

# URBAN HEAT ISLAND

A city becomes an **Urban Heat Island** when it gets hotter there than in the neighbouring rural areas. Heat accumulated and released in the urban environment results in a higher urban ambient temperatures compared to the surrounding urban environment.

## Types Of Urban Heat Island

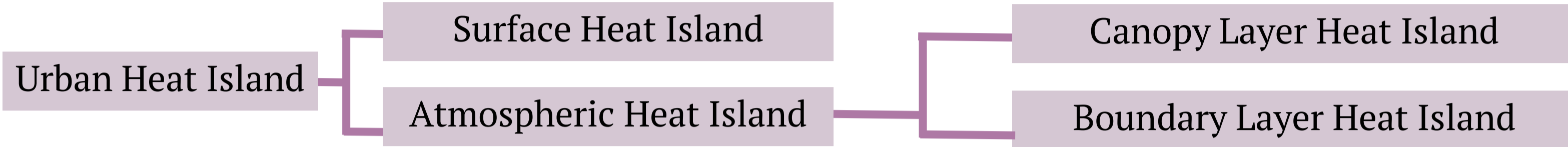
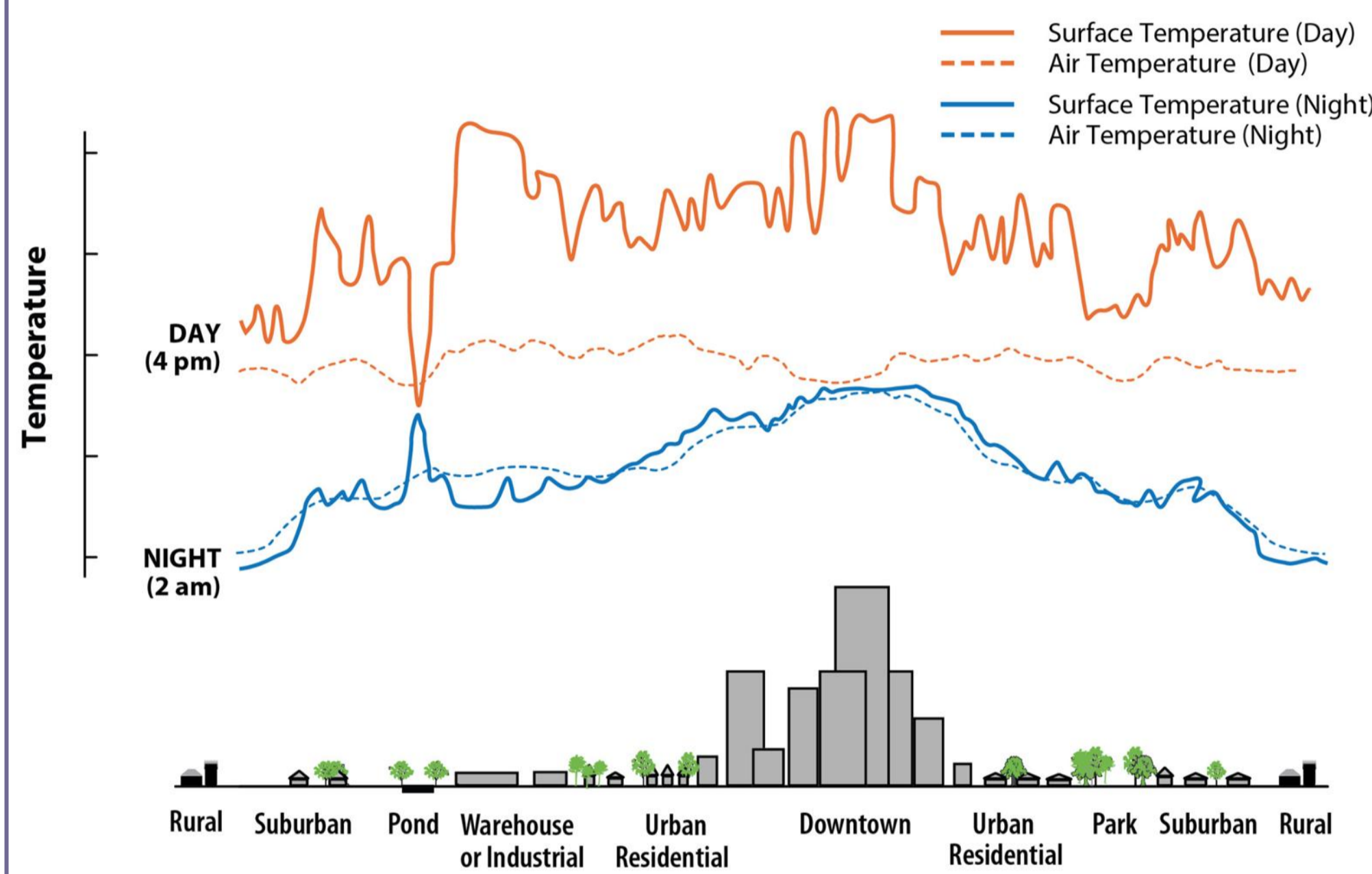


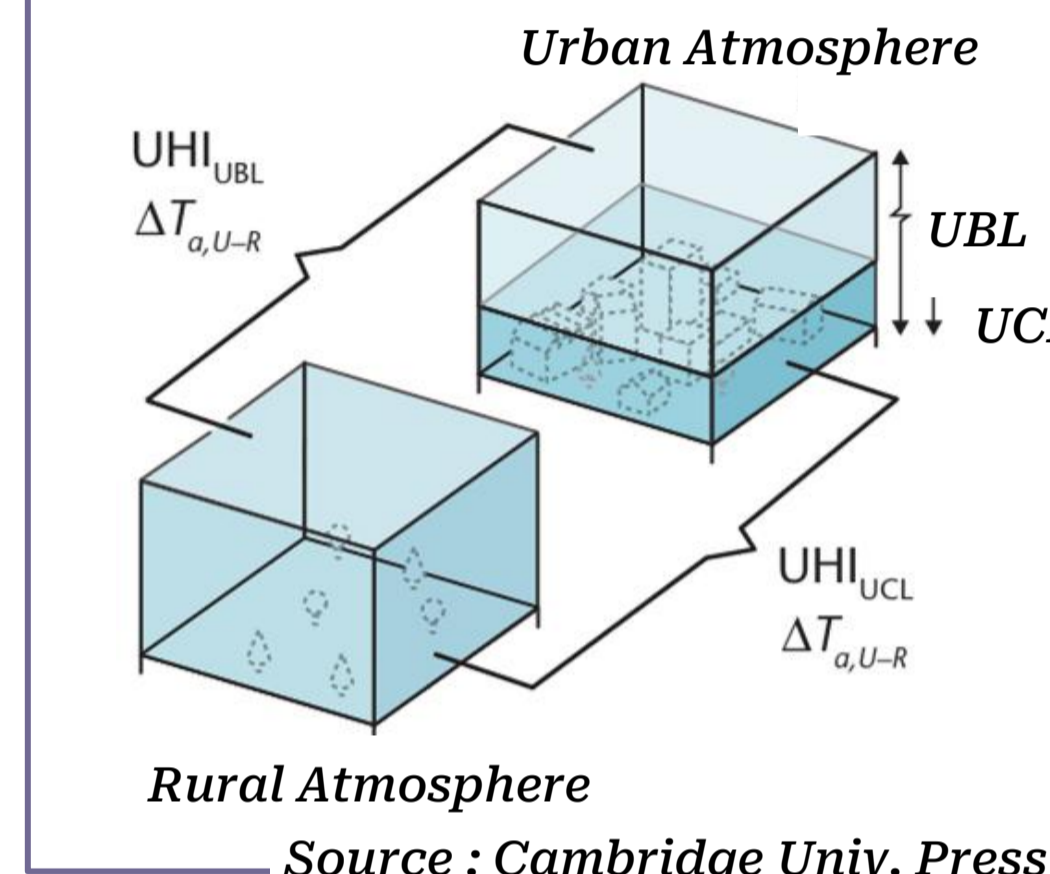
Fig: Cross Section -Spatial Variability of Urban Heat Island



Source : USGS

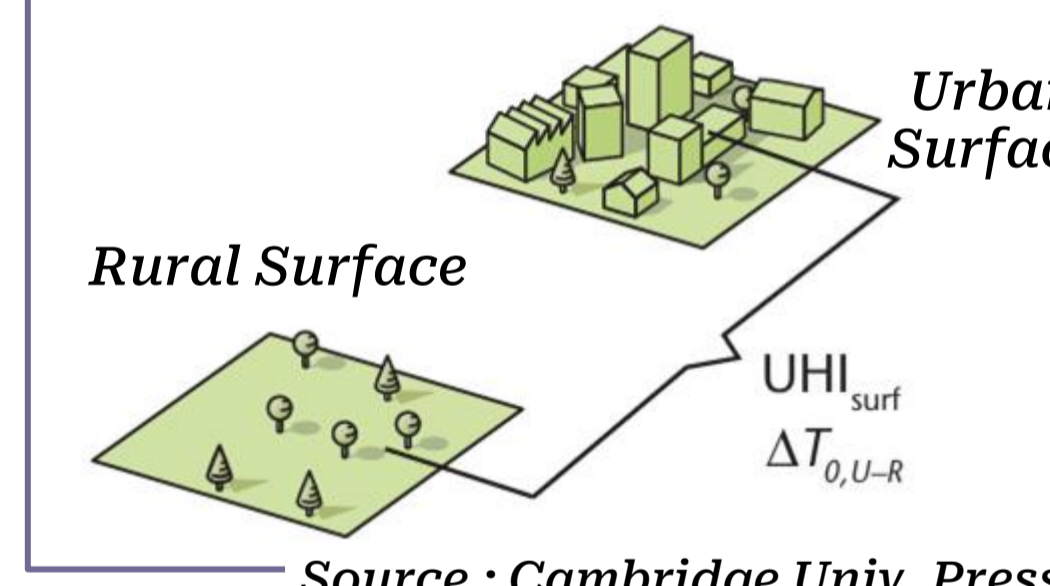
The highest temperature difference can be seen at the highly dense city centre whereas areas with green cover such as rural areas and park shows decrease in temperature.

Fig: Atmospheric Heat Island



Source : Cambridge Univ. Press

Fig: Surface Heat Island



Source : Cambridge Univ. Press

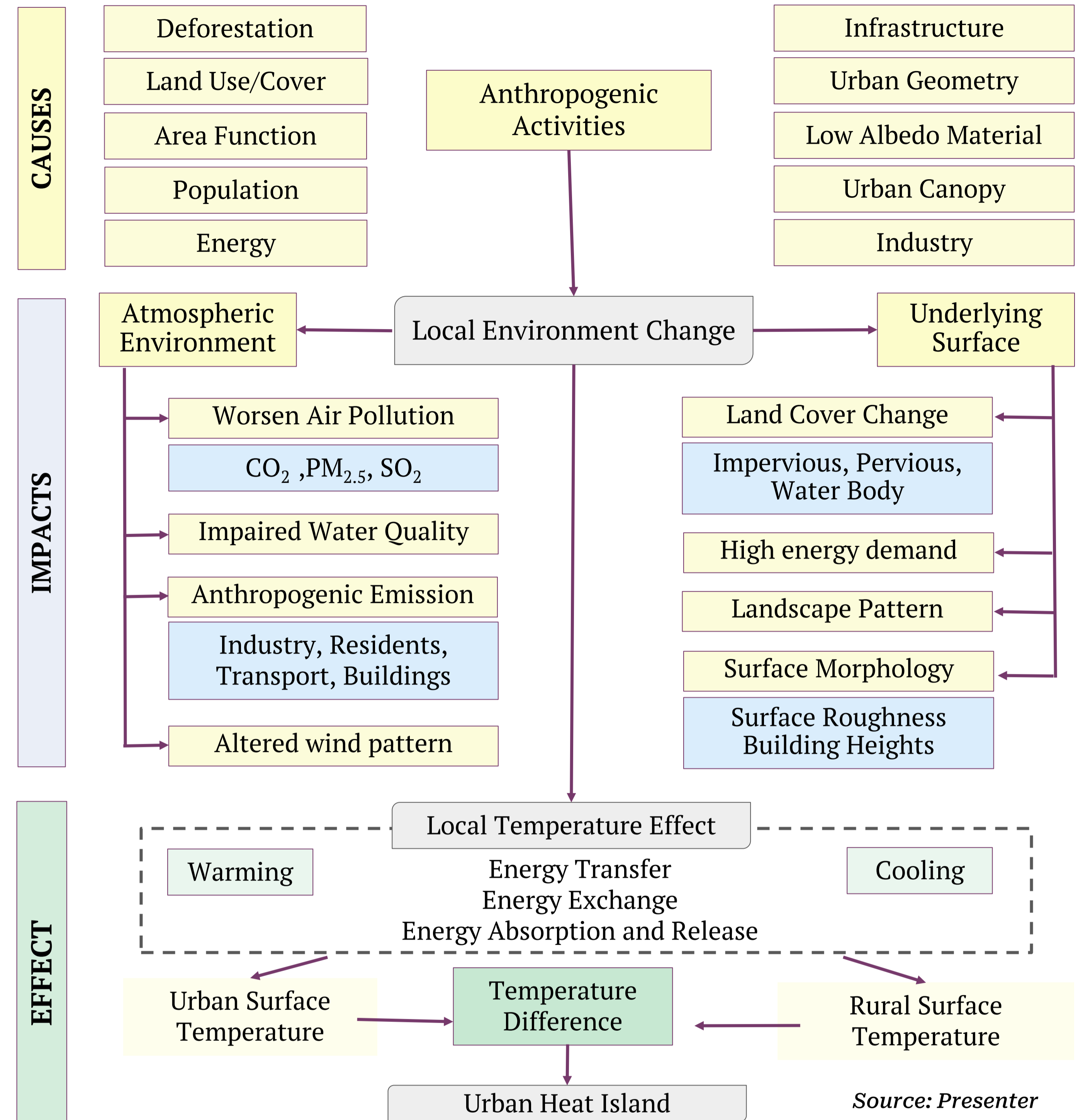
**Times of India**  
Higher mix of pollutants sent temperatures soaring in city: Study  
NIT Trichy study in Hyderabad found areas with high temperatures also had elevated CO, NO2, O3, HCHO, aerosols, and SO2 levels. Urgent urban...

**Times of India**  
Mumbai's spendings will be double of New York's to manage urban heat generated due to concretisation  
A study by Moody's RMS warns that Mumbai will spend more than double of New York's to manage urban heat due to concretization.

- Cities are typically hotter than the surrounding rural areas.
- Climate change & increased urbanisation are making communities hotter.
- Extreme heat increases peak power demand that can lead to power interruption.
- Extreme heat-major cause of weather related death & illnesses.
- High Temperature increase pollutant emissions and smog formation.

[1][3][4] U.S. EPA Heat Island and Equity, 2023 ; [2] Vose et al 2017, krayenhoff et al 2017; [6] Centres for disease control & prevention and WHO 2023

Fig: An interpretative framework of the surface urban heat island effect.



Source: Presenter

## Need of the Study

- UHIs exacerbate the impacts of climate change, leading to more frequent and severe heat waves. Mitigating UHIs is essential for enhancing a city's resilience.
- UHIs contribute to increased energy consumption as buildings require more cooling to maintain comfortable indoor temperatures.
- UHIs disrupt local ecosystems, affect water quality in urban water bodies, and lead to decreased air quality. Green spaces absorb pollutants.
- Industrial processes release pollutants affecting local air quality & public health.

## LITERATURE STUDY

Aim	Methodology/Tools	Conclusion	Finding
Do industrial parks generate heat island effects in cities? New evidence, quantitative methods, and contributing factors from a spatiotemporal analysis of top steel plants in China			
To investigate rationale of <b>UHI effect for understanding urban industrial heat sources</b>	1. Image Pre-processing 2. Land Cover Classification and Assessment 3. Land Cover Change Detection	An effective method to quantify the <b>warming effect derived from the urban industrial park</b> , and the spatiotemporal analysis	The existence of industrial heat island. <b>IHI effect is more severe in warm seasons and weakest in winter.</b>
Analysis of Urban Heat Island (UHI) in relation to NDVI. (Central University, Punjab, 2015) Grover Singh, Aditi Ram Babu			
Analysis of <b>UHI in relation to NDVI.</b>	Thermal Mapping through LANDSAT Images	UHI was found to be strong in Mumbai compared to that in Delhi	Changing <b>land-use patterns and green cover caused heat island.</b>
Land Use, Land Cover & Population Density Impact on Formation of Canopy Urban Heat Islands through Traverse Survey in the Nagpur Urban Area, India (ASCE Library, 2016) Rajashree Kotharkar & Meenal Surawar			
To compare the canopy UHI hotspots and heat sinks with respect to urban land use/land cover and population density	Area classification based on population density and 96 points lined up in 3 survey routes for Traverse Survey. The spatial analyst extension in ArcGIS was used to interpolate by kriging method and thermal isotherms were plotted.	The land use/land cover affects the UHI effect by thermal-biological variation of surface materials. <b>Canopy-layer UHI effect increase with increase in population, building and population density</b>	To compare the <b>canopy UHI hotspots and heat sinks with respect to urban land use/land cover</b> and population density
Spatial variation of surface urban heat island magnitude along the urban-rural gradient of four rapidly growing Indian cities (Taylor & Francis, 2021) Pir Mohammad & Ajanta Goswami			
To identify relationship of LST and surface urban heat island with the degree of impervious surface and green spaces (GS)	Retrieval of LST by converting digital number (DN) to radiance Convert the radiance images into brightness temperature by considering the black body concept. Extraction of impervious surface and green spaces. Urban-rural gradient analysis .	<b>Strong negative correlation of LST and fraction of Impervious Surface</b> in Ahmedabad, Nagpur, and Jodhpur, while a positive correlation observed in Guwahati city. The importance of green spaces has been highlighted for maintaining urban temperature	To identify relationship of Land surface temperature and surface urban heat island (SUHI) with the degree of impervious surface (IS) and green spaces
Interaction between UHI & pollution island during summer in Berlin (Elsevier, 2018) Huidong Li, Fred Meier, Xuhui Lee, Tirthankar Chakraborty, Junfeng Liu, Martijn Schaap, Sahar Sodoudi			
Investigation of impact of urban heat island on near surface PM10 concentrations.	1. Calculations of the intensities of AUHI and SUHI 2. Calculations of the intensities of AUPI and NSUPI 3. Calculation of the change of SUHI intensity caused by the urban-rural difference of incoming radiation	Spatial consistency between SUHI and AUPI, with higher LST and AOD in the urban areas. <b>UHI strengthens the turbulent dispersion of particles in the urban areas</b> , decreasing the NSUPI. Negative Correlation between AUPI and NSUPI.	Investigating UHI impact on near surface PM <sub>10</sub> conc. through analysis of in-situ & remote sensing observations of aerosols & meteorological variables
Impact of urban heat island on regional atmospheric pollution. (Elsevier, 2005) C. Sarrata, A. Lemonsub , V. Massona , D. Guedalia			
To study the impact of land cover on local meteorology.	1.Generalities and modelling configuration 2. Evaluation of the atmospheric model	Nocturnal & diurnal urban effects on the primary and secondary regional pollutants, more specifically the ozone and the nitrogen oxide (NOx).	<b>Land cover impact on local meteorology &amp; atmospheric pollutants spatial distribution.</b>
Coorelation of surface temperature of rooftops, streetscapes and urban heat island effect - central sydney (JSTOR, 2015) Ehsan Sarifi, Steffan Lehman			
To explore most heat resilient feature precinct scale.	Identifying sUHI, Building Thermal Performance Index,	Higher Open Area Ratio and Street network intensity correlate significantly to higher UHI. <b>10% inc. in greenery, 10% dec. in temp.</b>	Limited to spatial data available, on <b>spot micro climate measurement required.</b>

- 10% increase in greenery can decrease temperature by 10%.
- Higher open area ratio & street network intensity correlate with higher UHI.
- Industrial Heat Island effect more severe in warm seasons, weaker in winter.
- Increase in density, buildings, and population, the canopy-layer UHI increases.
- UHI strengthens turbulent dispersion, decreasing near-surface UPI
- Agricultural/Vacanta area has lower albedo and absorb more solar radiation.
- CO2 released have low heat trapping potential but large quantity leads warming

## RESEARCH GAPS

Lack of comprehensive & standardized policies mitigating UHI in India. (*Grover Singh, Aditi Ram Babu*)

Understand the variability in UHI intensity on Factors such as urban morphology, land use, green spaces, & local climate.

Studies have examined the influence of industrial zones on UHI there remains limited research explicitly quantifying the impact of industrial areas on LST.

## RESEARCH QUESTIONS

How do various factors impact the ability to counteract UHI effect and create more comfortable climates within industrialized urban areas?

How air pollution contribute to the exacerbation of the UHI, and what impacts does it have on thermal characteristics ?

Investigating whether the typical Spatial Variability of Urban Heat Island theory hold true across all cases.

## AIM OF THE STUDY

**To investigate the Urban Heat Island (UHI) phenomenon in an Industrial Area**

## OBJECTIVE OF THE STUDY

To establish understanding of UHI phenomenon in an Industrial Town/s - Jamshedpur Urban Agglomeration.

To analyse variations of urban parameters - vegetation, water bodies, building material on local climate.

To recommend strategies to mitigate of Heat Island Effect.

## SCOPE OF THE STUDY

Develop methodologies to quantify the cooling effect due to increasing green and reducing impervious surfaces. Identify suitable locations for creating/enhancing green spaces.

Identifying energy trapping in air pollution and their impact on Urban Heat Island.

Explore techniques to reduce impervious surfaces through urban design, permeable pavements, and other strategies.

## METHODOLOGY

### 1. Literature Review

Investigate factors causing heat island formation and their impacts

Identify research gaps in existing works

### 2. Develop Aim, Questions and Objectives

Frame primary aims guiding the assessment and Key Questions related

Establish measurable objectives and heat mitigation quantification

Study Area Selection and Delineation

### 3. Data Collection

Satellite data and Meteorological Data

Reconnaissance and Household survey

Location	Jamshedpur	Adityapur	Mango	Jugsalai	Villages	Total
Samples	47	43	29	21	20	160

### 4. Land Use Land Cover Mapping

Data Acquisition and Pre-processing

Land Cover Classification

Accuracy Assessment by confusion matrix

### 5. Normalized Difference Vegetation and Built Up Index Calculation

Required band from USGS

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

### 6. Land Surface Temperature Retrieval

Conversion of the DN to spectral radiance (L)

Conversion of spectral radiance to BT in Kelvin

Conversion from Kelvin to Celsius

### 7. Correlation of LST with Land Use, NDVI and NDBI

Fishernet creation for study area

Multi Value addition to attribute table.

Regression analysis for variables.

### 8. Temperature analysis for Industrial, Commercial, Residential

Old vs New Industrial Area difference

Roof Material and Height effect

Buffer analysis of Indus./ Com.

### 9. Ward Analysis

Temp. variation-green typology

Temp. variation-Housing Typology

Land Use Temperature variation

### 10. Compare density, income and social factors with UHI.

### 11. Conclusion

Finding on interactions of vegetation, industries and heat mitigation

Recommending planning initiatives improving sustainability & climate

Result Generation

## AREA CONTEXT

No study on effect of industries on UHI

First Planned Industrial City of India

One of Largest Industrial estate.

Unique Industrial Landscape.

