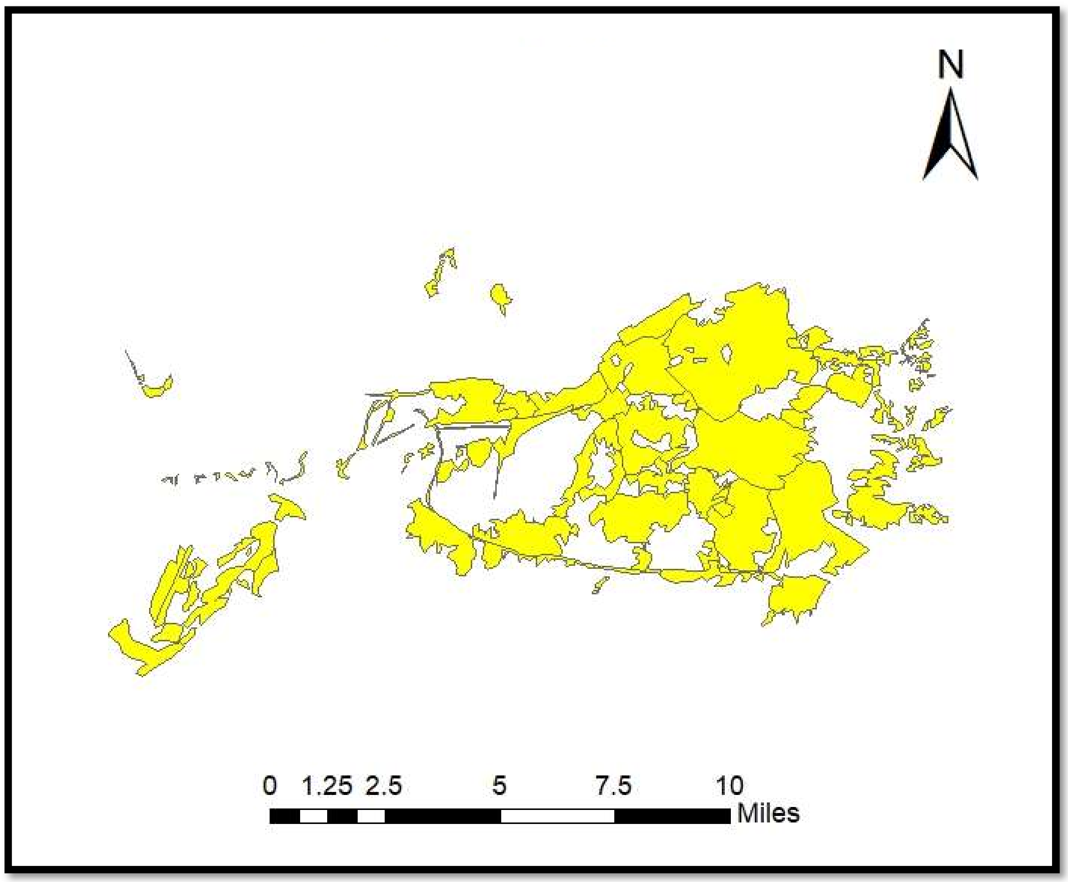


Fig 26: Map showing extracted Built-up land in 2004 (Guwahati)