Fig: Administrative structure of JUA

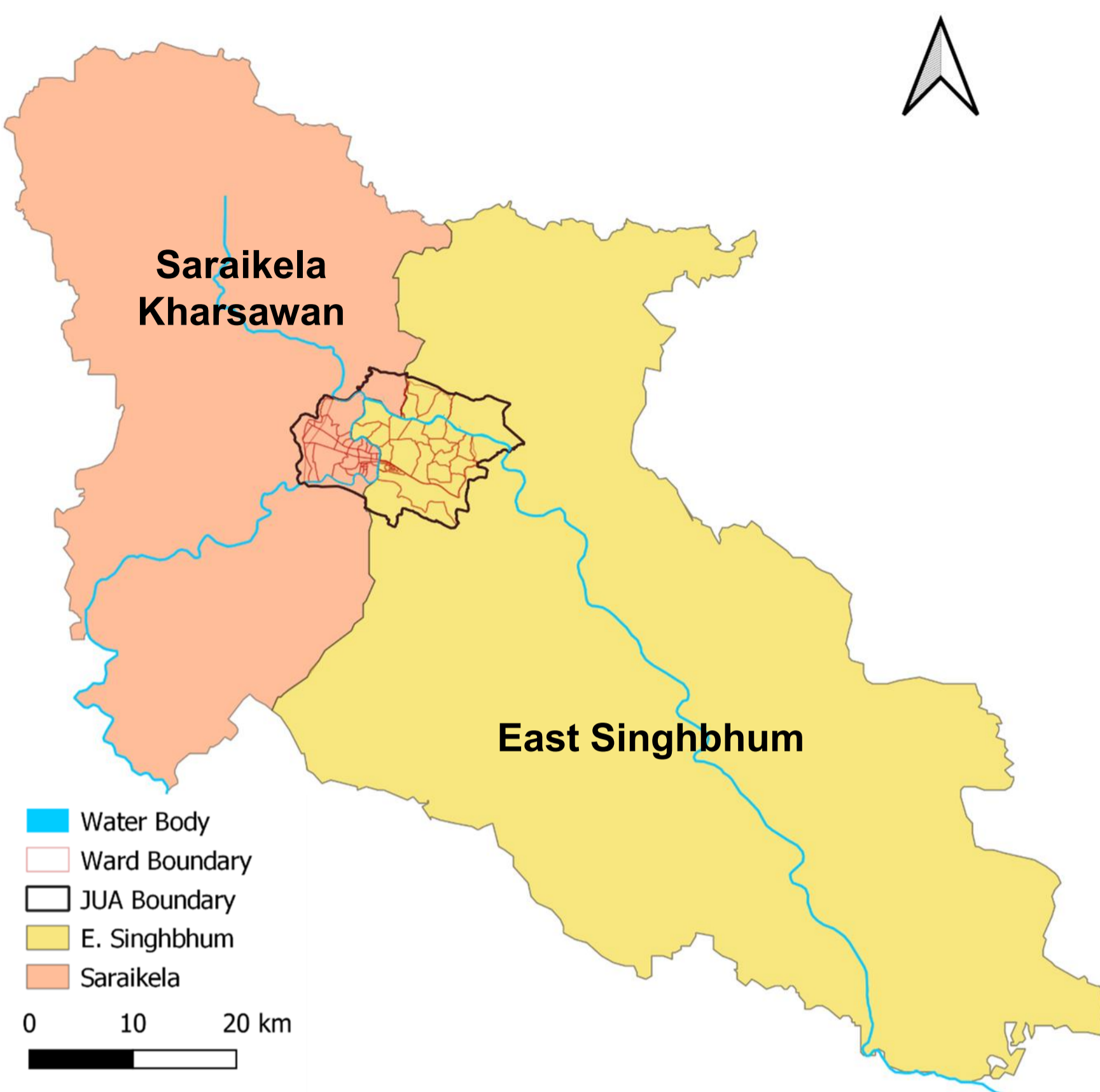


Fig: Growth Pattern of Jamshedpur.

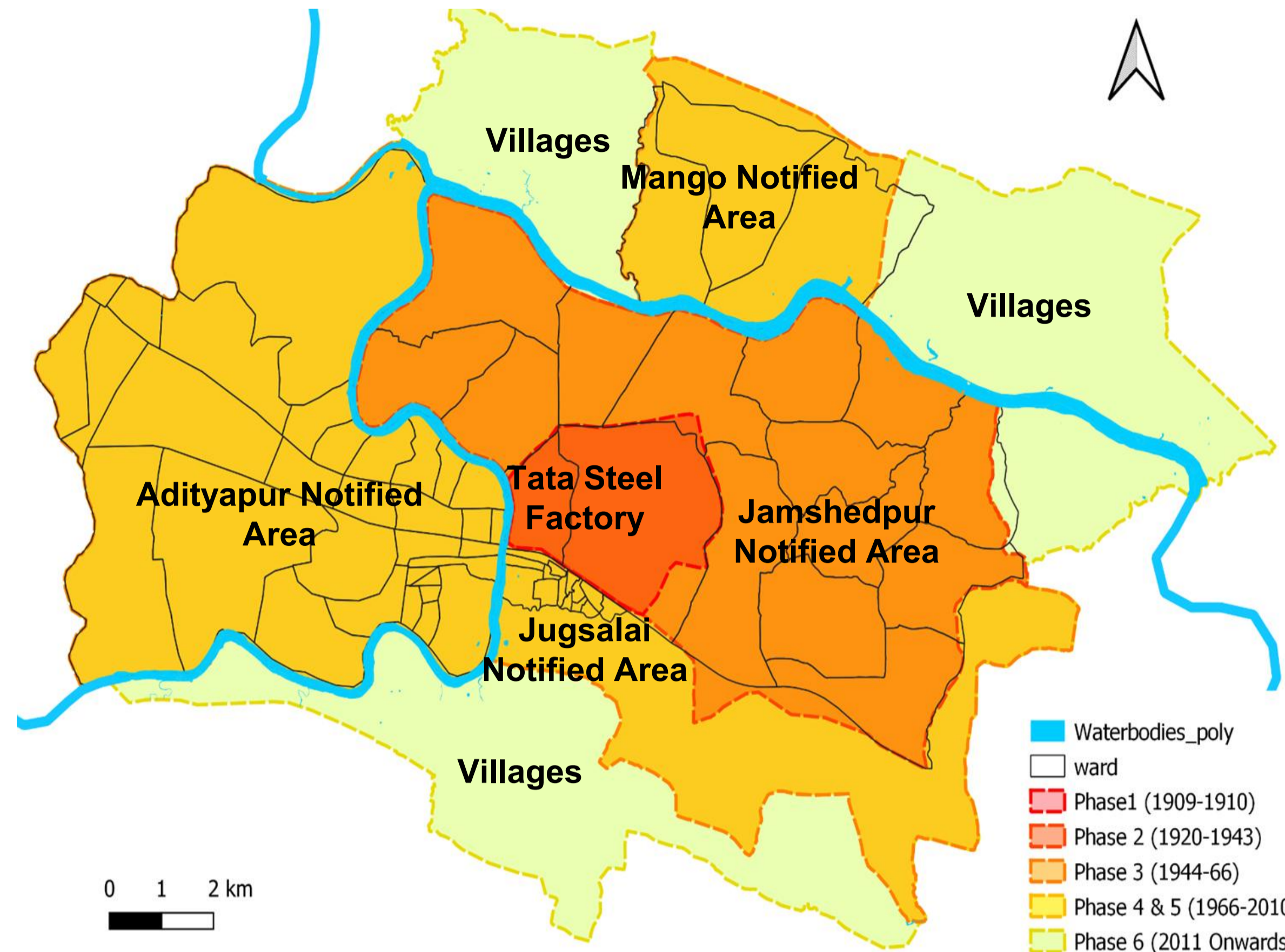
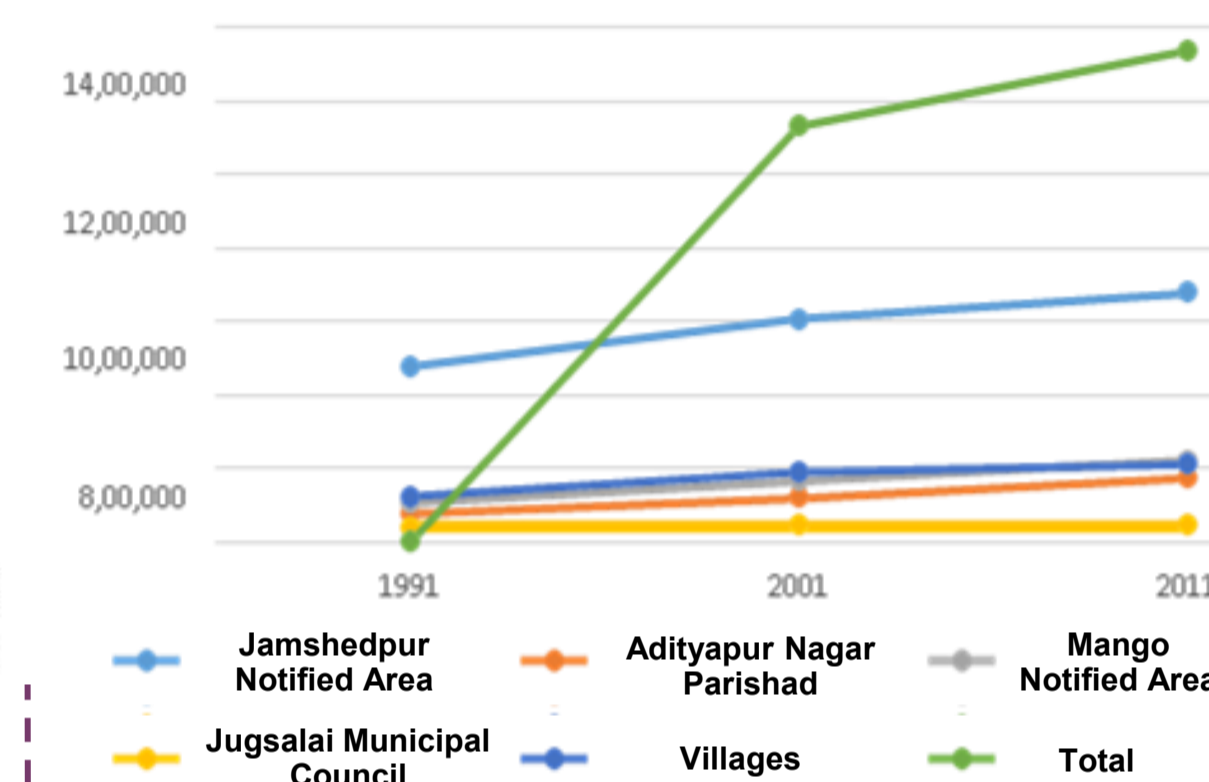


Fig: Population Growth Trend of JUA

	1991	2001	2011
Jamshedpur Notified Area	4,78,950	6,08,768	6,77,350
Adityapur Nagar Parishad	77,803	1,19,233	1,74,355
Mango Notified Area	1,08,100	1,66,091	2,23,805
Jugsalai M. C.	38,623	46,114	49,660
Villages	1,25,715	1,91,396	2,11,961
<b>Total</b>	<b>8,29,191</b>	<b>11,31,602</b>	<b>13,37,131</b>

Fig: Population Trend



JUA had a population of 1,337,131 in 2011, with varied growth rates across its constituents, from rapid expansion in Adityapur to slower growth in Jugsalai, and 11.99% below 6 years old.

Fig: Land Use Map (2020)

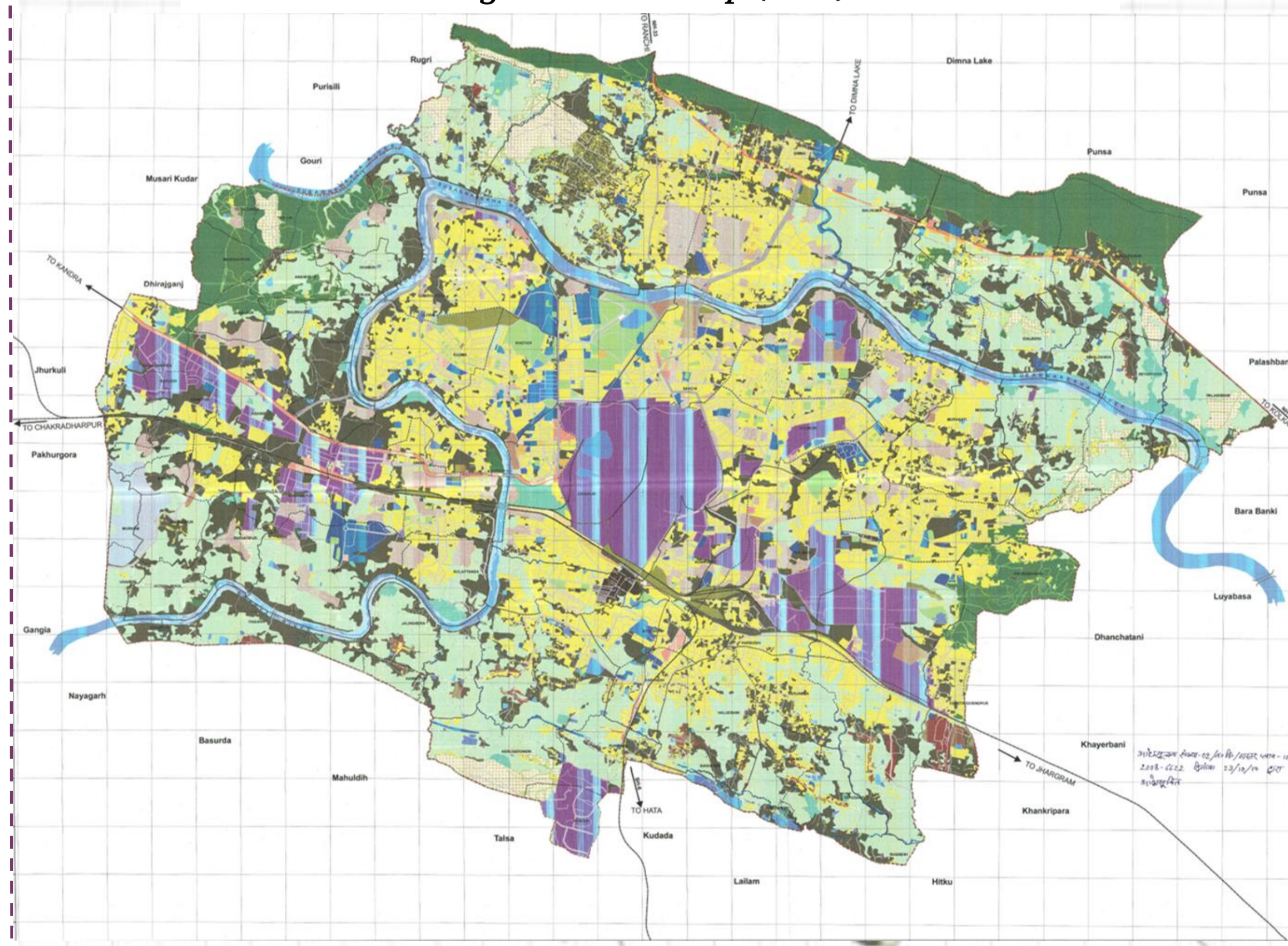
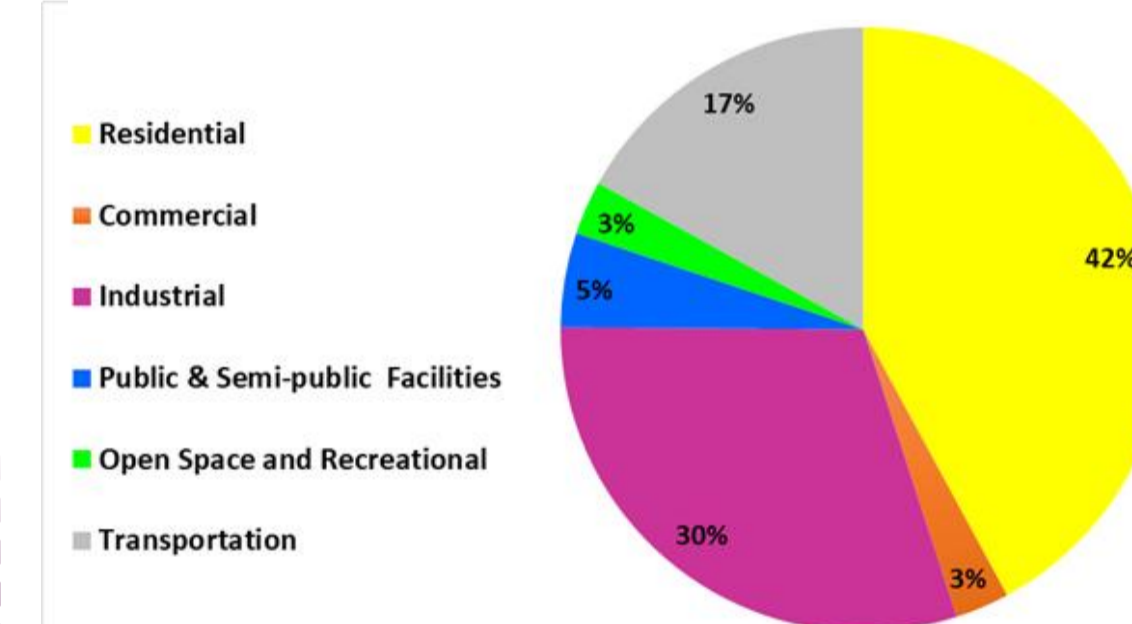
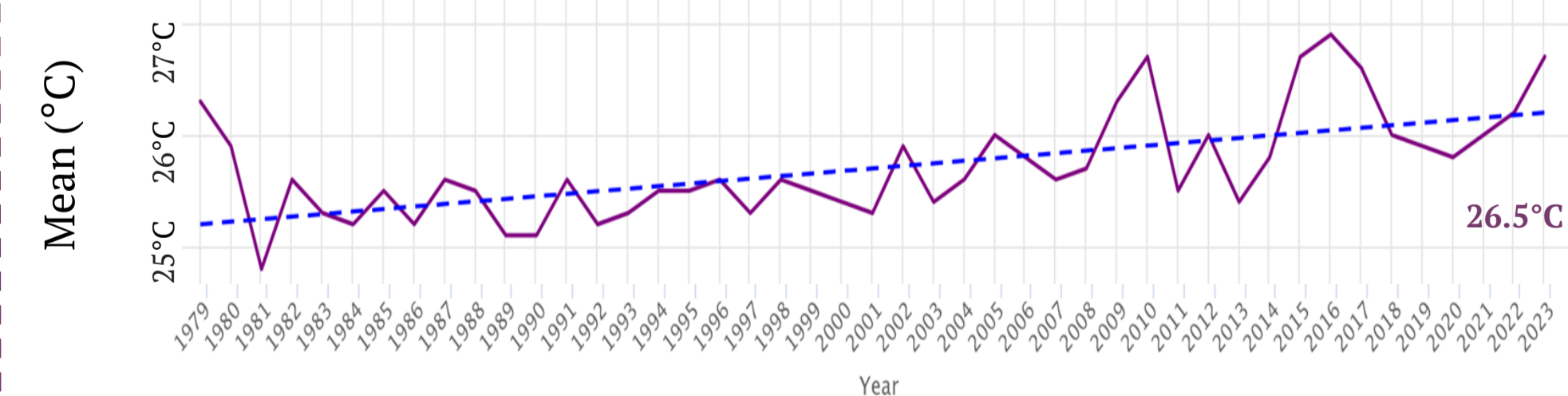


Fig: Land Use Percentage



In the Jamshedpur Urban Agglomeration, residential land use prevails at 42%, followed closely by industrial activity at 30%, reflecting its industrial heritage.



The temperature trend is positive and it is getting warmer due to climate change. The temperature trend has increased from 25.2°C in 1979 to 26.5°C in 2023. There has been variation of 1.4°C in 45 years.

The **Jamshedpur Urban Agglomeration (JUA)** consisting of Jamshedpur, Adityapur and Mango notified areas, Jugsalai municipality & 8 villages of Ghorabandha, Chota Govindpur, Gadhra, Sarjamdah, Haludbani, Kitadih, Bagbera and Parsudih.

The study area is partly spread over **two administrative districts** of East Singhbhum and Saraikela-Kharasawan within Jharkhand.

## HISTORY OF JAMSHEDPUR

Jamshedji Tata in 1907 discovered the village of Sakchi in the Chota Nagpur plateau region and decided to build the first steel plant of India. Construction began in 1908, and on February 16, 1912, the plant rolled out its first steel ingot. This led to the establishment of the planned industrial city of Jamshedpur.

Fig: LULC map and Land Surface Temperature for year 1990

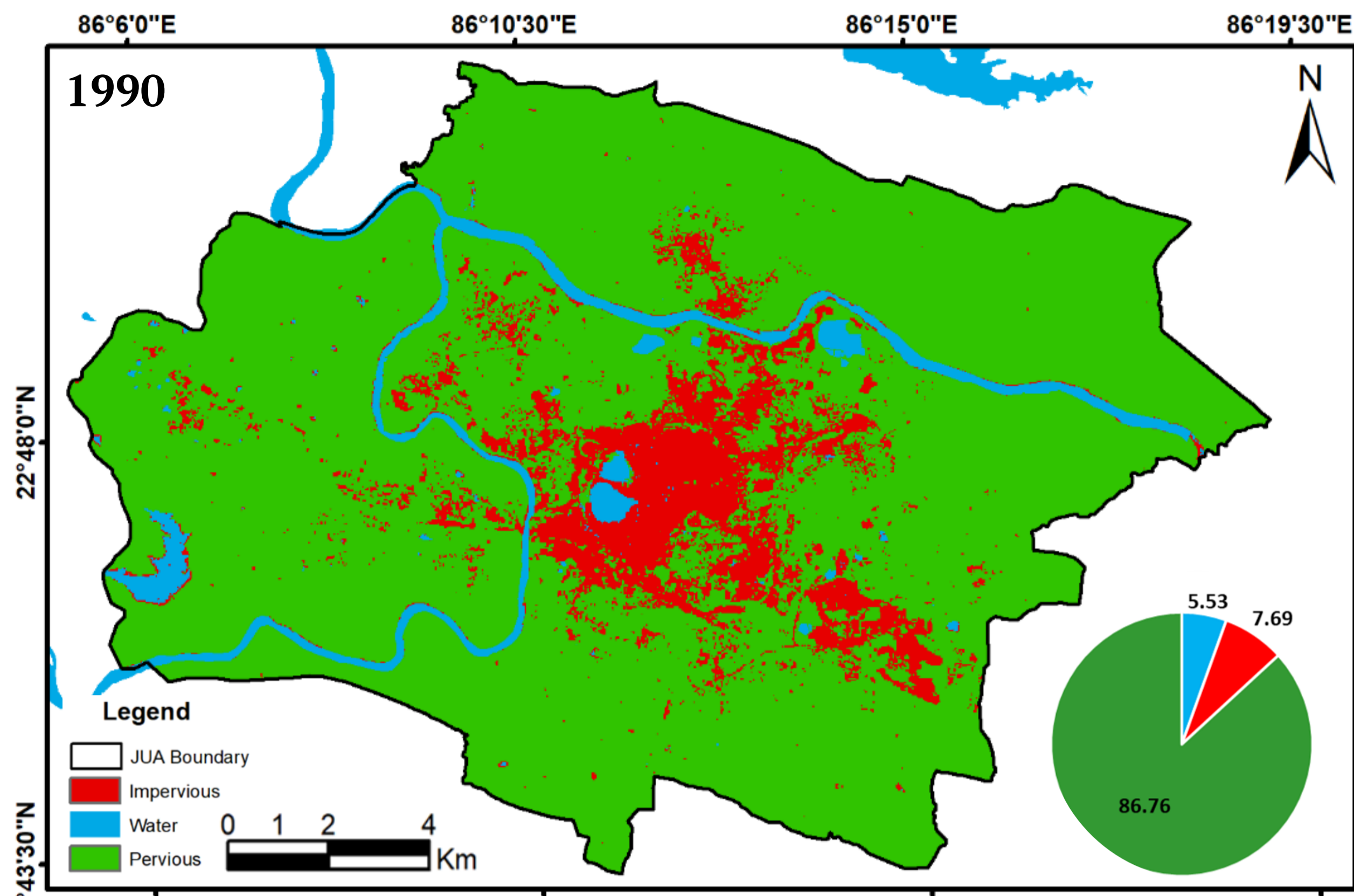


Fig: LULC map and Land Surface Temperature for year 2025

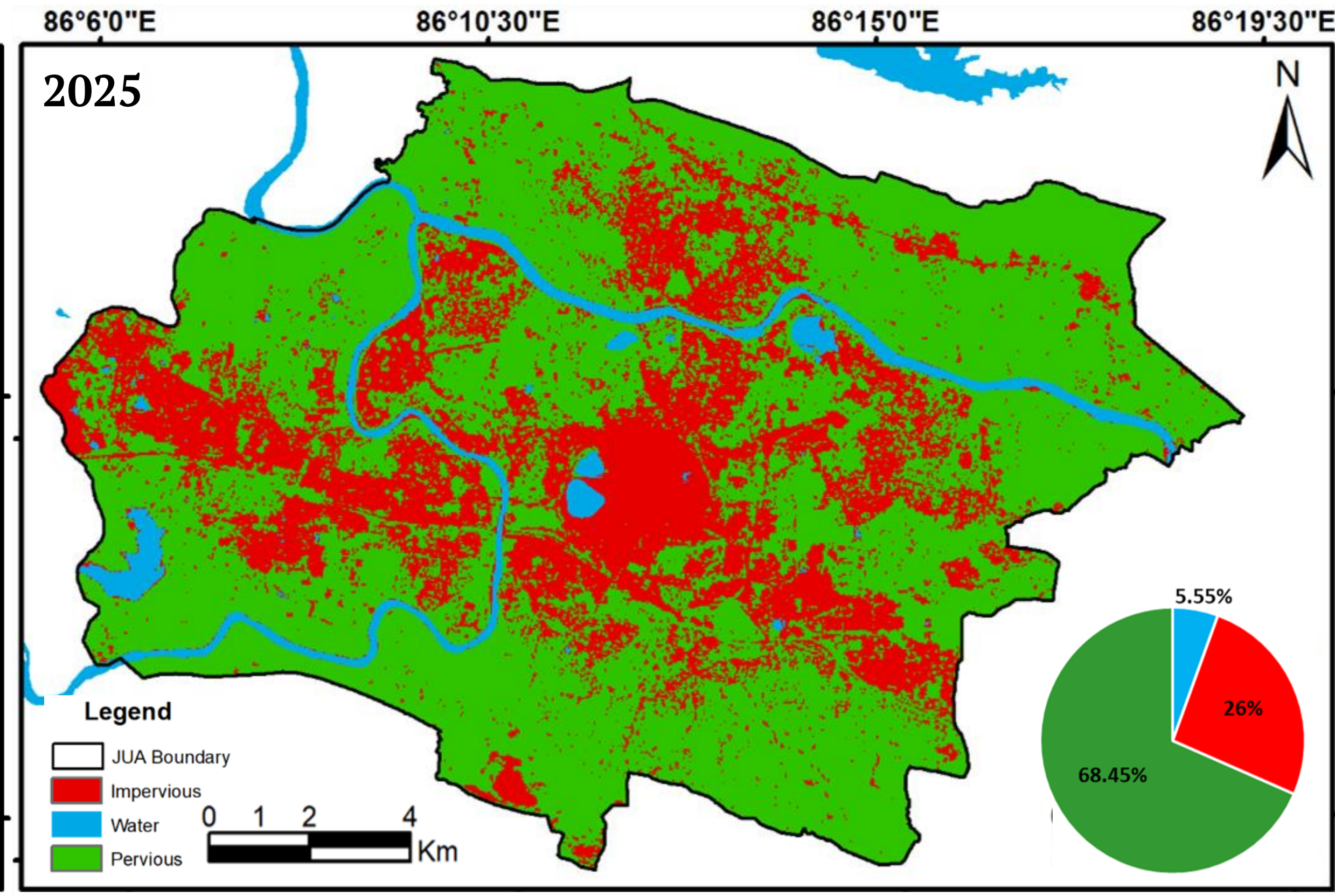


Fig: Area under each °C (1990)

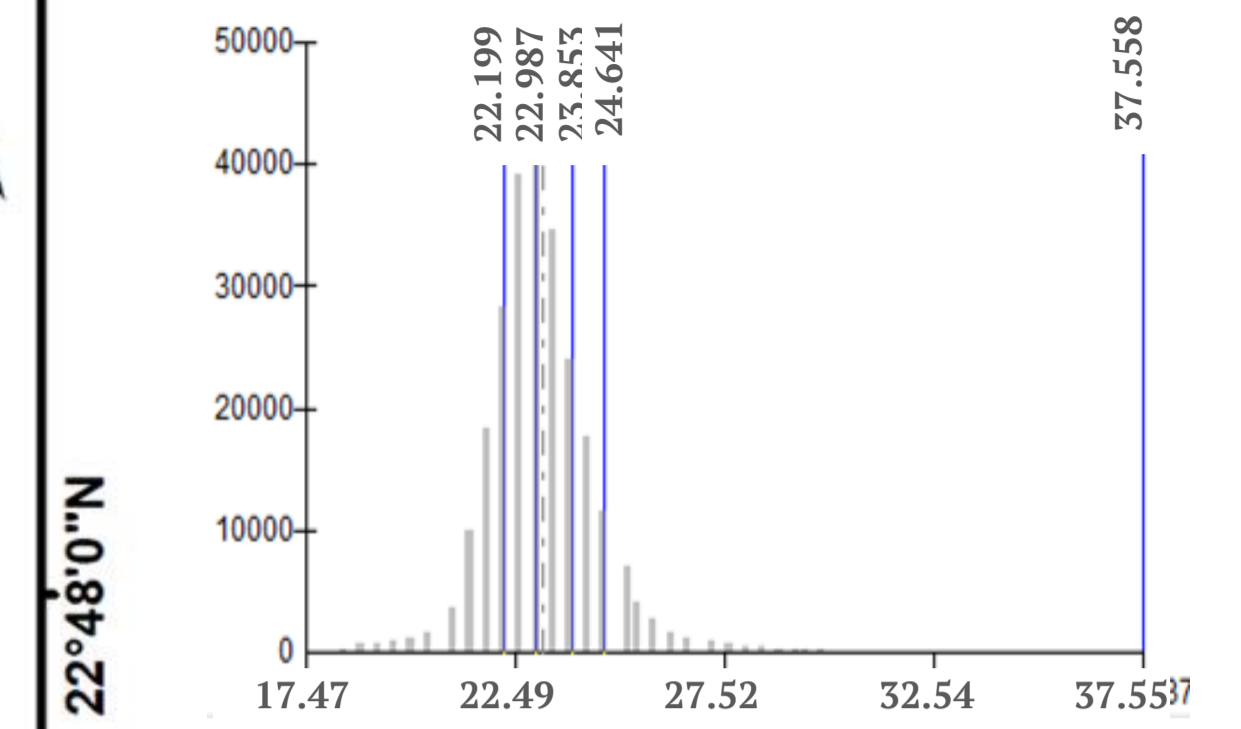


Table: Land Cover Temp. °C (2025)

1990	Min	Max	Mean
Impervious	17.47	37.55	25.29
Pervious	18.78	29.92	23.05
Water	17.47	27.93	21.53

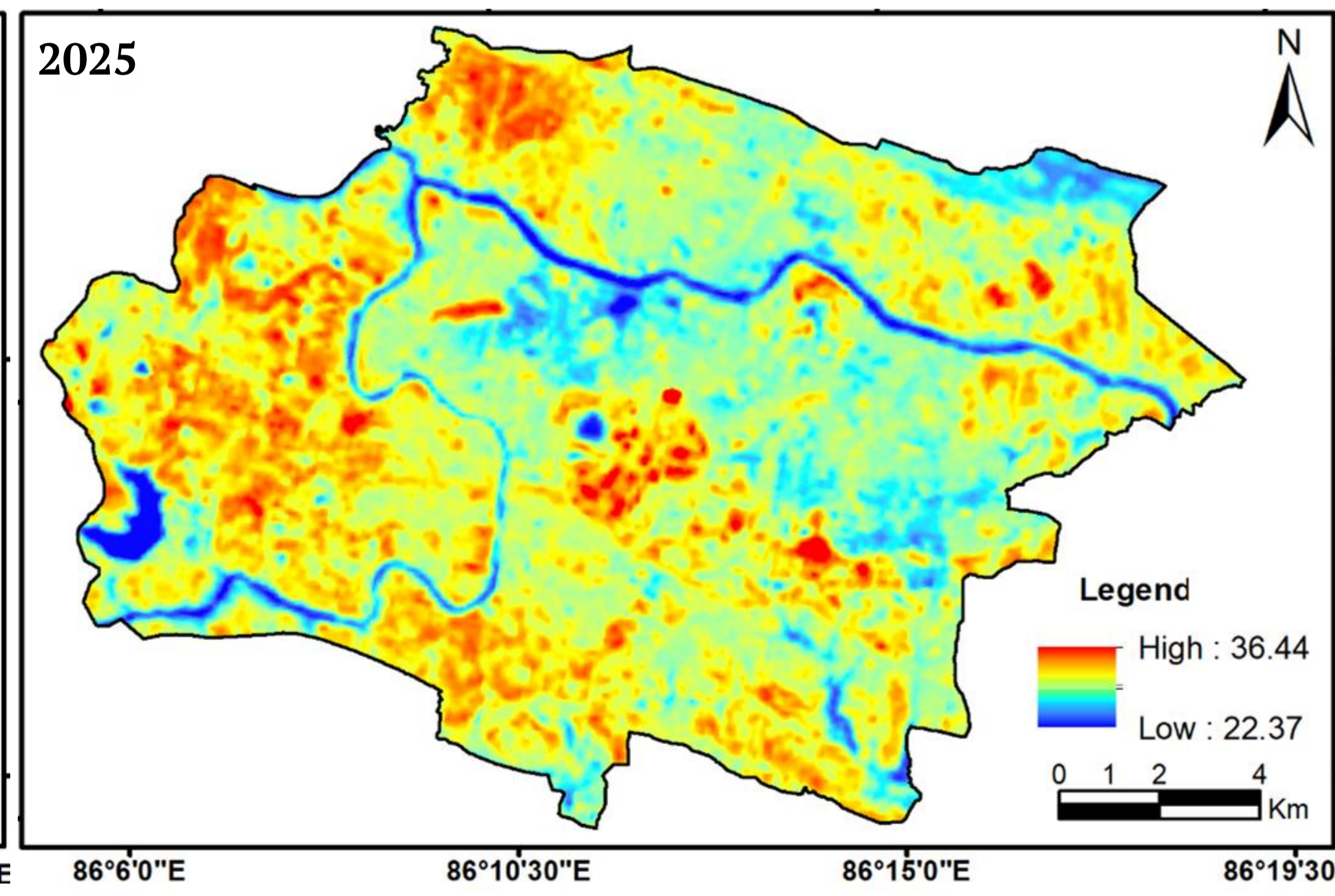
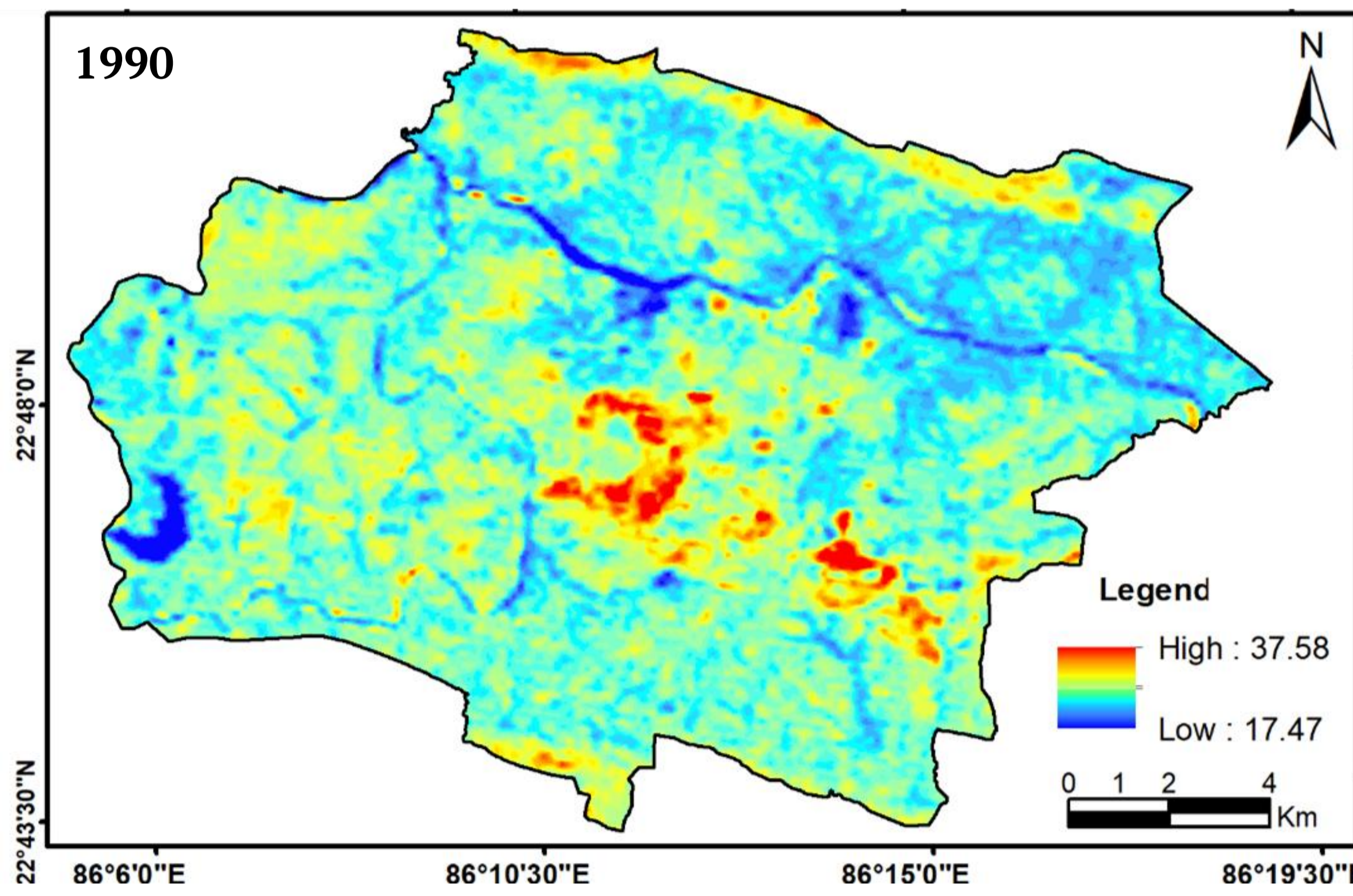


Fig: Area under each °C (2025)

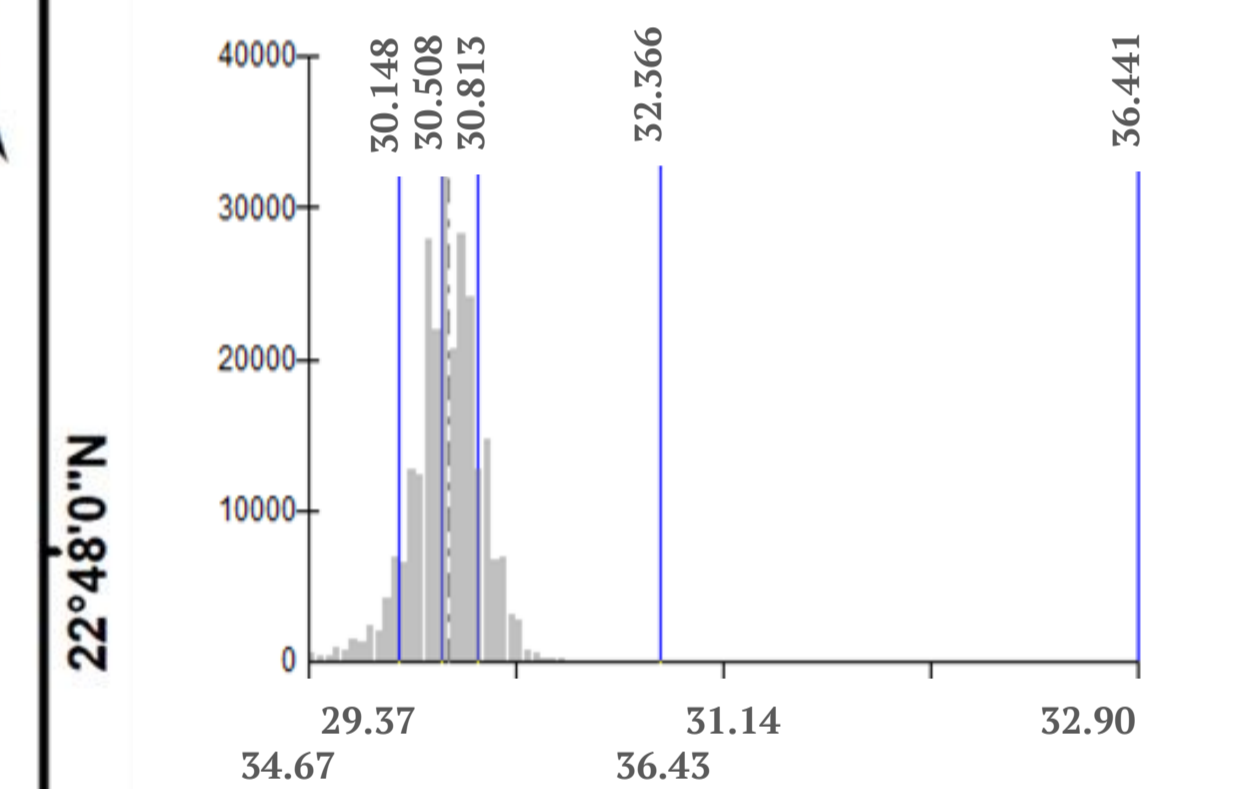


Table: Land Cover Temp. °C (2025)

2025	Min	Max	Mean
Impervious	19.34	36.44	28.67
Pervious	19.54	31.41	23.57
Water	17.67	28.07	24.15

In 1990 the city was mainly confined south of the Swarnarekha river where as in 2025 the urban area has expanded towards west side forming Adityapur area. North side of the river i.e Mango area has seen high density development. The temperature difference between impervious area has decreased significantly. For the year 1990 the difference with min and maximum temperature was 20.08°C and for 2025 it is 17.1°C. Industrial area of Adityapur saw a significant increase in temperature in the 30 years.

- Impervious areas have increased by 238% and pervious has decreased by 21%.
- The area under with higher temperature range has increased significantly in 35 years.
- Significant increase in temperature in Adityapur Area.

## Normalised Difference Vegetation Index (1990-2025)

Fig: Normalised Difference Vegetation Index for 1990

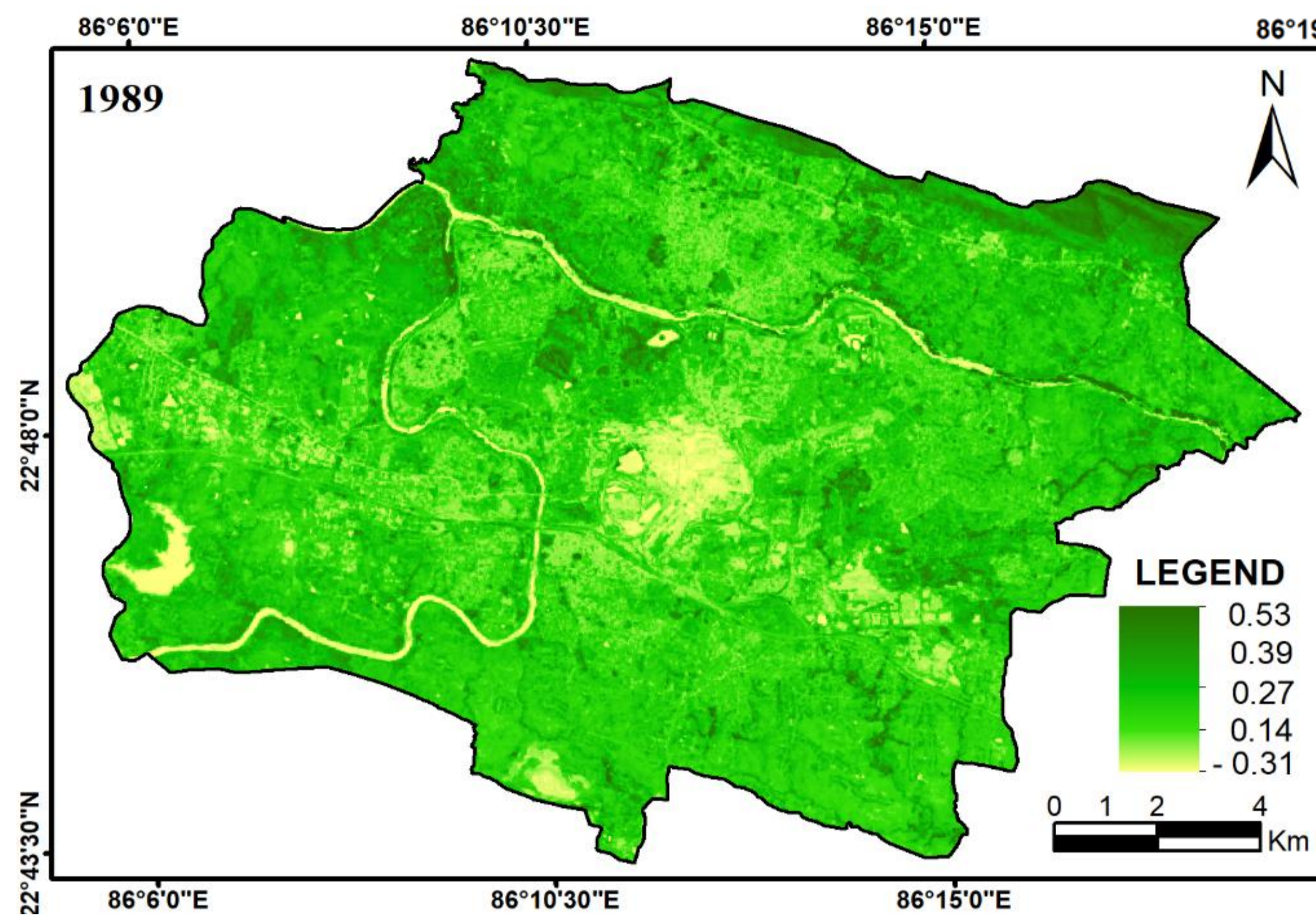


Fig: Normalised Difference Vegetation Index for 2025

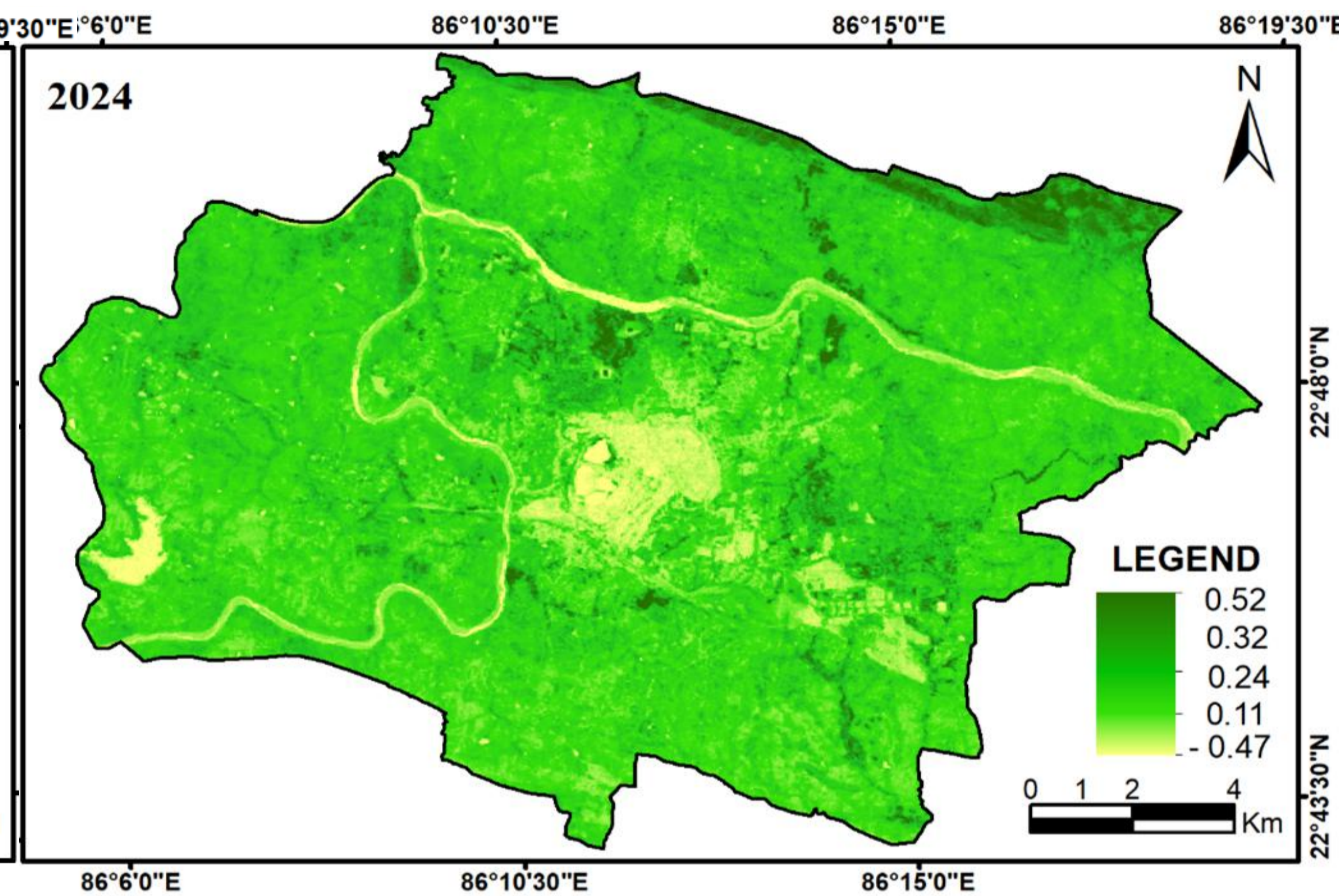


Fig: LST NDVI Correlation (1990)