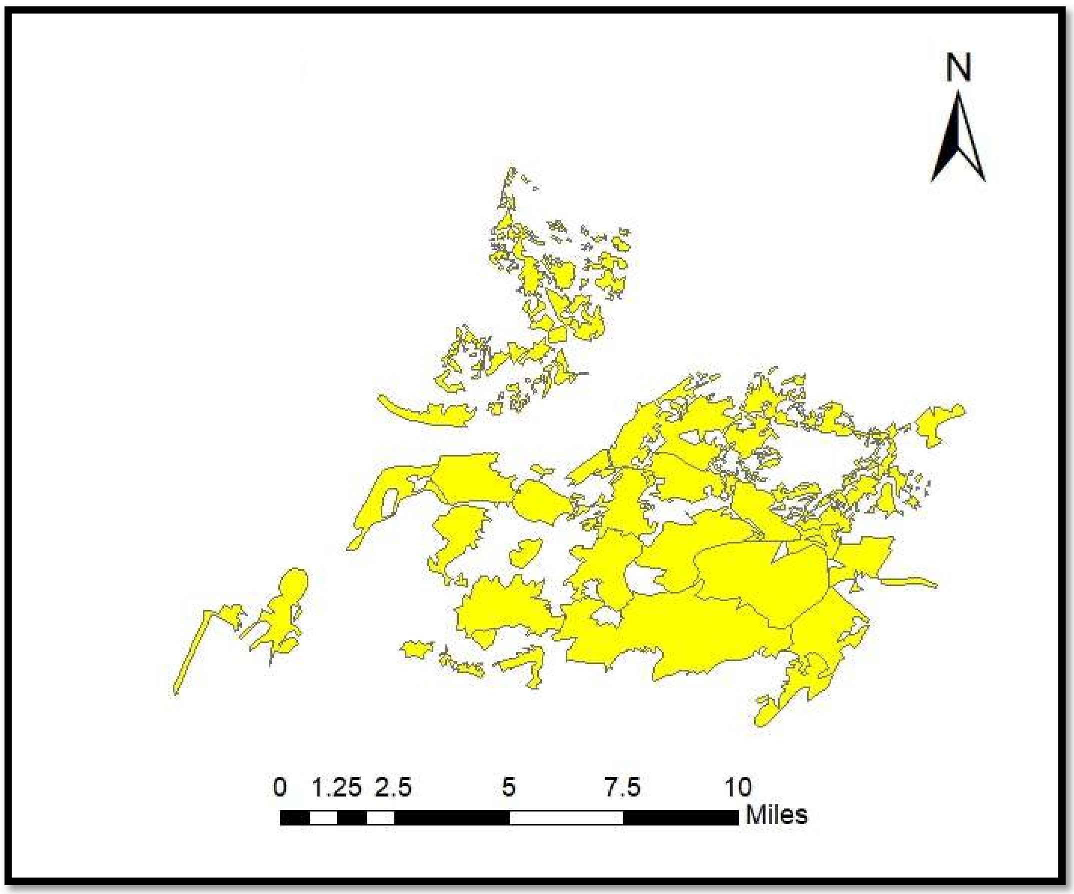


Fig 27: Map showing extracted Built-up land in 2009 (Guwahati)