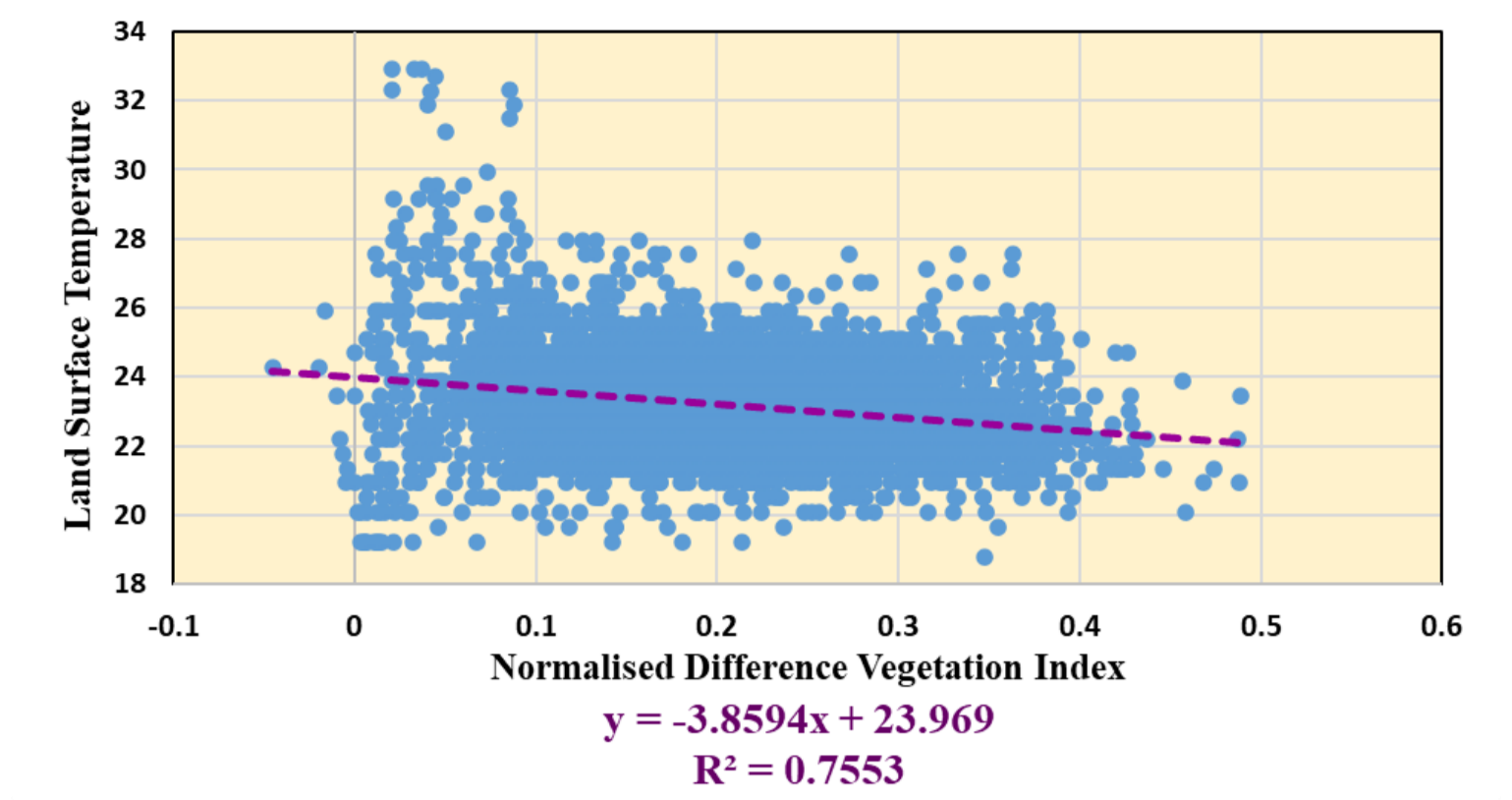
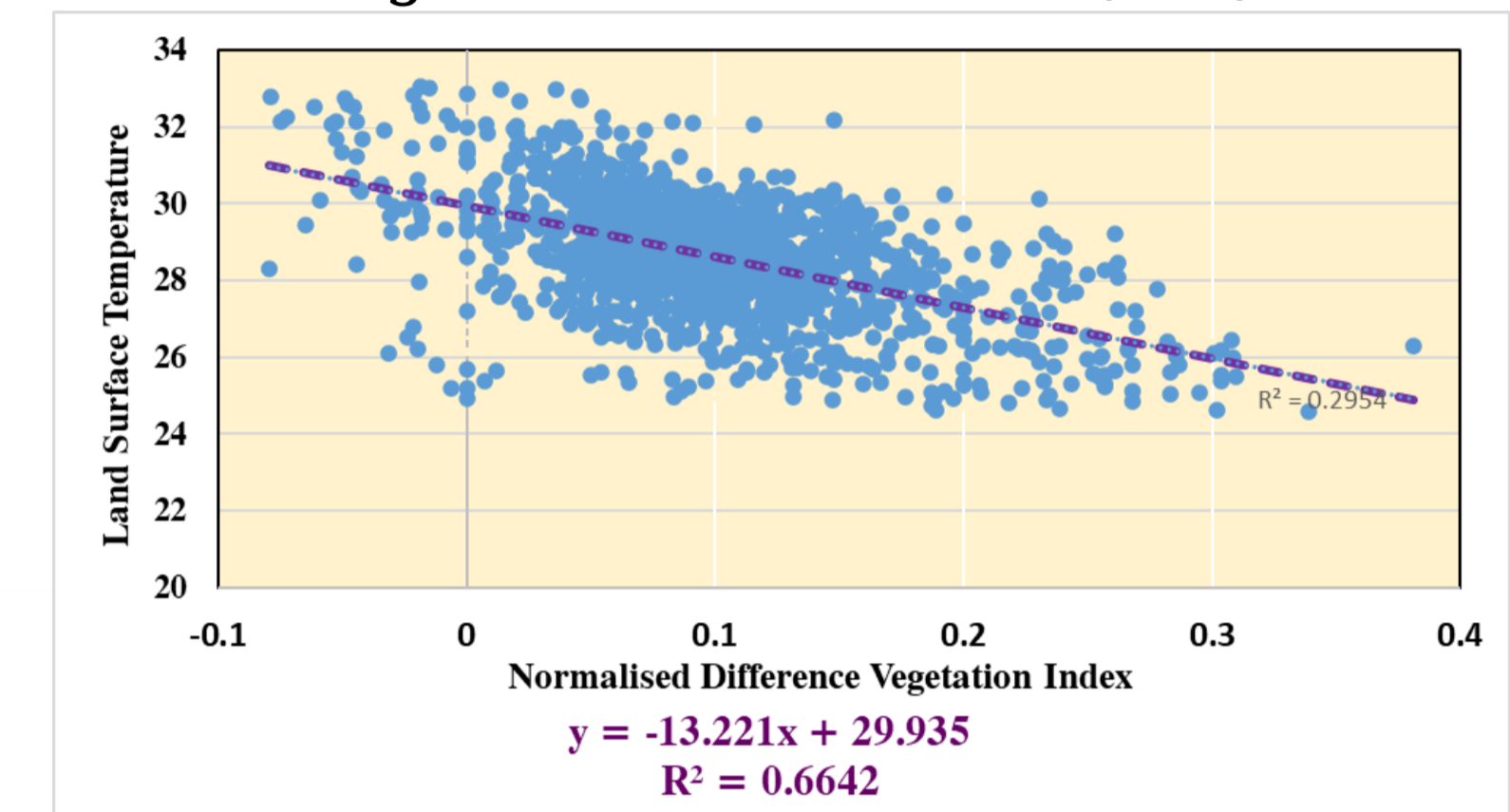


Fig: LST NDVI Correlation (2025)



NDVI is a measurement of greenness of vegetation cover by remote sensing measurements. The dense vegetation has significantly decreased in Adityapur and Mango area whereas in Jamshedpur there is hardly and difference. For every unit increase in NDVI, the LST decreases by 8.149 units for year 2025. About 8.71% of the variation in Land Surface Temperature can be explained by the linear relationship with NDVI.

## Normalised Difference Built Up Index (1990-2025)

Fig: Normalised Difference Built Up Index for 1990

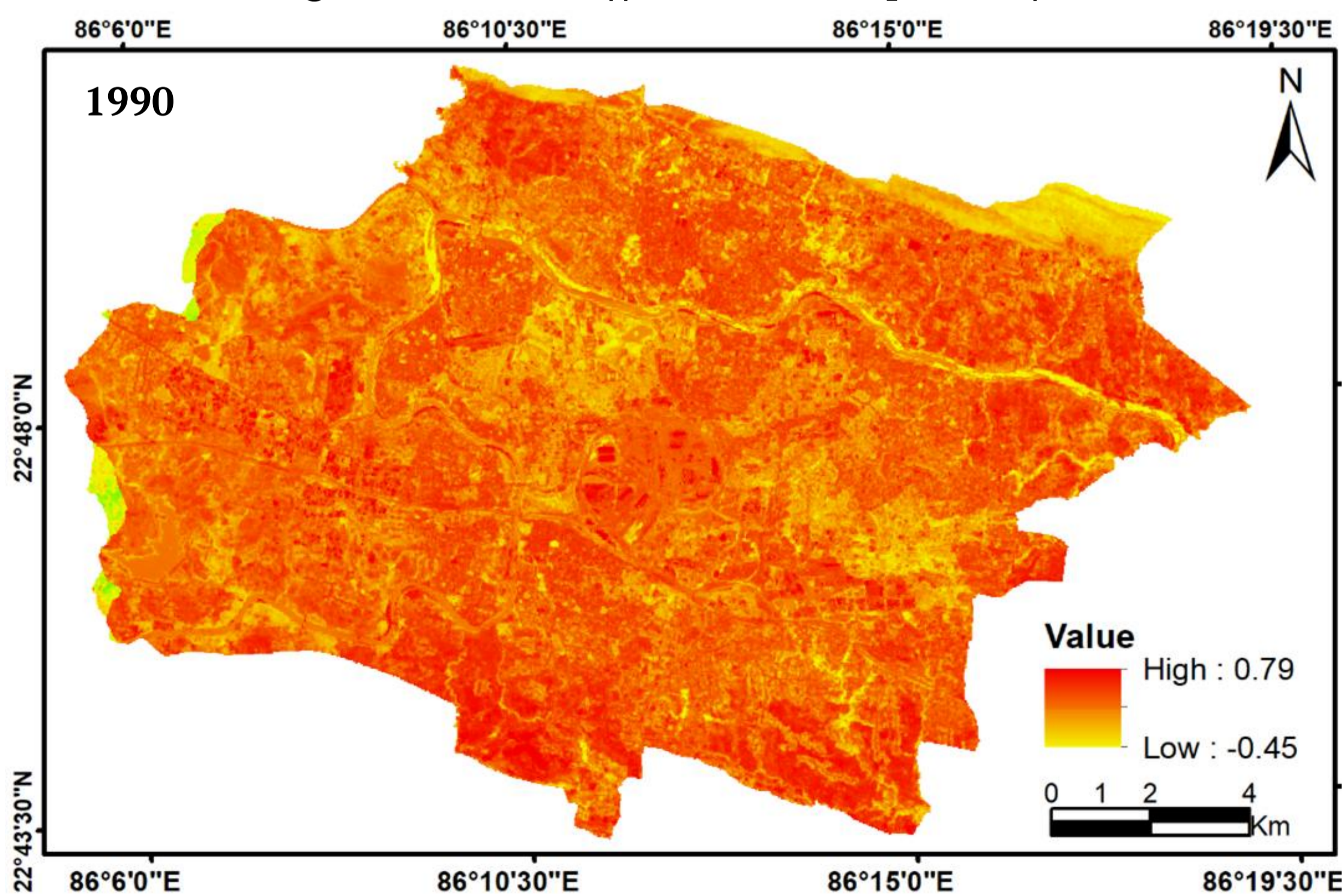


Fig: Normalised Difference Built Up Index for 2025

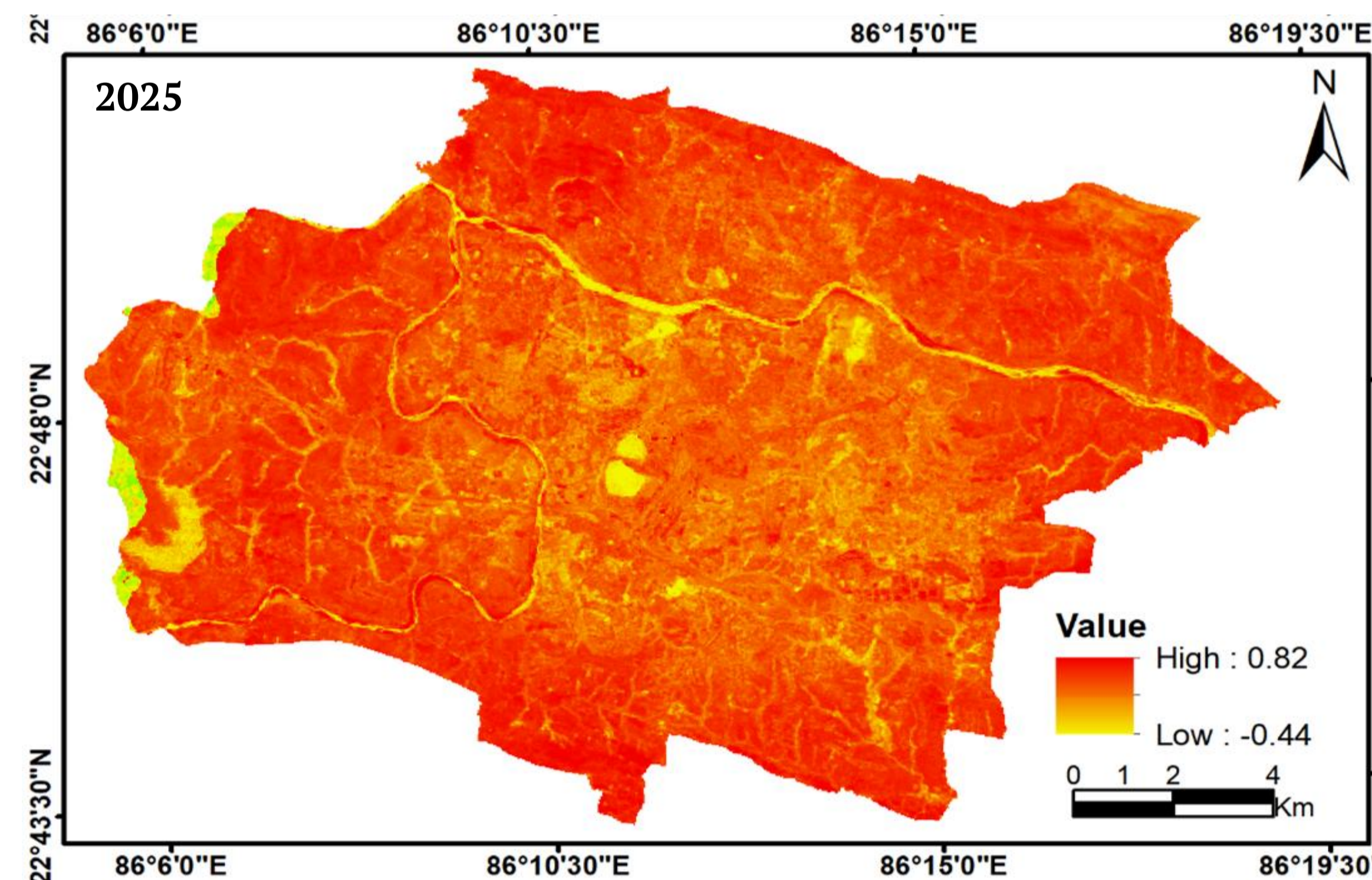


Fig: LST NDBI Correlation (1990)

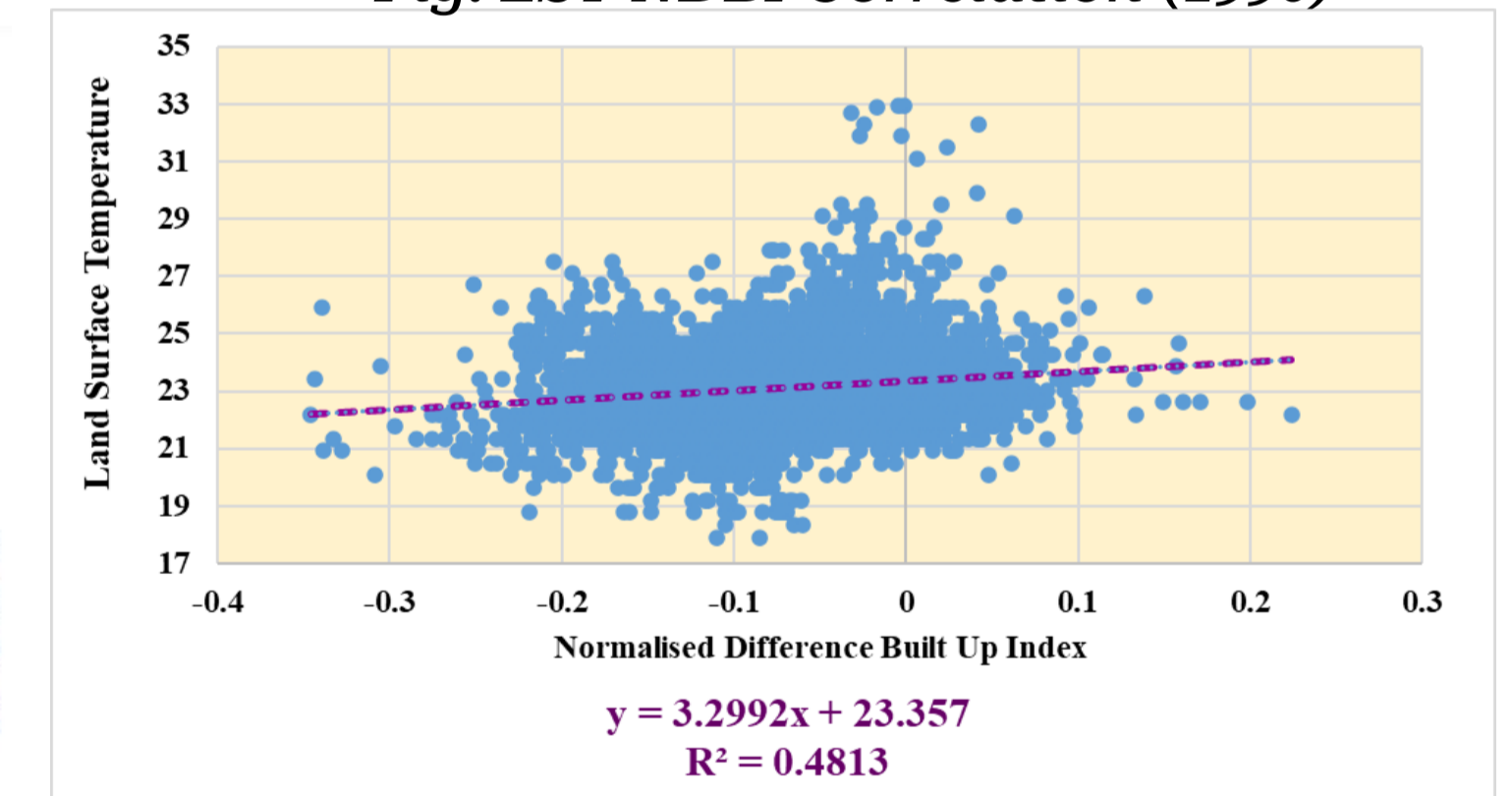
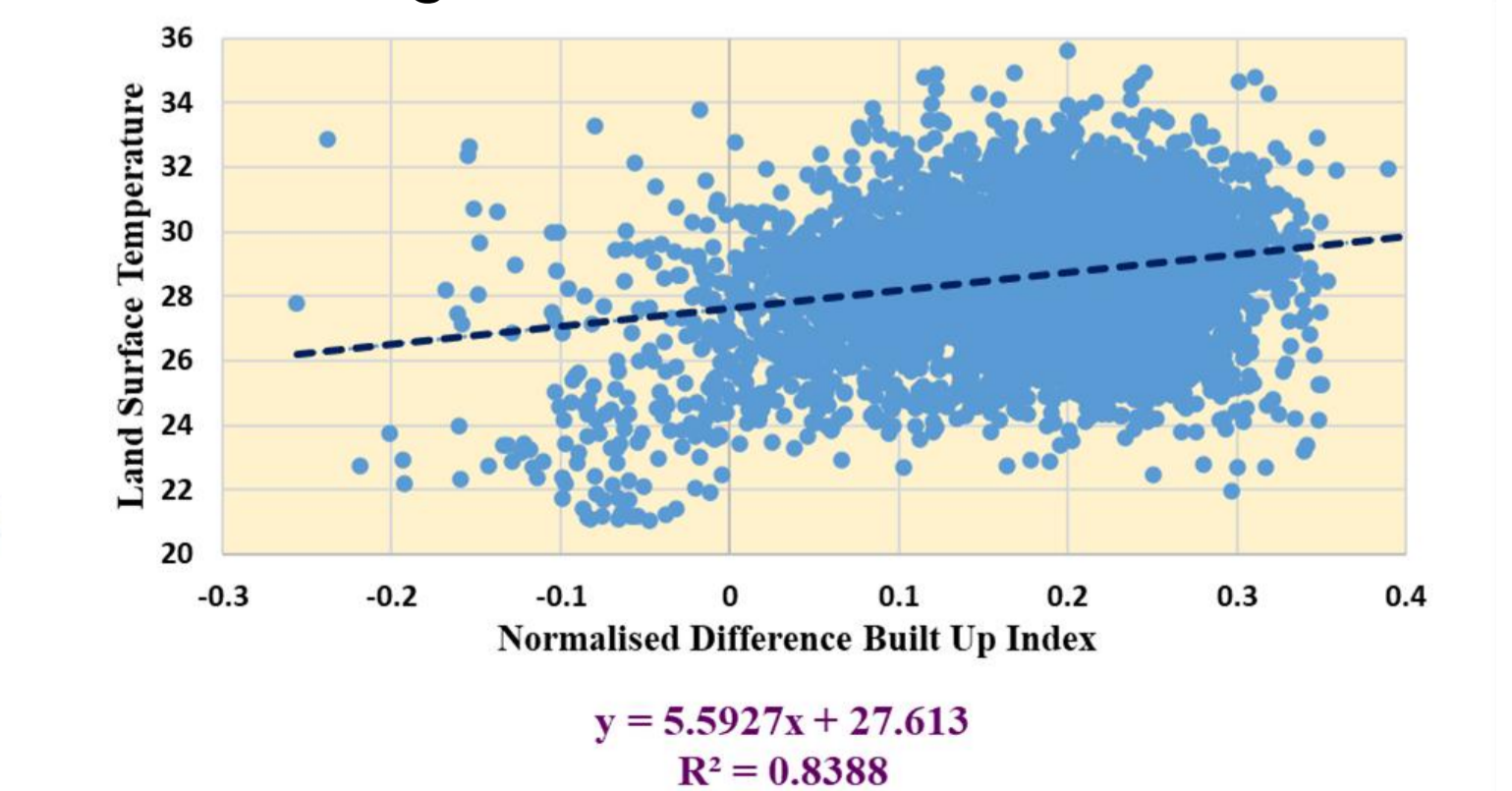