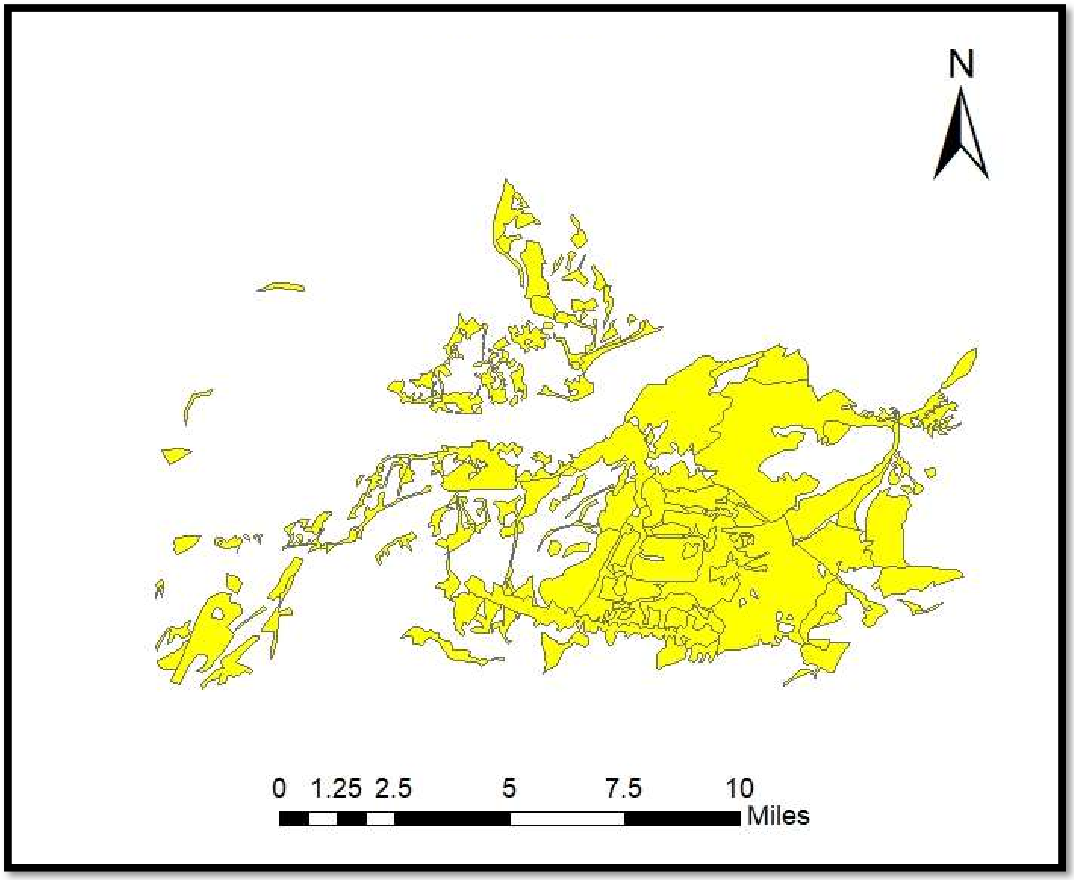


Fig 28: Map showing extracted Built-up land in 2014 (Guwahati)

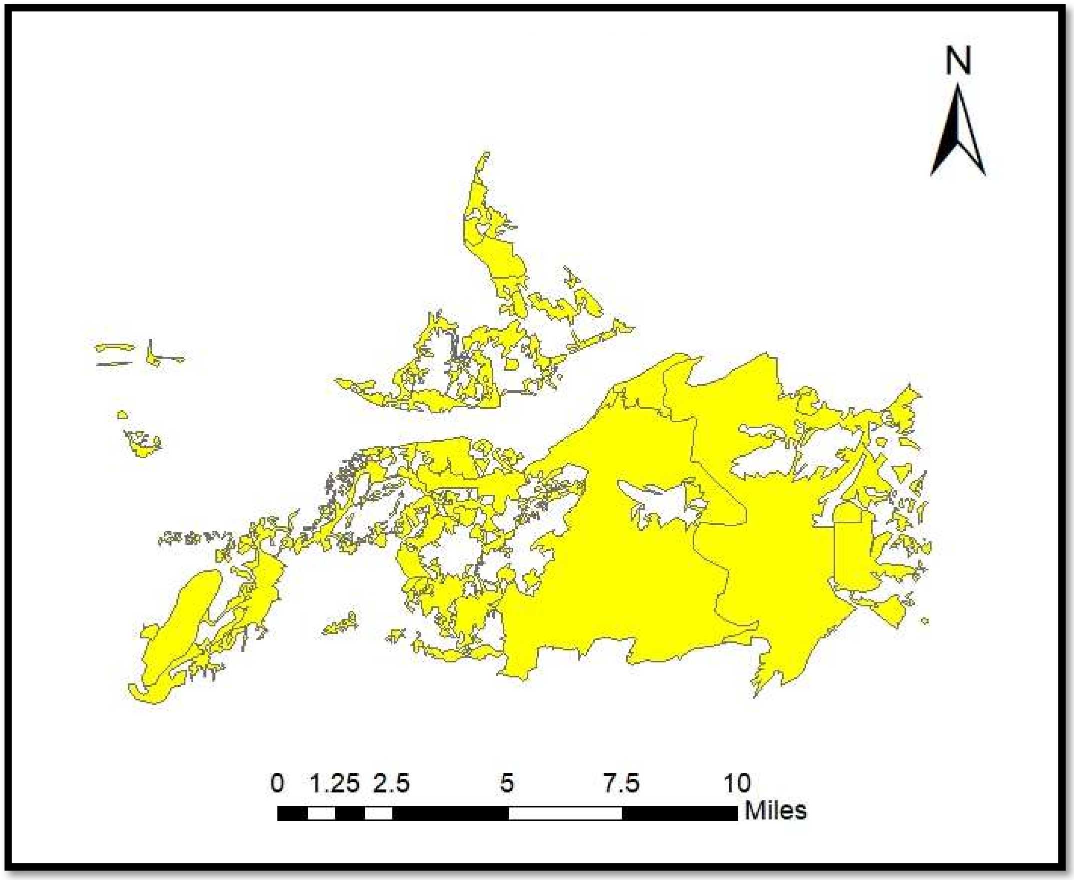


Fig 29: Map showing extracted Built-up land in 2019 (Guwahati)

4.3. RESULTS

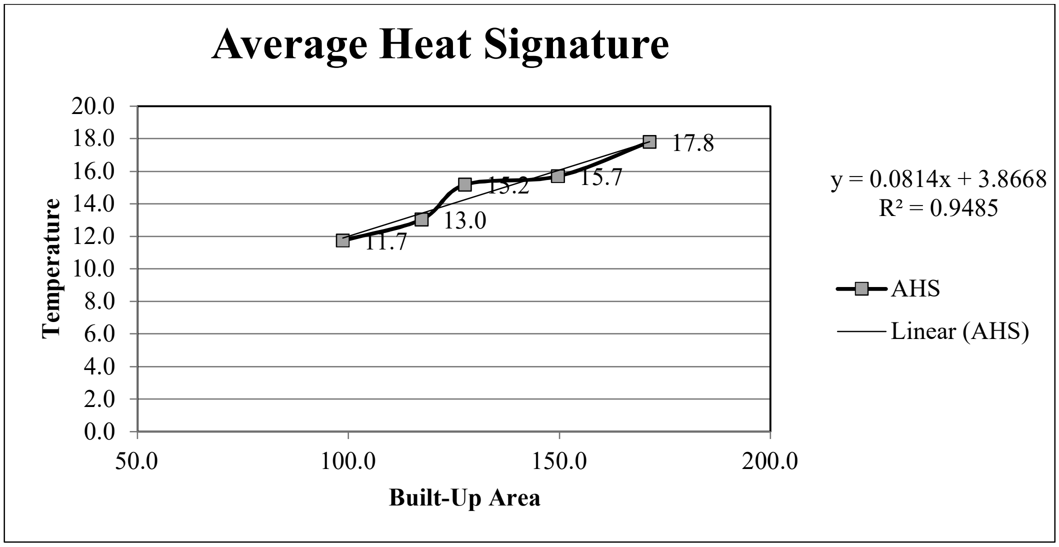


Fig 30: Relationship between LST and Built-up area

Year	Built-up (km^2)	Avg. Heat Sign.(˚C)
2004	98.7	11.7
2009	117.4	13.0
2014	127.7	15.2
2019	149.7	15.7
2025	171.4	17.8

- The table above shows the relationship between BU and AHS of the years-2004, 2009, 2014 and 2019. This relationship has been further used to plot a graph where x represented BU whereas y represented AHS and then derive an equation from the graph as:

$$\mathbf{y = 0.0814x + 3.8668}$$

- As, the proposed Guwahati master plan 2025 has *3 New Towns*, which have not been assigned there usage (e.g- Residential, Green spaces, etc) in future so the BU of 2019 has been added to 50% of the *New Towns'* unassigned area considering as BU. This has been done to predict an estimated BU land in 2025 which has come out to be approx. **171.4 km²**.

➢ After, the BU area of 2025 was estimated, it was placed in the equation above to find an AHS for 2025 which came out to be approx. **17.8 ˚C.**