Fig: LST NDBI Correlation (2025)

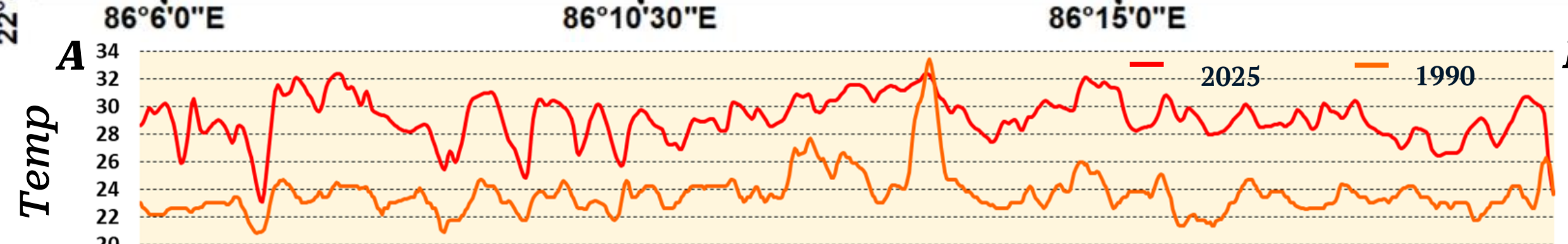
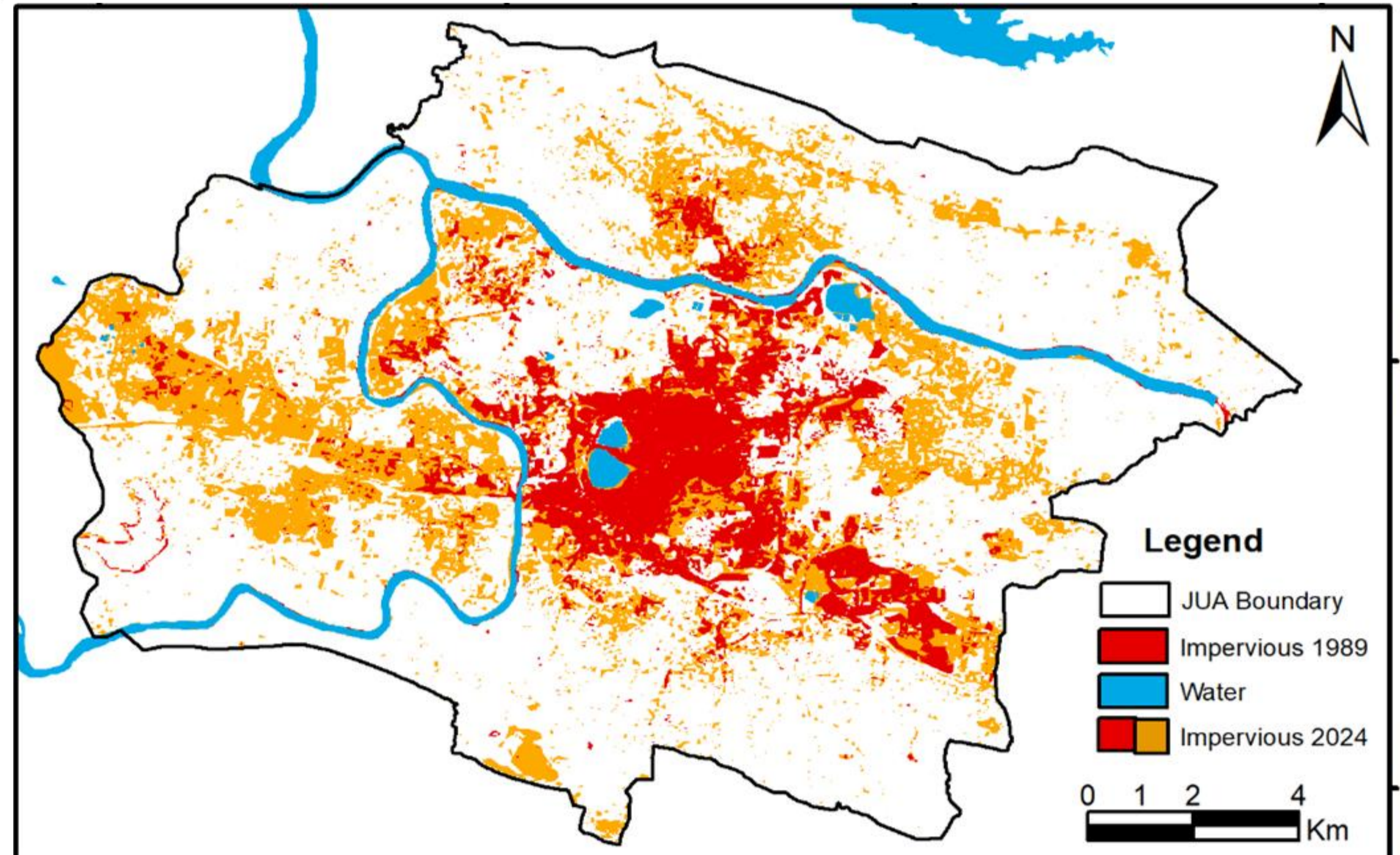
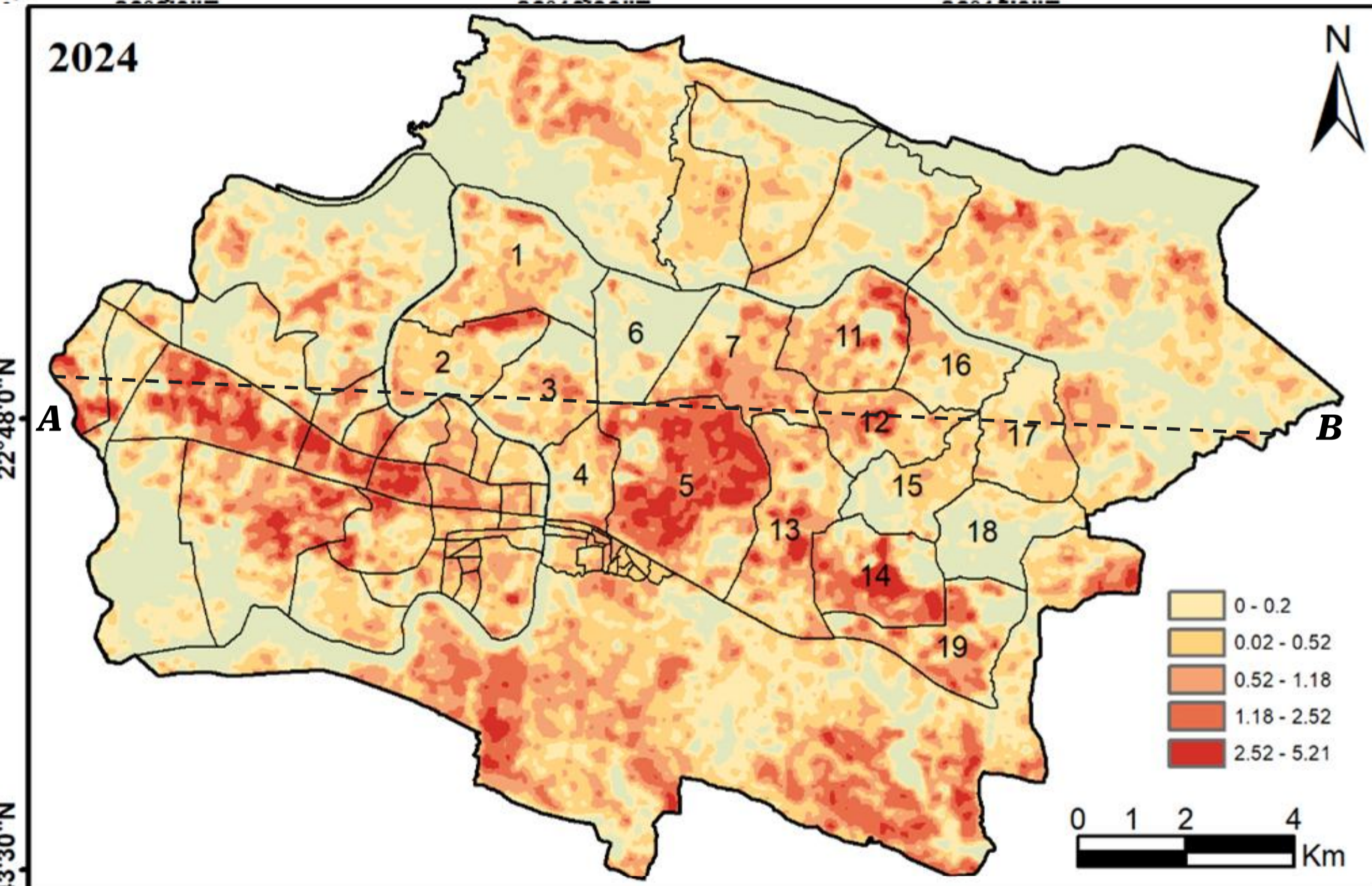
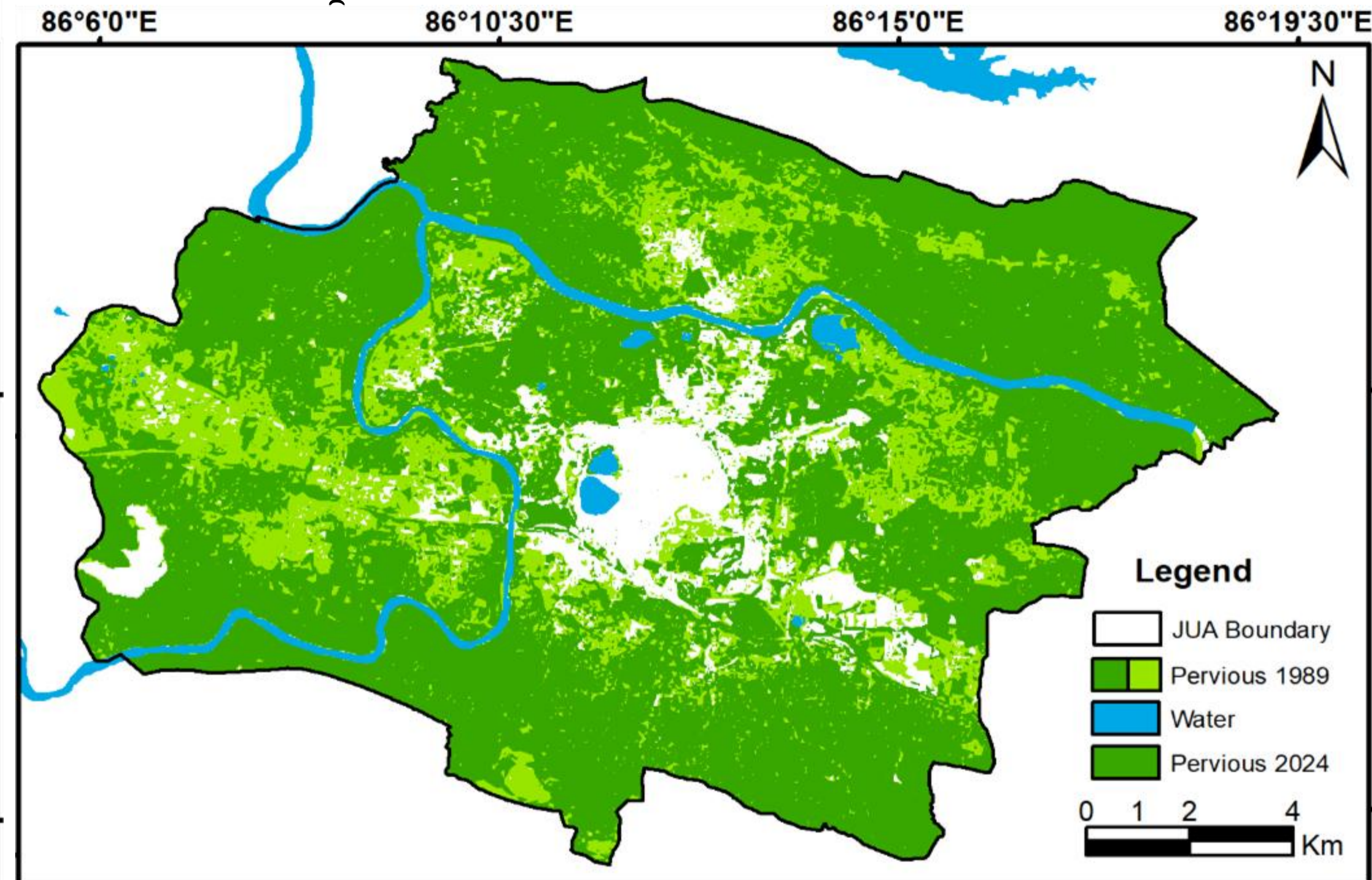
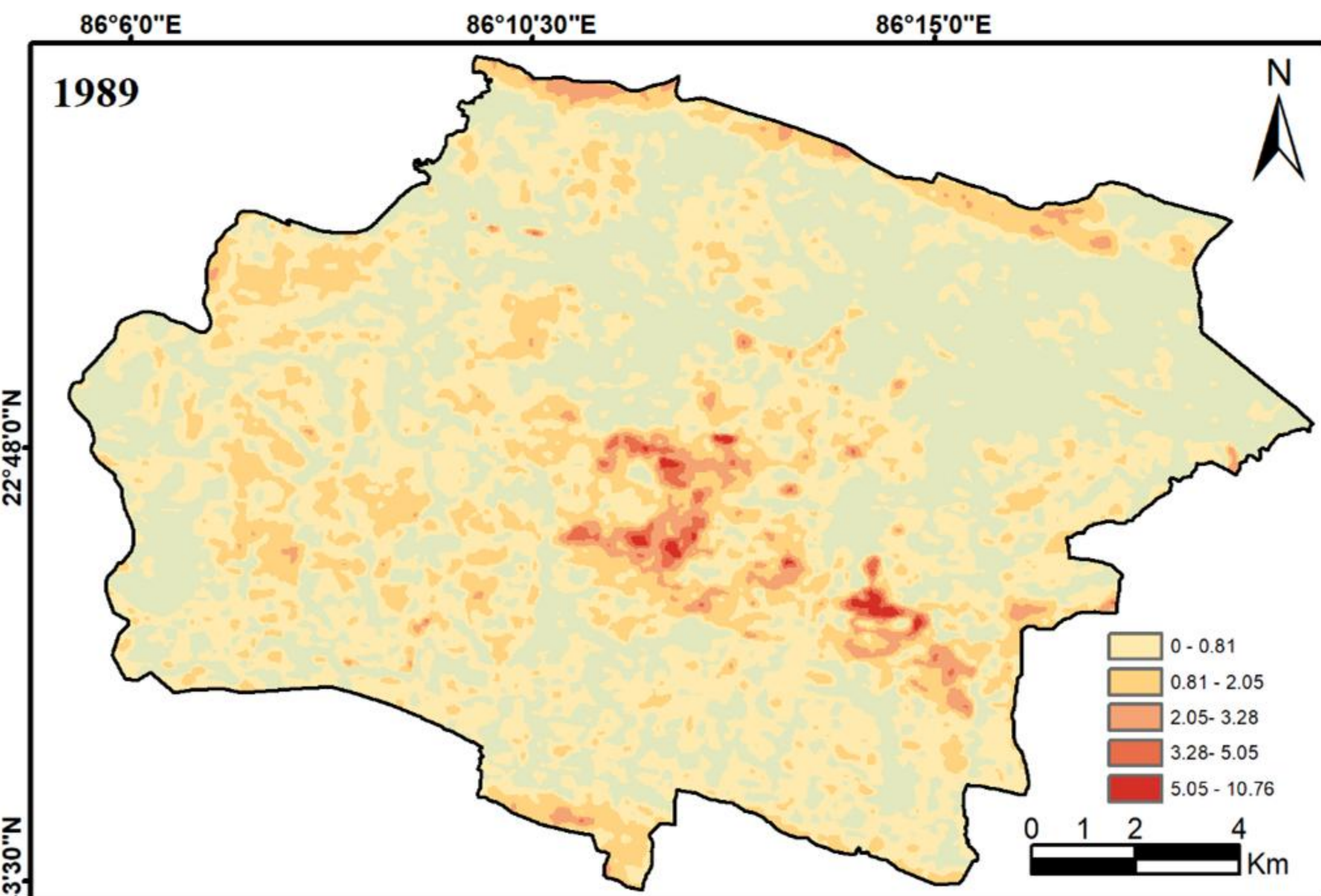


NDBI is a remote sensing index derived from satellite imagery used to identify and map built-up or urbanized areas. Built up has significantly increased all the area. But the water is visible due to frequent cleanliness drive. The values of  $R^2$  for 1990 and 2025 are 0.4813 and 0.8388, respectively. These values are relatively low, indicating that the NDBI alone is not a strong predictor of LST for those years.

## Urban Heat Island Map

Fig: Heat Map of JUA ,1990 and 2025

Fig: Decrease in Pervious and Increase in Impervious Area over 35 years



Heat map are generated for the year 1990 and 2025. Distribution of heat shows concentration of higher temperature at particular area forming hotspot and concentration of lower temperature forming cool spots.

LST for JUA ranges from 13.8°C to 42°C. Higher UHI value at industrial core of Jamshedpur and Adityapur.

Comparing UHI with LULC - Barren land with less or no vegetation shows similar range of temperature as industrial area.

Industrial area of JNAC that is ward no 4,5 11 and 14 are identified as major hotspots.

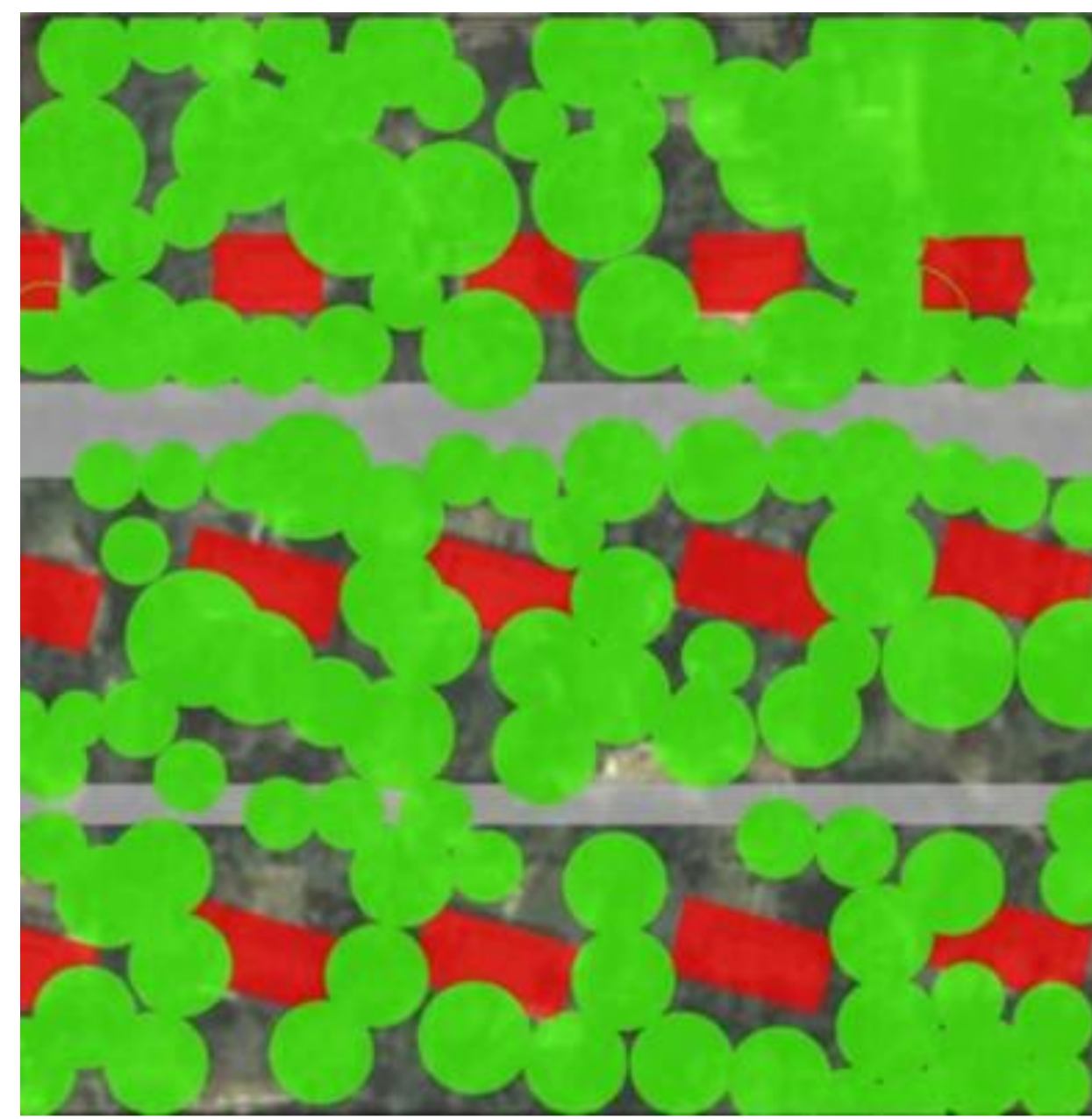
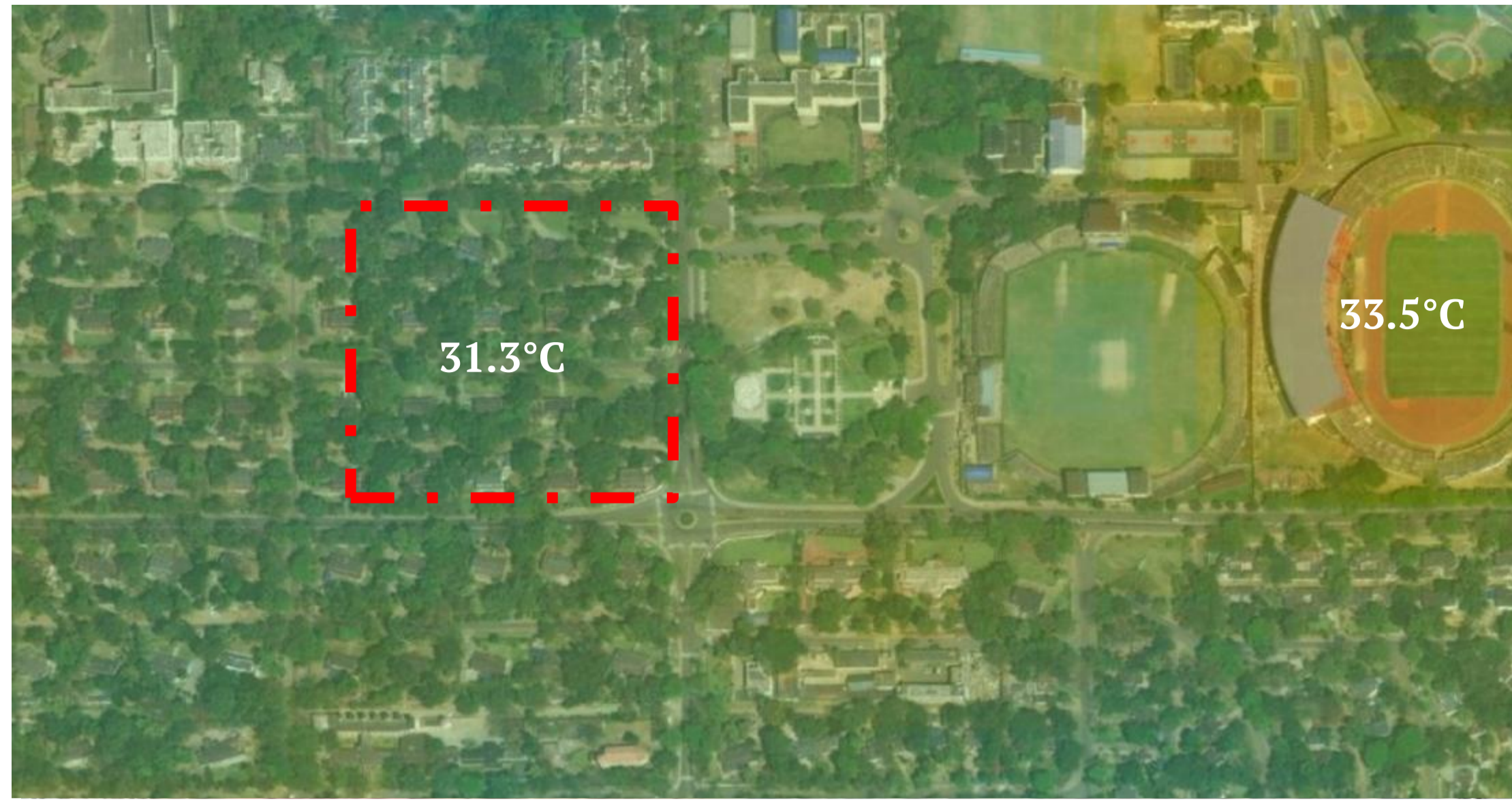
Residential area of Jugsali and Industrial patches of Adityapur shows higher value of temperature.

Ward no 6 ,15 ,17 and 18 are the areas with 30.4 to 32.9°C temperature range.

Ward no 6 consist of jubilee park having area 2 Sq Km and water body 14 Ha.

The cool pockets are found significantly in the JNAC boundary which is well planned. These cooler patch have significantly minimize the spread of UHI in JNAC area, which is absent in Adityapur area. UHI intensity noted is 6-7°C in JUA area.

Fig: Heat map of Cooler residential area in Jamshedpur



	Area (SQ M)
Building Unbuilt Ratio	11.6
Built Up	4638
Green Coverage	25168
Permeable Area	30362
Impermeable Area	9638
Height	G
Road	5000
Temperature	30 - 31.3°C

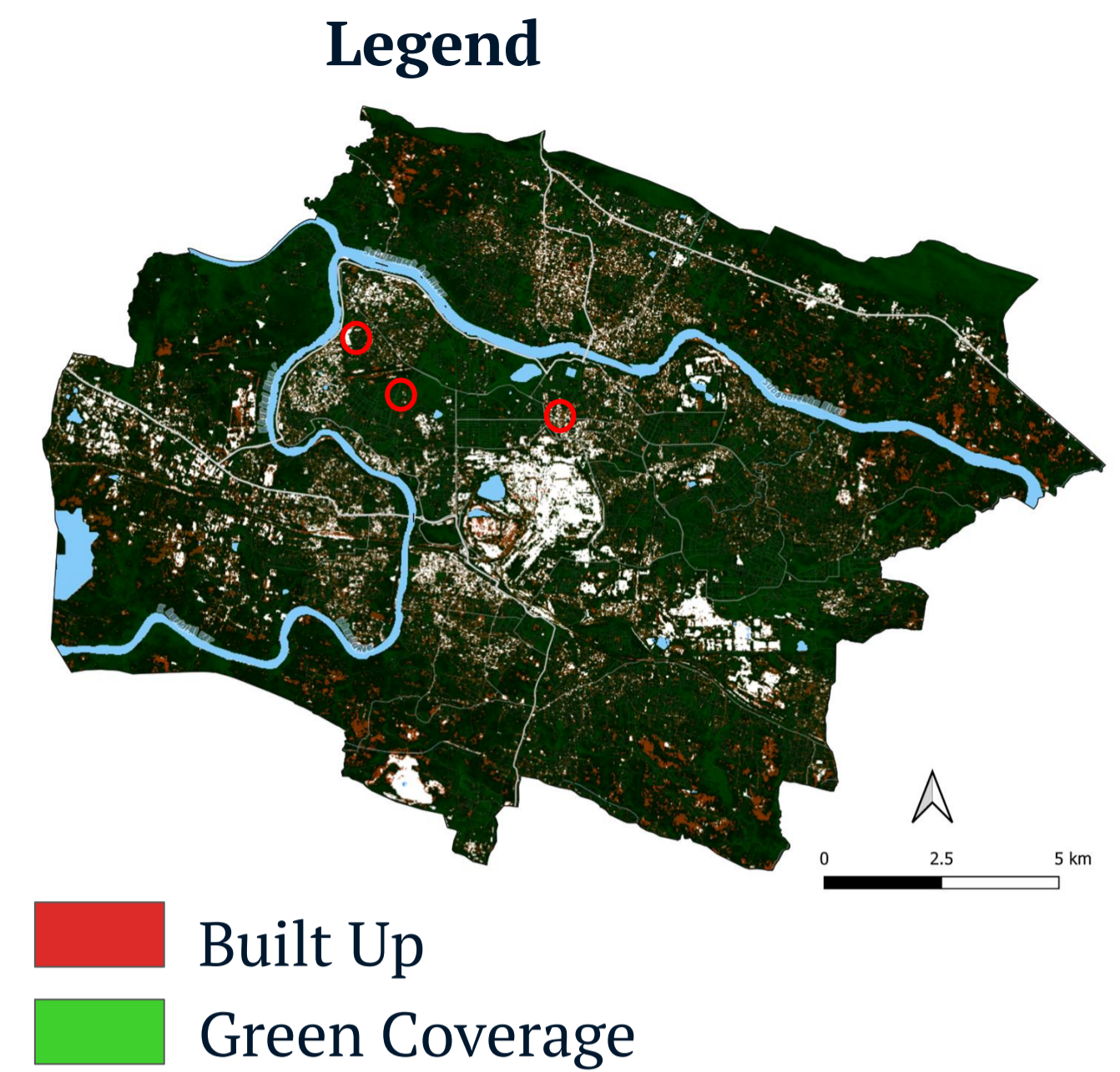
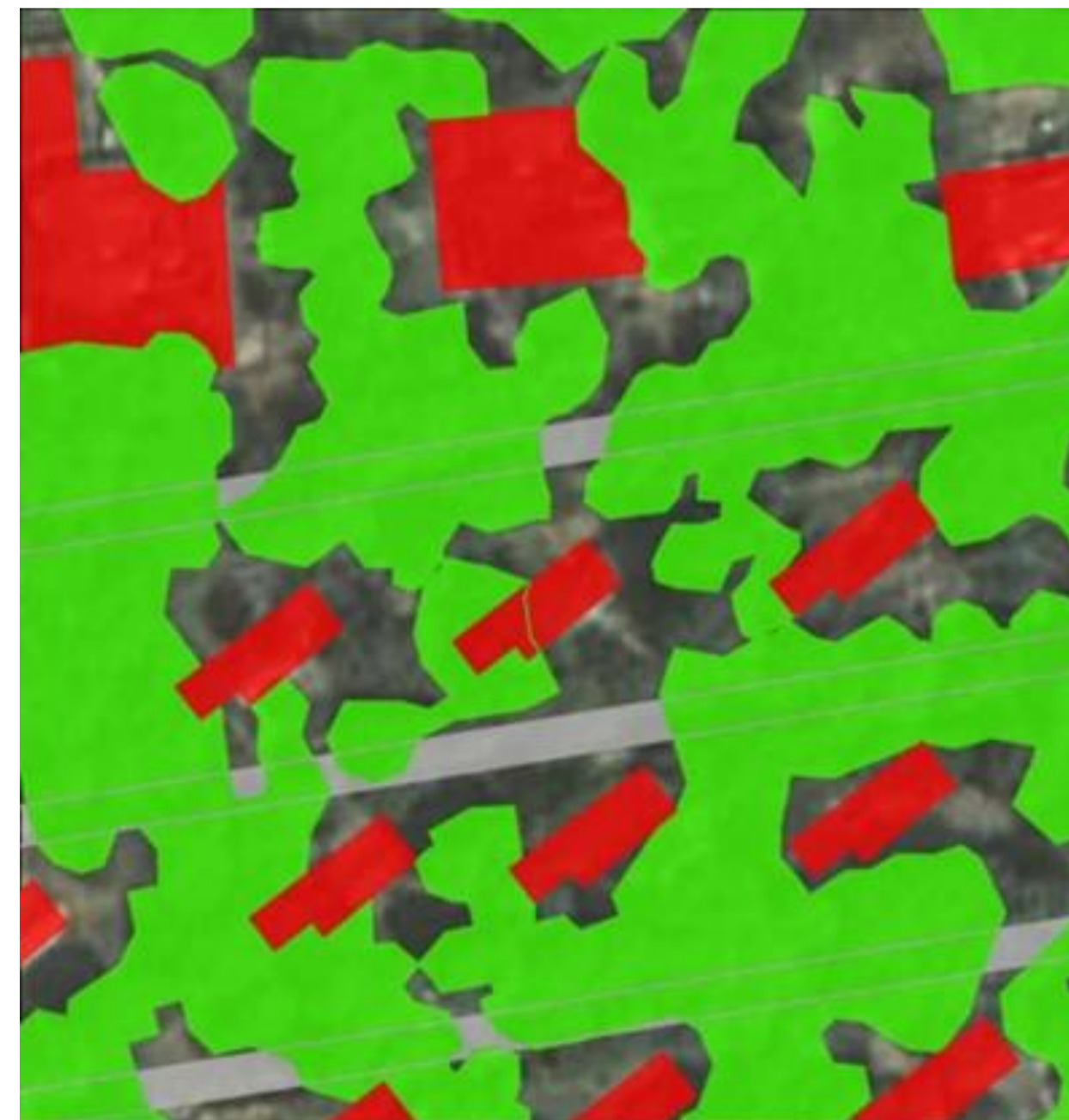
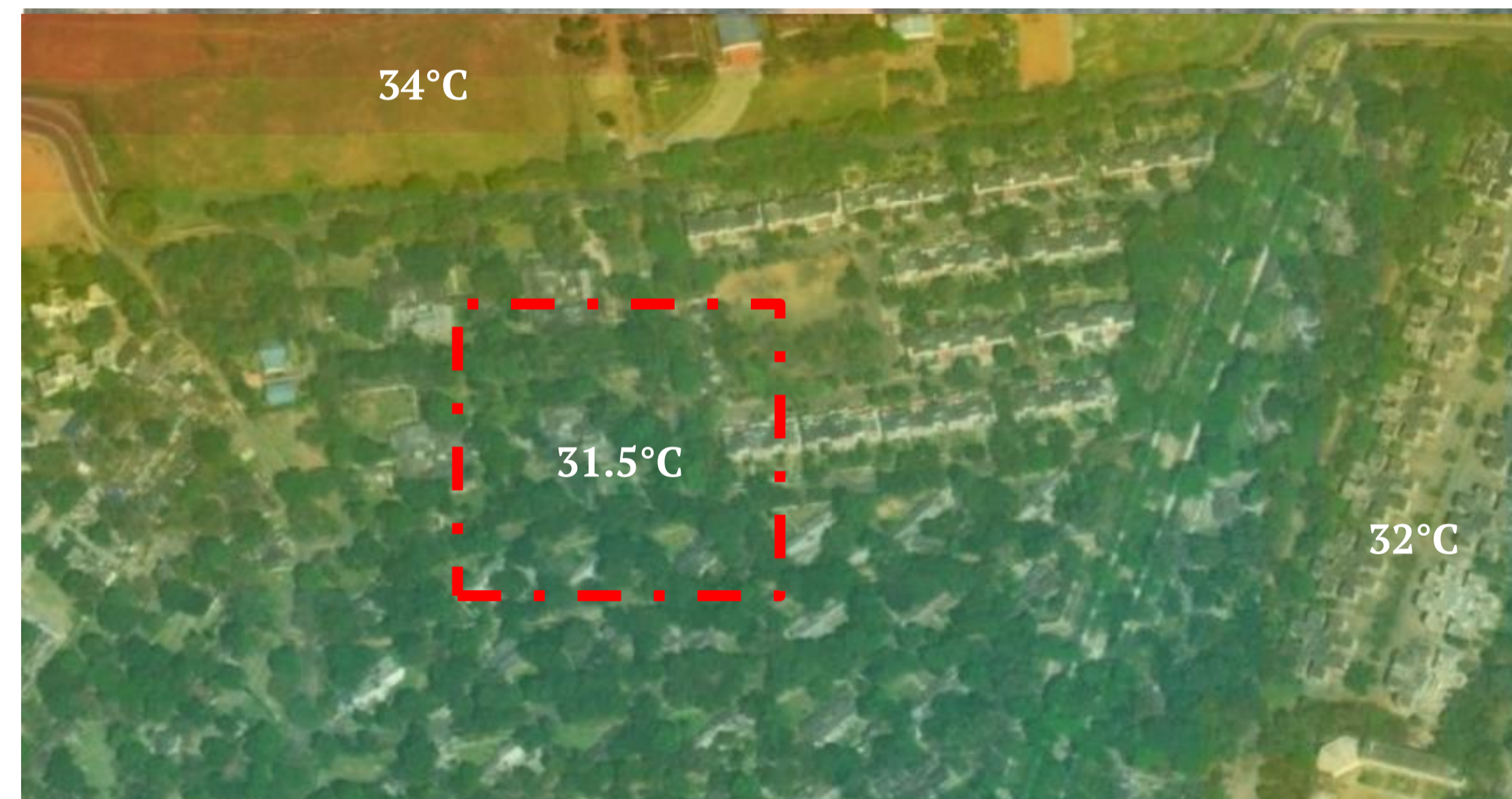


Fig: Heat map of Cooler residential area in Jamshedpur



	Area (SQ M)
Building Unbuilt Ratio	13.65
Built Up	5450
Green Coverage	24248
Permeable Area	30350
Impermeable Area	9650
Height	G
Road	4203
Temperature	30 - 31.5°C

The three area for analysing effect of green are :-

1. Planned Area of Sakci
2. Planned Area of Sonari
3. High Density Planned area of Sonari, Jamshedpur

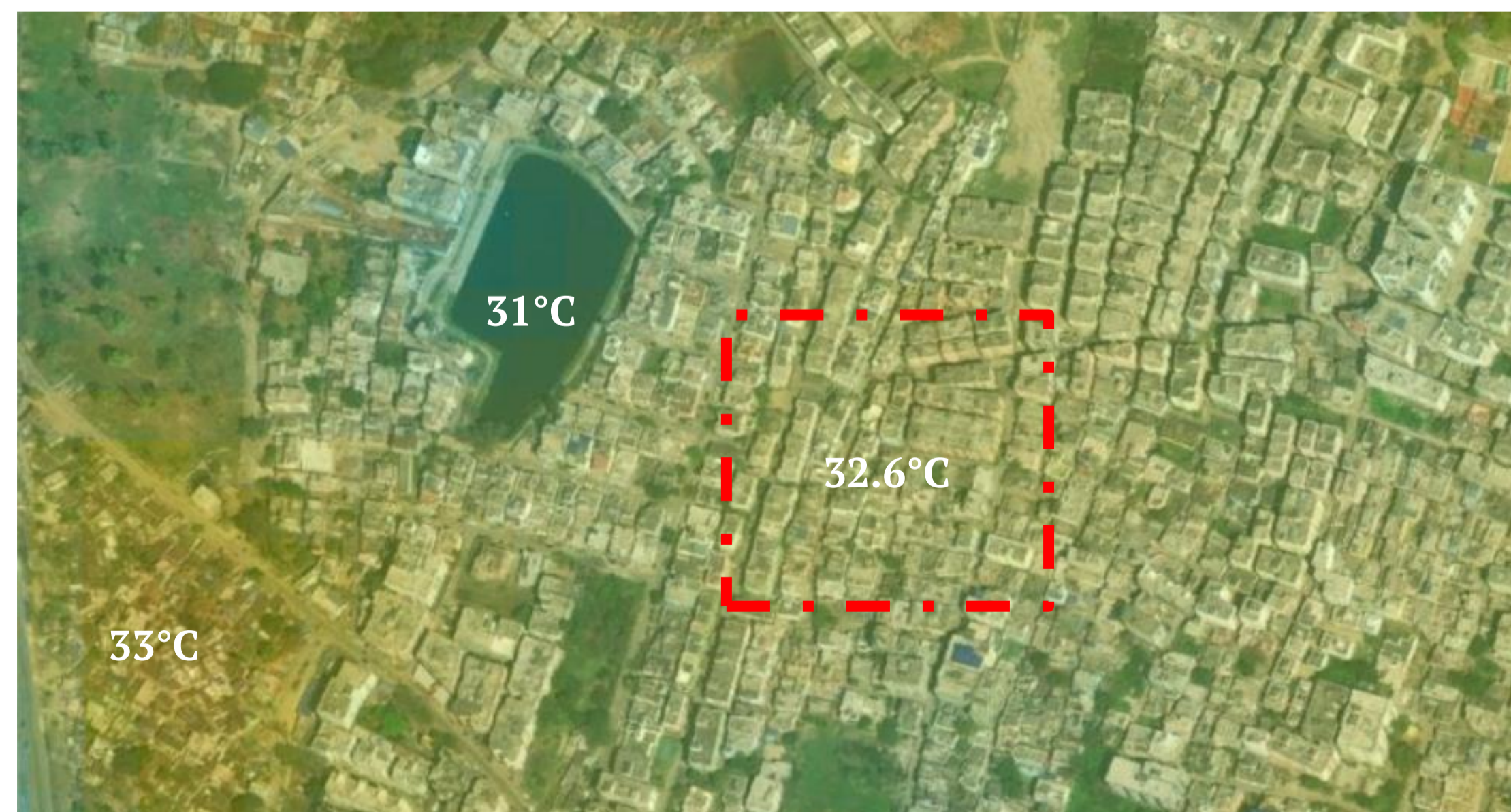
From scenario 1 and 2 shows lower density residential area with built up 13 % and green cover 60-62% and permeable surface 85% shows difference of 1°-2°C.

For highly dense neighborhood observe built up 60-62%, Green coverage 3-8% and permeable surface minimum 4% shows considerably lower temperature as compared to other highly denser areas.

Configuration of 45% built up, 13 - 15% green , 8-9% of permeable surface shows comparatively lower temperature for mid dense neighborhood.

1,18,252 sq.m. more green in 1000000 sq.m. can reduce temperature by 1°C.

Fig: Heat map of highly dense residential area of Sonari



	Area (SQ M)
Building Unbuilt Ratio	61.7625
Built Up	24705
Green Coverage	1441
Permeable Area	1861
Impermeable Area	28992
Height	G+2 to G+4
Road	4287
Temperature	31.7-32.6°C

## Urban Heat Island at Micro Level

Heat map of urban area was carefully assessed and few hotspots and cool spots were selected for further understanding of UHI.

Neighbourhood is selected based on presence of Residential, Commercial, Industrial & types of green areas within same neighbourhood.

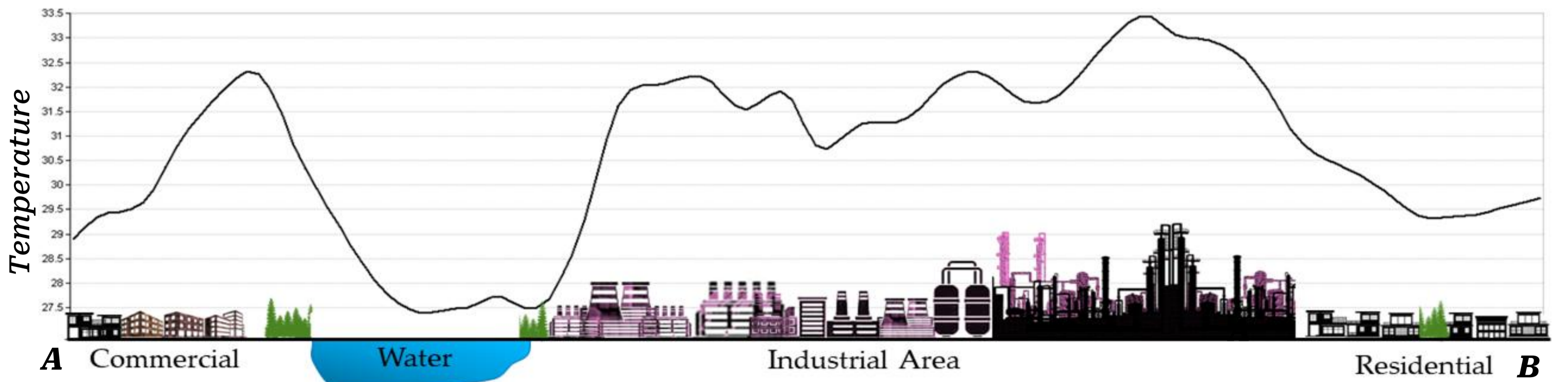
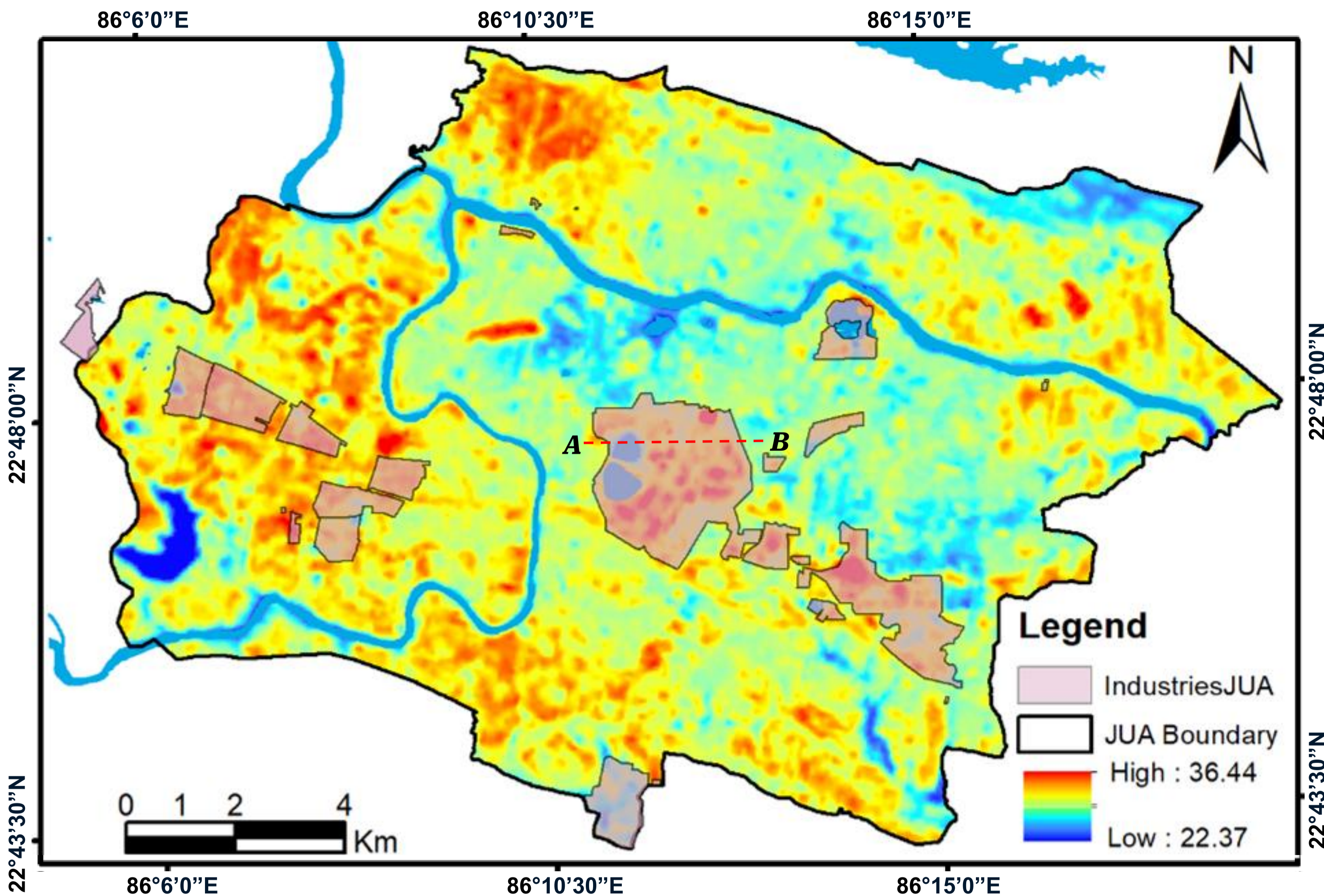
<b>Industrial Area</b>	1. Adityapur Industrial Area	2. Jamshedpur Industrial Area
<b>Commercial Area</b>	1. Sakchi Market (Oldest Market)	2. Bistupur (Upscale market)
<b>Residential Area</b>	1. Purani Basti Jugsalai	2. Baba Tilak Majhi Basti (Slum Area)
<b>Neighbourhood Area</b>	1. Golmuri (Part of ward 13)	

## Industrial Area

### Jamshedpur Industrial Area

2304 ha of Industrial area. 90 % Industries located are heavy industries.