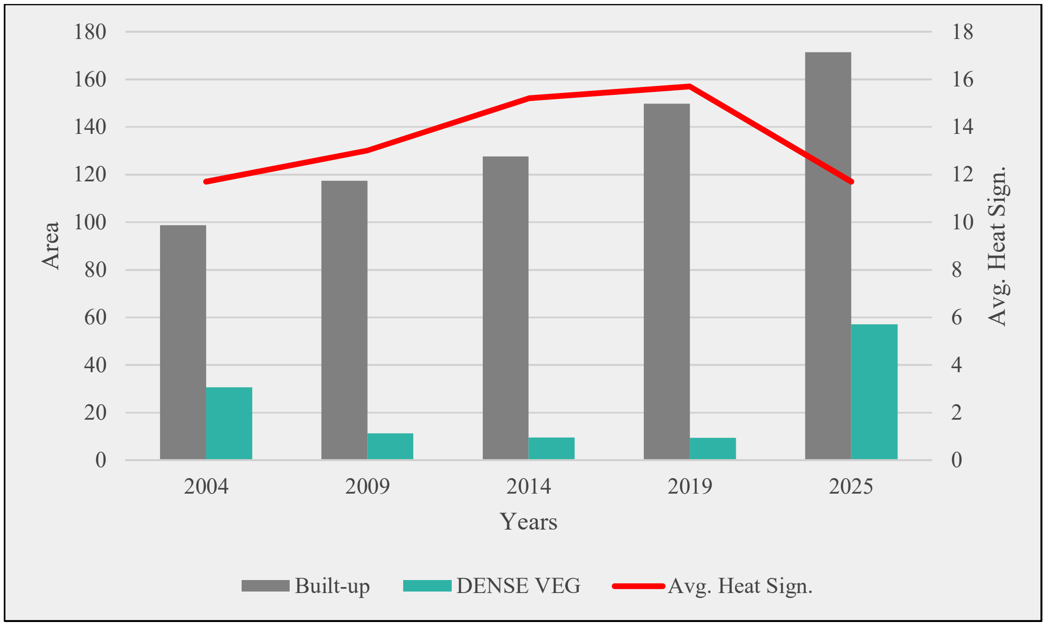


Fig 31: Relationship between Built up area and dense vegetation w.r.t. Temperature

Year	Built-up (km^2)(BU)	Dense Vegetation (km^2)(DV)	Avg. Heat Sign. (˚C)	Ratio between BU & DV
2004	98.70240	30.653256	11.7	3.219886
2009	117.35055	11.21808	13	10.46525
2014	127.66008	9.647123	15.2	13.23711
2019	149.67336	9.364597	15.7	15.98574
2025	171.36781	57.13333	11.7(approx.)	3.00

➢ The table above shows a new factor i.e., the Dense Vegetation. The ratio between BU and DV of the years- 2004, 2009, 2014 and 2019 has been calculated and the minimum ratio came out to be of 2004 i.e., approximately **3:1.**

➢ Also, the most suitable AHS in the end of month February came out to be of 2004 i.e., **11.7 ˚C**.

- So, as to maintain the ratio of **3:1** and the AHS of **11.7 ˚C** in 2025, the DV required to tackle the UHI effect was estimated to be **57.133 km^2.**
- The trend which is estimated till the study of 2019 is:

Trend	
↑	Built-up area
↓	Dense Vegetation area
↑	Land Surface Temperature

whereas

- The trend which is estimated for 2025 w.r.t. 2019 is:

Trend	
↑	Built-up area
↑	Dense Vegetation area
↓	Land Surface Temperature

DISCUSSIONS

- **NDVI-** The NDVI of the images has been calculated to know the quality and quantity of vegetation with the increase in time and also to calculate LST with it.
  - **As the calculation of NDVI is an automatic process, therefore the results are not accurate.**
  - After knowing the quality of vegetation, the *dense vegetation* only has been taken into account for further usage.
  - The difference between 2004 & 2009 and 2014 & 2019 data is due to the data of different satellites i.e., LANDSAT 4-5 and LANDSAT 8 respectively.
  - Its values are measured from -1 to +1 where more than 0 represents vegetation.
- **LST-** LST has been calculated to know the difference between temperatures of Built-up area and Dense Vegetation.
  - With the increase in time, the temperature increases considerably.
- **Dense Vegetation area-** The DV area has been extracted from the calculated NDVI.
  - The area has been extracted after validating the NDVI data with the FCC of the LANDSAT imageries with the help of digitisation.
- **NDBI**- NDBI has been calculated to have an idea of increase in built-up area in Guwahati with growing years.
  - The values of NDBI also range from -1 to +1 and the values below zero represent vegetation and above zero, with the darkness of shade, the density of built-up increases.

CONCLUSION

- The work of this dissertation can be concluded as:
  - The urban growth when linked to heat island effect showed that the ratio of built-up and dense vegetation in 2004 of approx. 3:1 jumped to the ratio of approx. 16:1 in 2019 and to maintain the ratio of 2004, the dense vegetation required came out to be approx. 57.13km^2.
  - This project gives an approach to minimise the impact of urbanisation at macro level while trying to utilise urban cool islands to counter heat islands.
  - **Reduction in UHI effect-** The vast amount of built-up which already exists cannot be just vanished and so some measures which can be helpful in reducing the UHI effect can be planting **trees and vegetation**, making **green roofs** and **cool roofs** and construction of **cool pavements**. **Green belts** are policies and land use zone designation used in land use planning to retain areas of largely undeveloped, wild, or agricultural land surrounding or neighbouring urban areas. And which can be attained by assigning areas in *New Towns* in Proposed Guwahati Master Plan 2025.

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