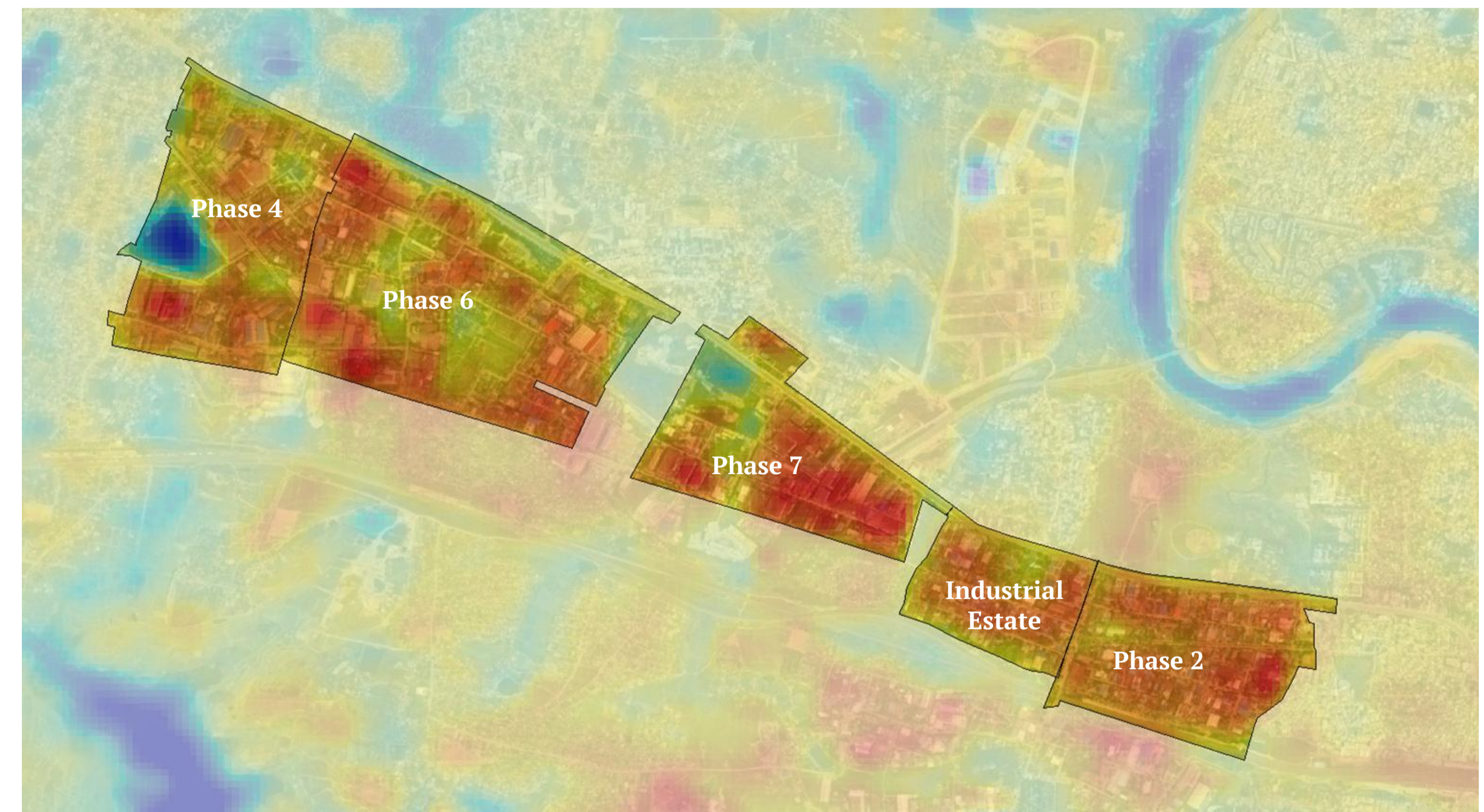
Fig: LST of Industrial Area and Cross section of Industrial Area



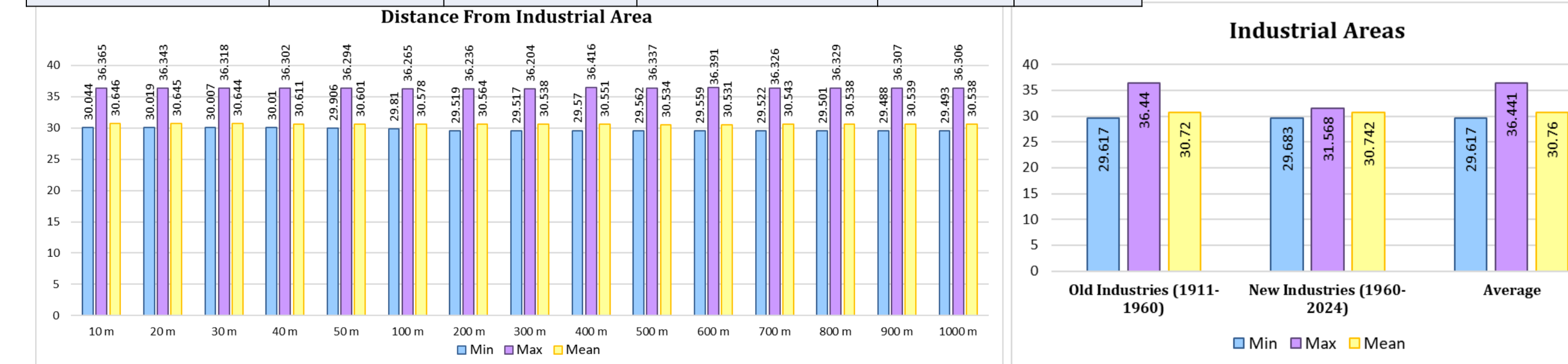
### Adityapur Industrial Area

1711 Ha of Industrial area. It is divided into 8 different industrial layouts.

Fig: Distance from Industrial Area (upto 3 Km)



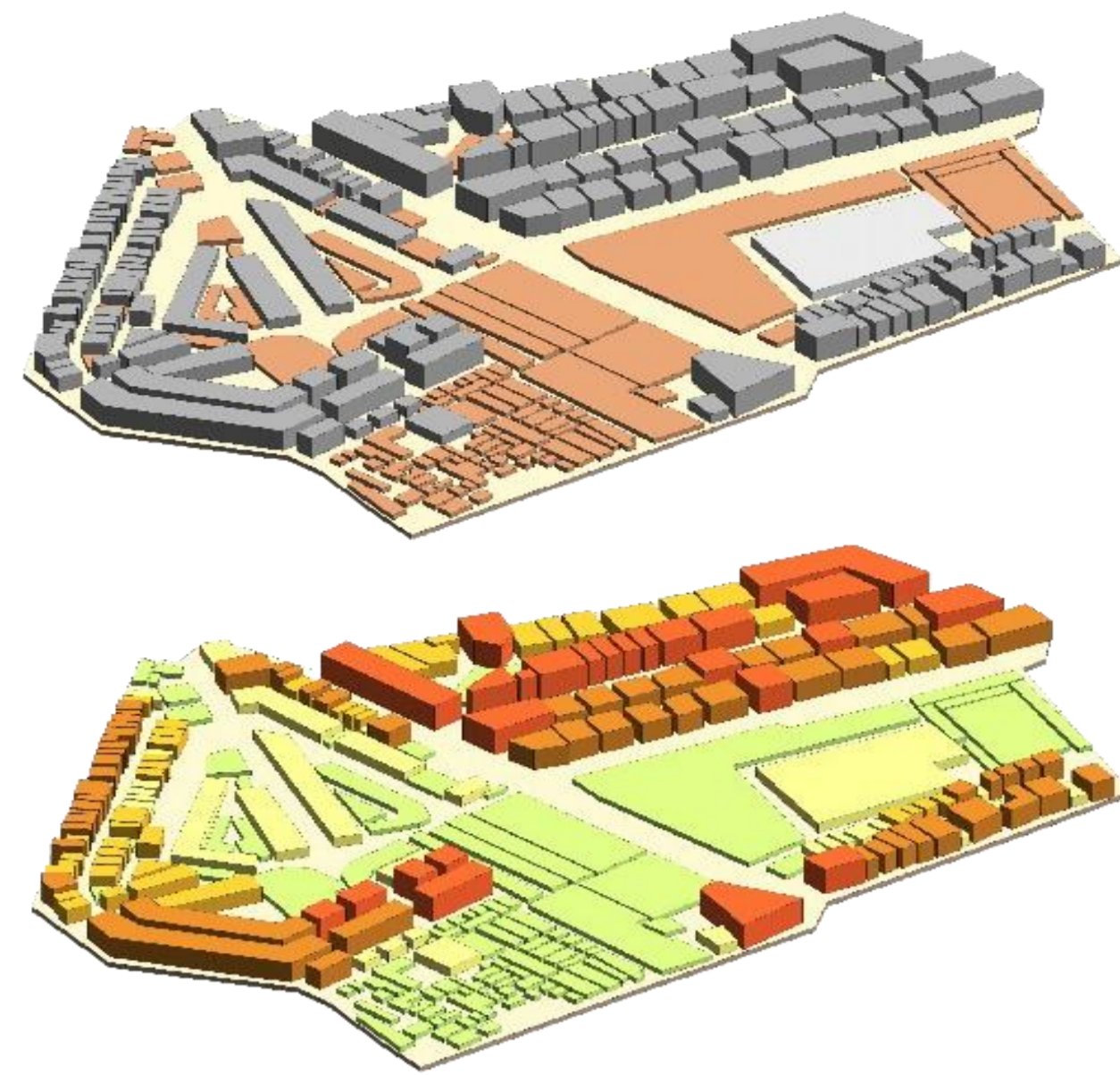
	Built up(sq m)	Total area (sq m)	Built unbuilt ratio	Temp max	Temp min	
Phase 2	185099	479063	0.39	35.9°C	33°C	Phase 6 less dense as compared to others having green area.
Phase 7	163113	432005	0.38	37 °C	30°C	Phase 7 has water body. 93% structures are made of metal sheets
Phase 4 & 6	532936	1733222	0.31	38°C	29°C	Phase 4 have larger plot sizes.
Indus. estate	114642	299042	0.38	36°C	33.3°C	



### Commercial Area : Sakchi Market



Fig: Roofing material & height mapping



Sakchi market is one of the major commercial center and specializes in wholesale and retail market. Shop sizes varies between 5.76 Sq m to 4000 Sq m .

A large no of shops are single floored with higher value of temperature is observed along these shops. In summer temperature increases significantly making uncomfortable for people to shop and sell.

Fig: Roof Material

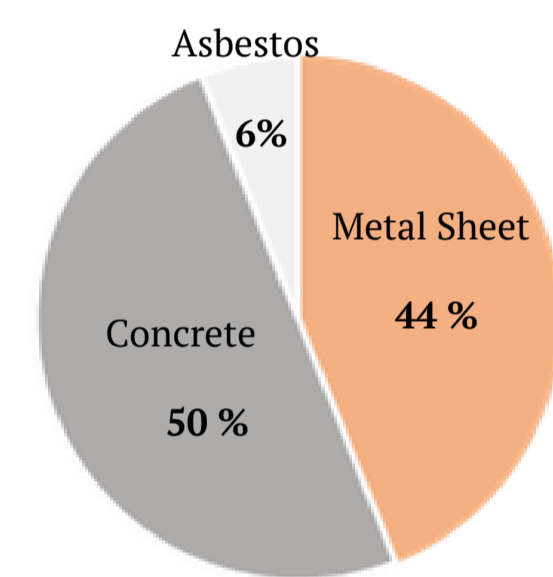
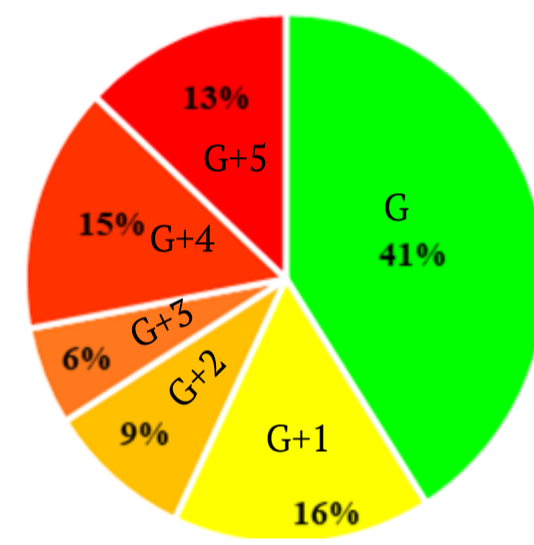


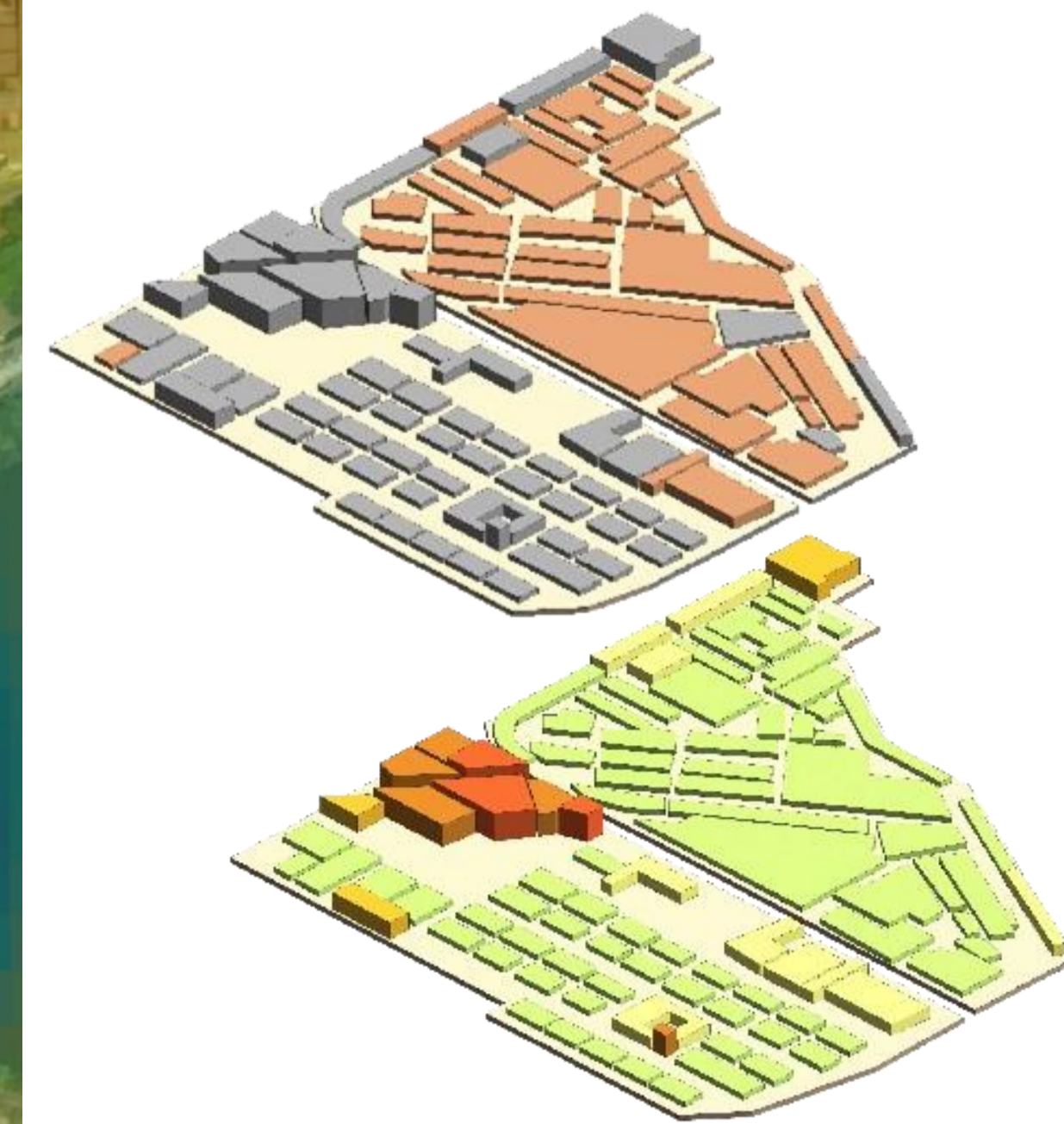
Fig: Height Map



### Commercial Area : Bistupur Market



Fig: Roof material & Height Map



Bistupur Market is the main high-end retail hub. 76% of buildings are ground floor. Market area exhibit higher temperature as compared to surrounding.

Commercial area have 3°C higher value of temperature. Metal sheet easily get heated up, making the surrounding area also warmer. It increases the cooling demand of building.

Fig: Roof Material

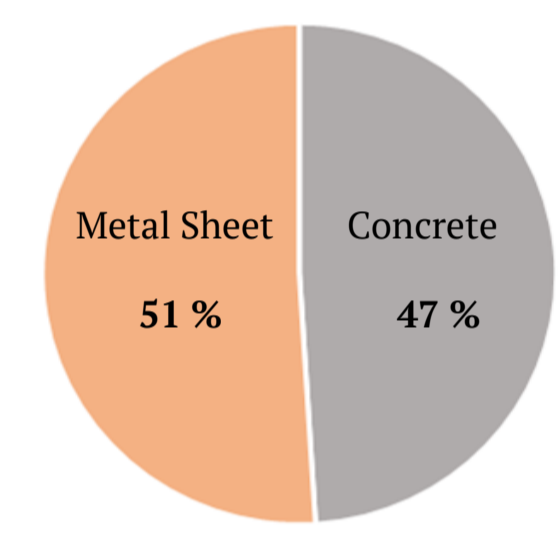
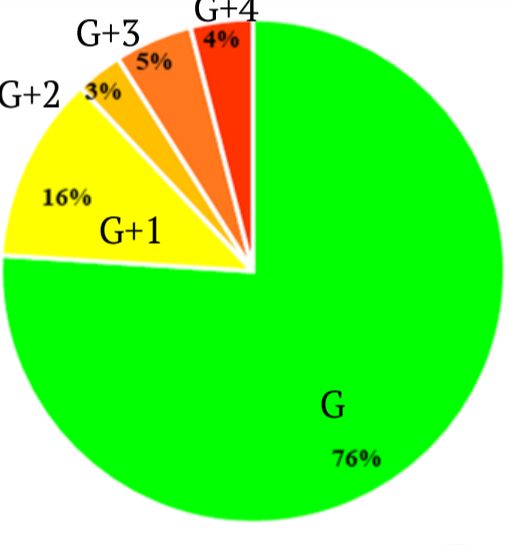


Fig: Height Map



### Residential Area : Purani Basti, Jugsalai

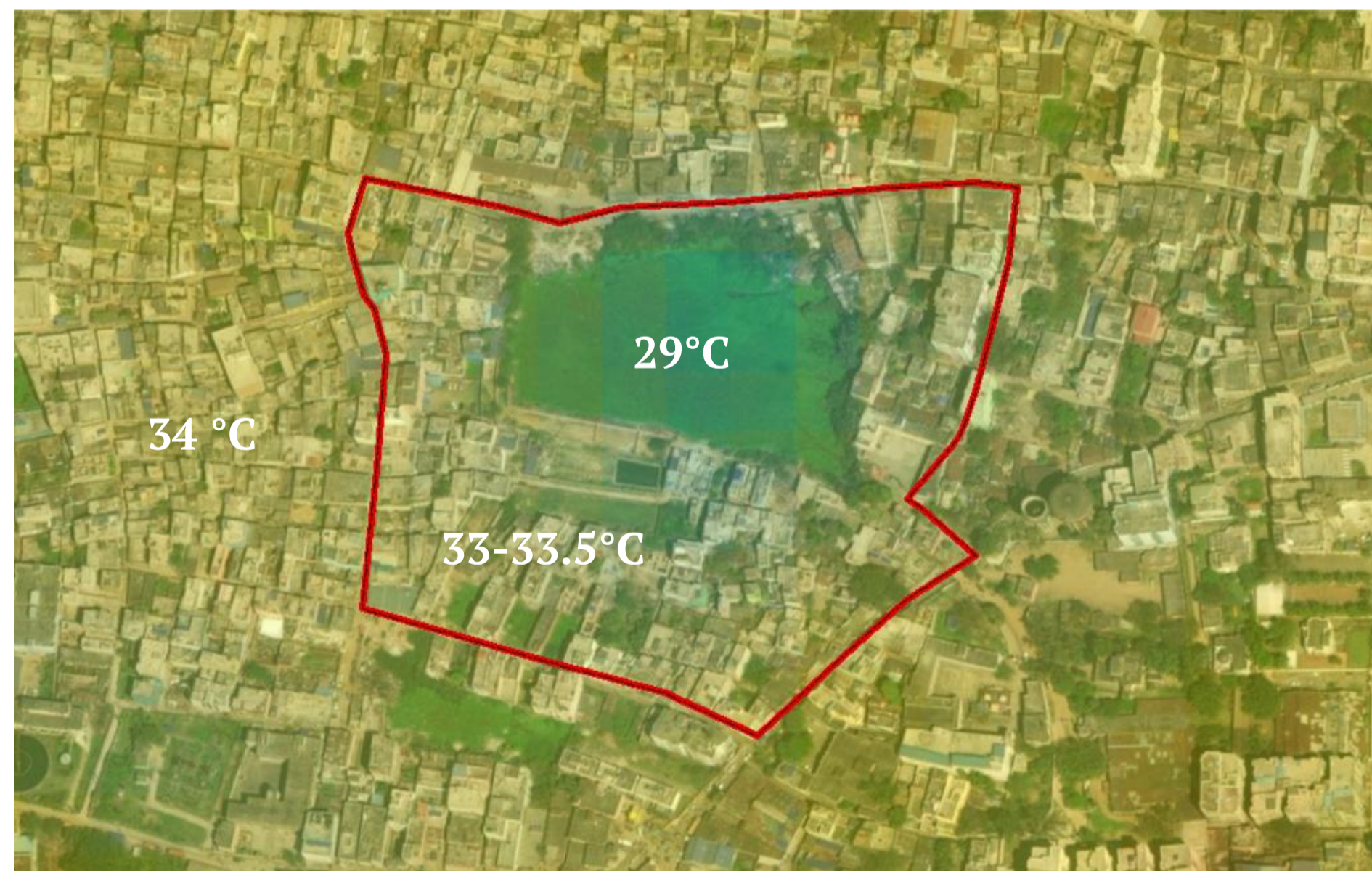
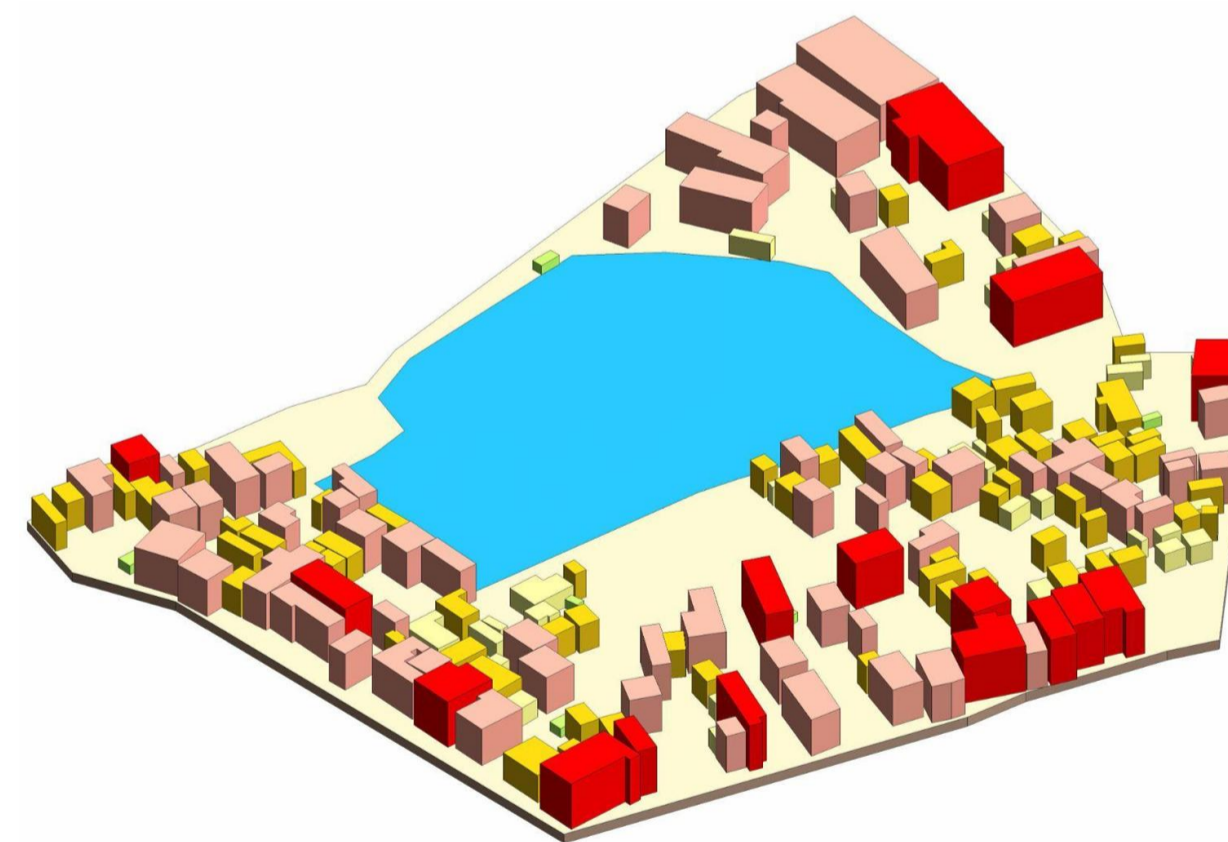


Fig: Roofing material & height mapping



Jugsalai housing district for accommodating overspill population of Jamshedpur, is a high density area. Higher temperature is observed in mixed use stretch.

Jugsalai talab has lowered temperature and its affect can be noticed upto 100m.

Fig: Roof Material

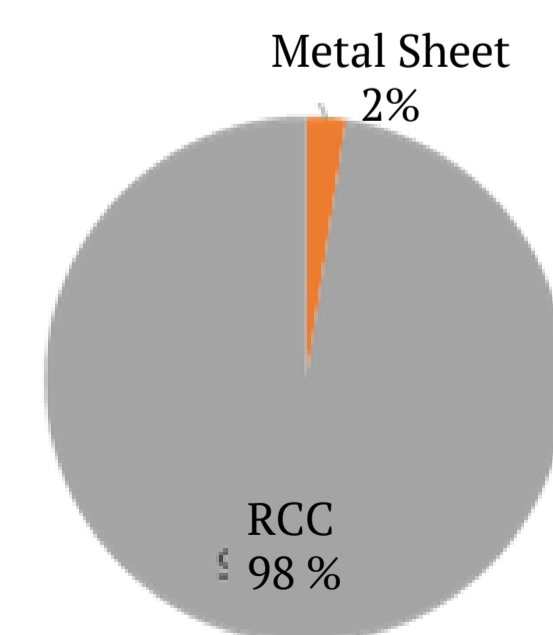
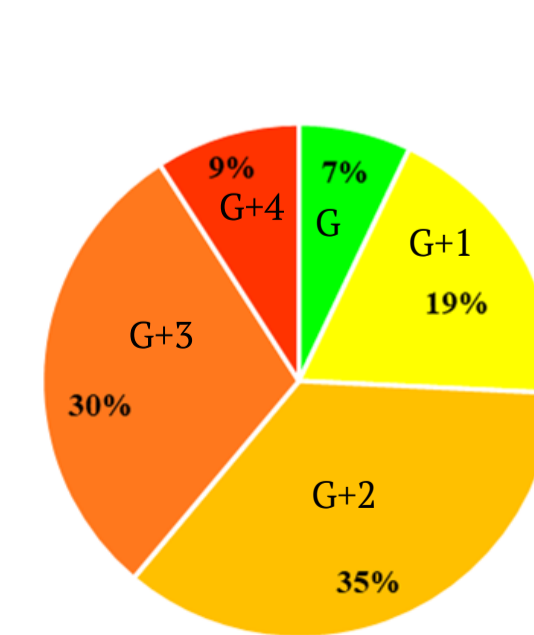


Fig: Height Map



### Residential Area : Baba Tilak Majhi Basti

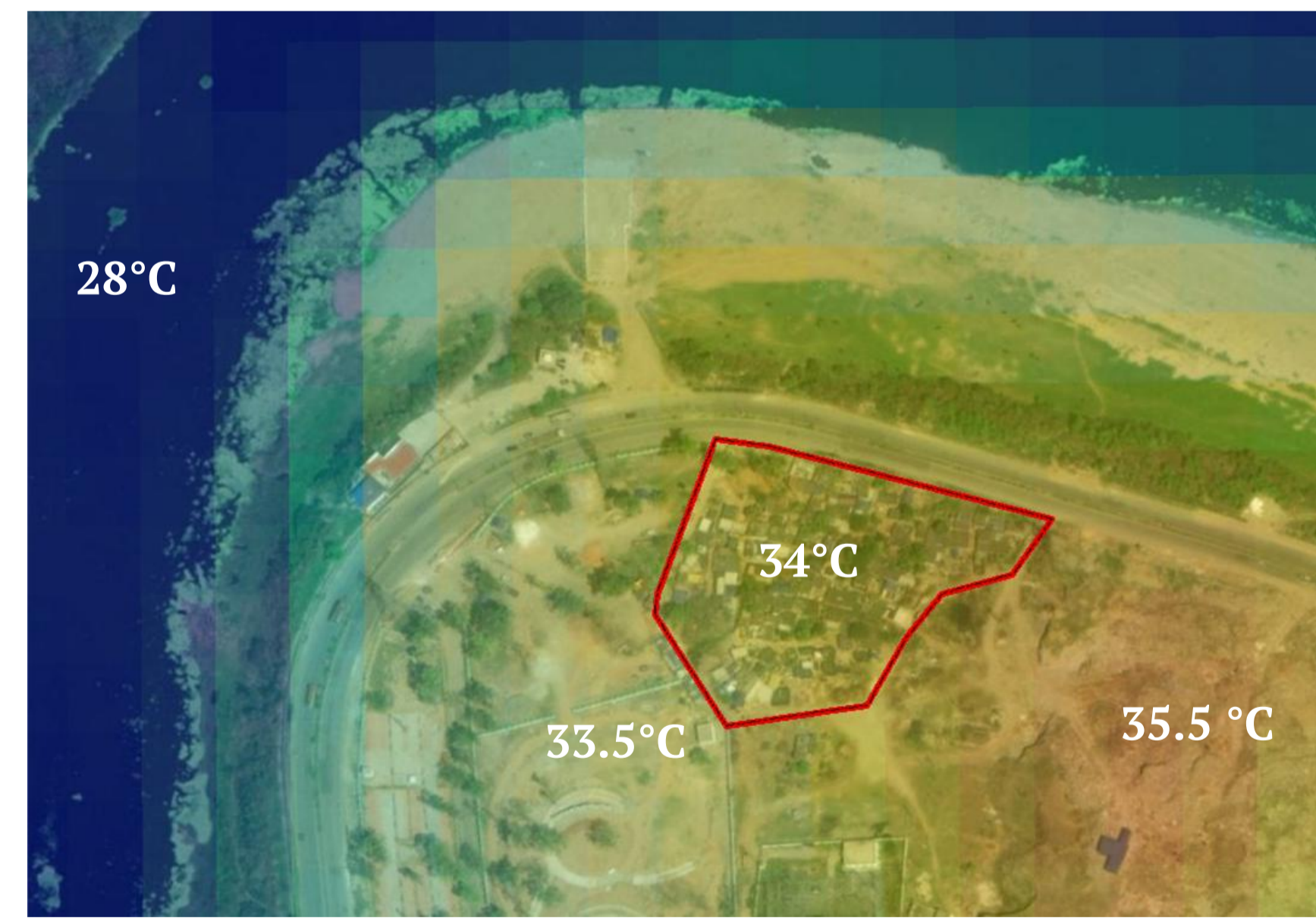
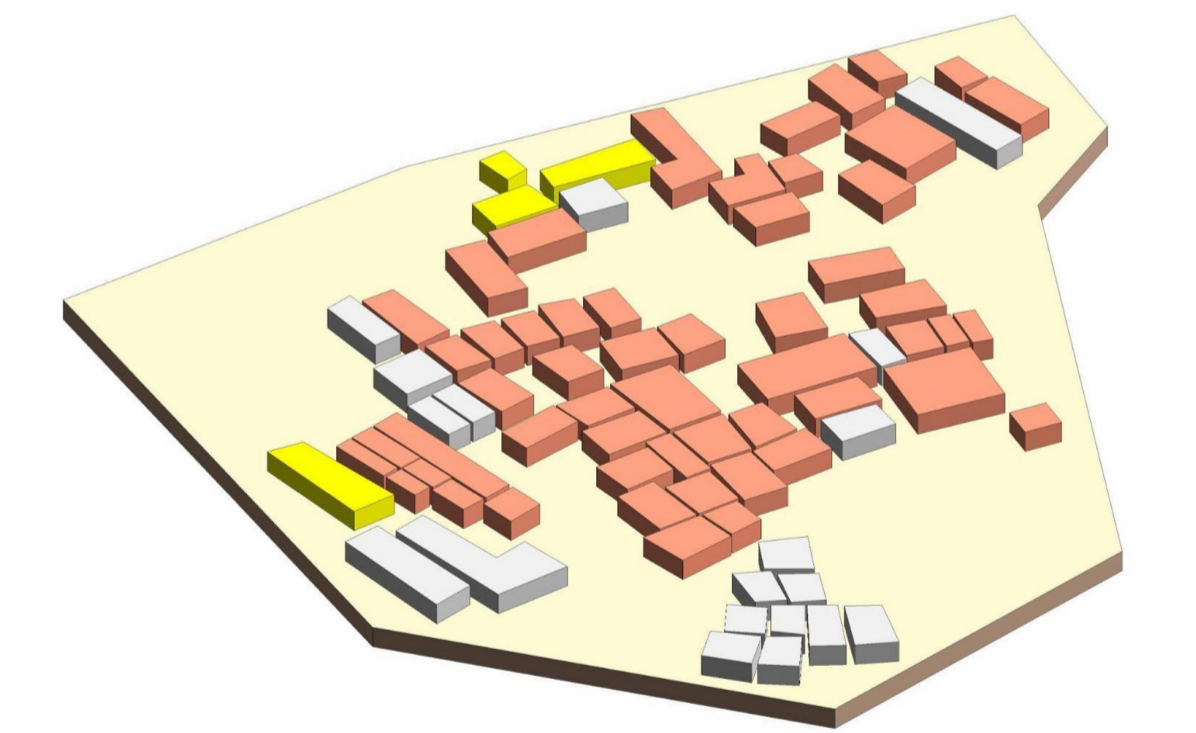


Fig: Roof material (Single storey)



The area is surrounded by landfill site on east and electricity grid in south side. The confluence of river is site for blue green development which is untapped.

Proximity to the landfill site significantly influence the temperature. The residential area close to landfill experience 35°C temperature.

Fig: Roof Material

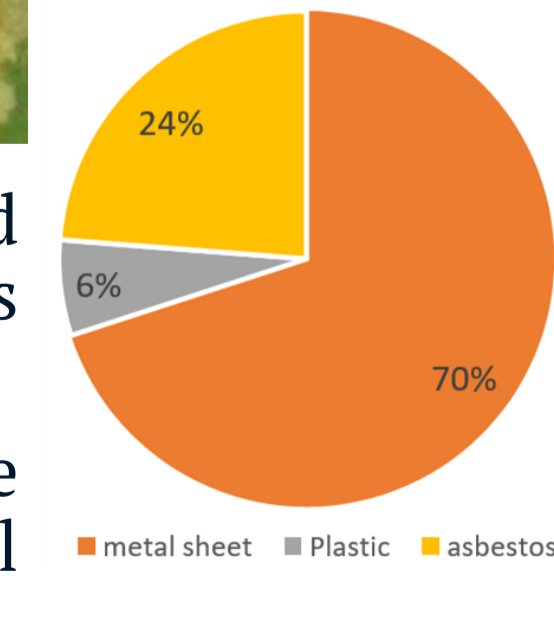


Fig: Structure Type

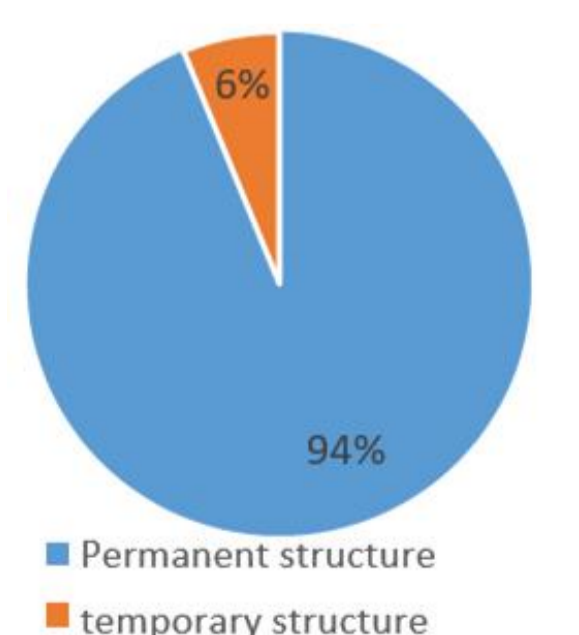


Fig: Land Use of Neighbourhood

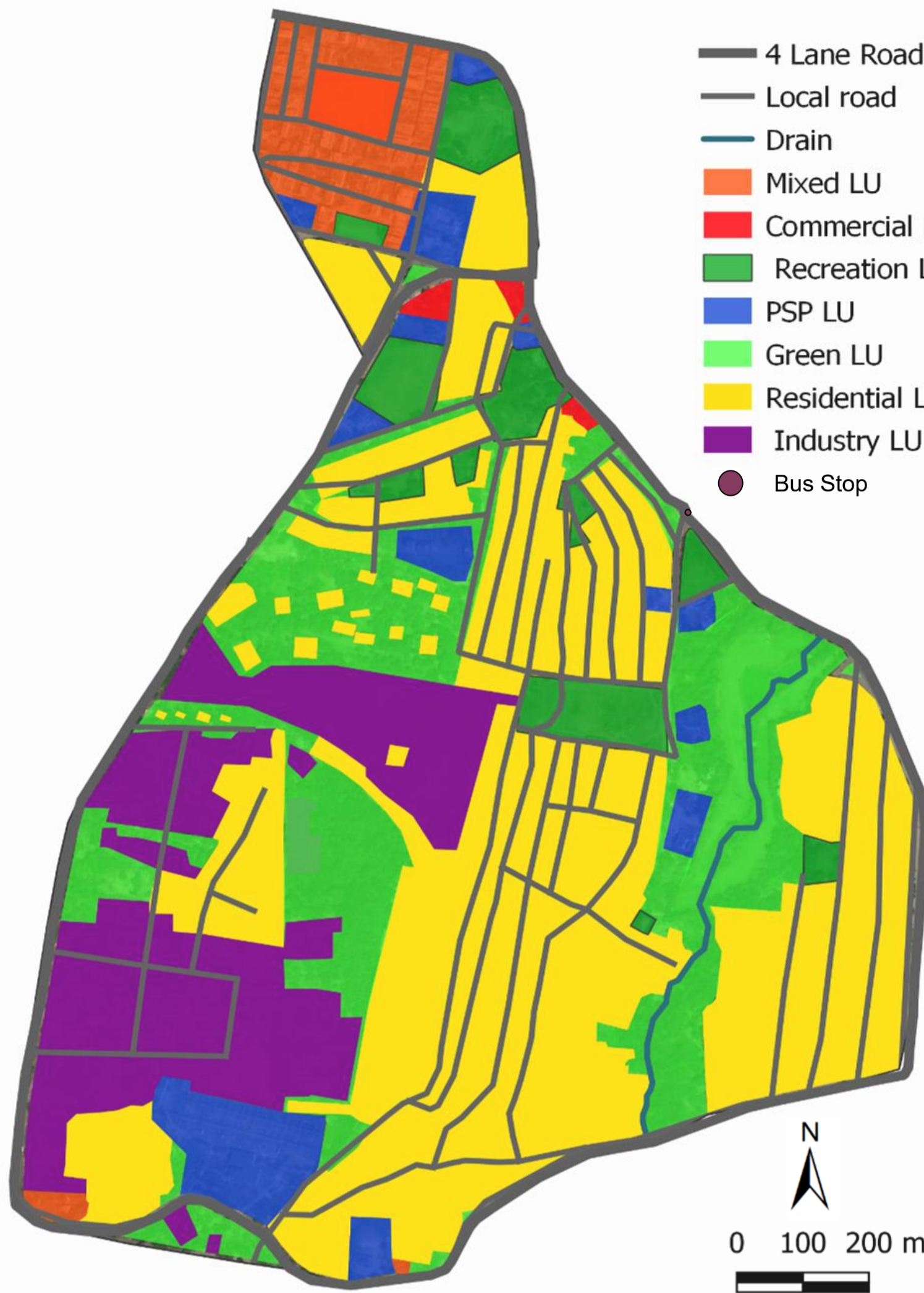


Fig: Green Area of Neighbourhood

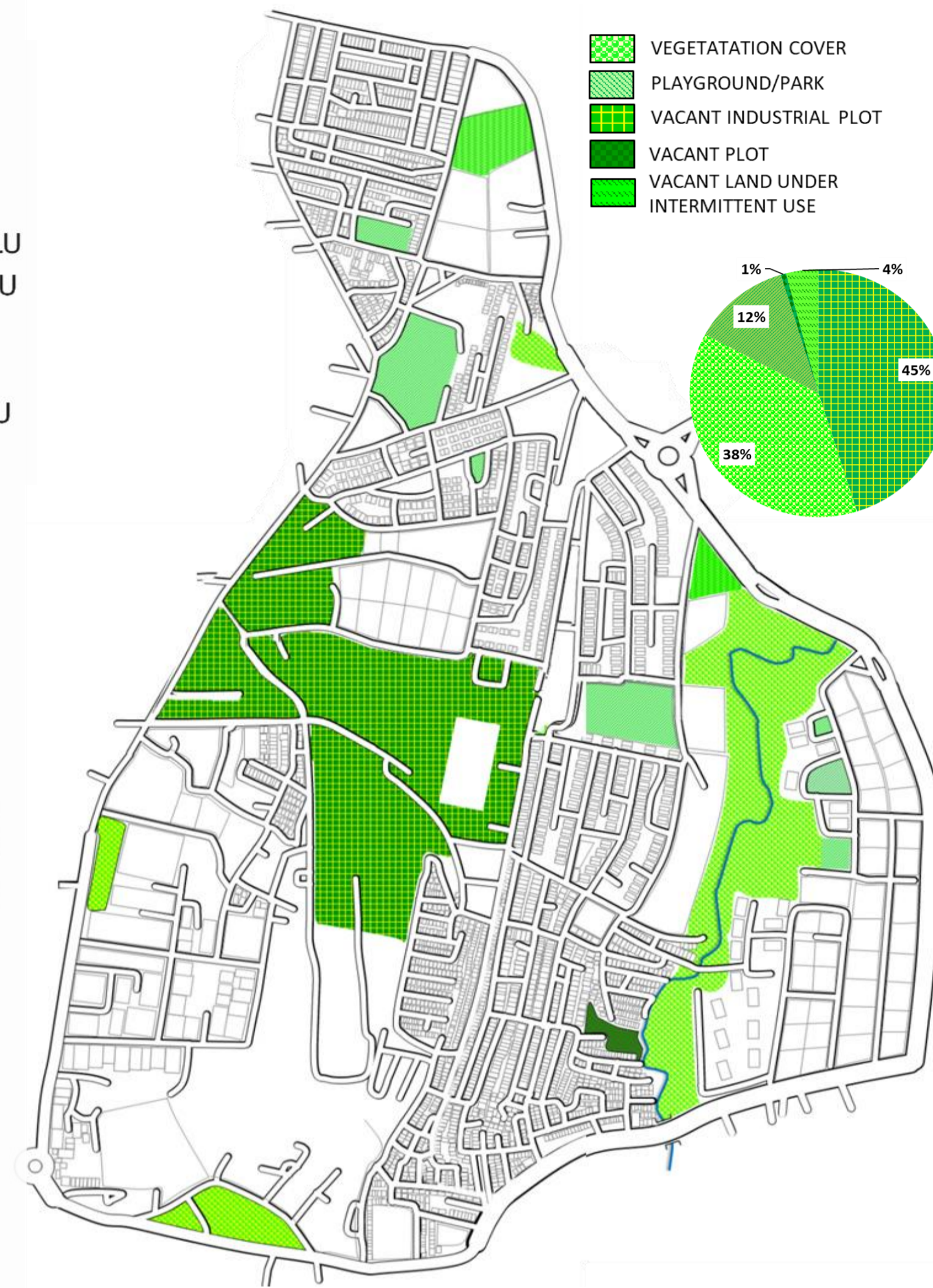


Fig: Housing Typology Map of Neighbourhood

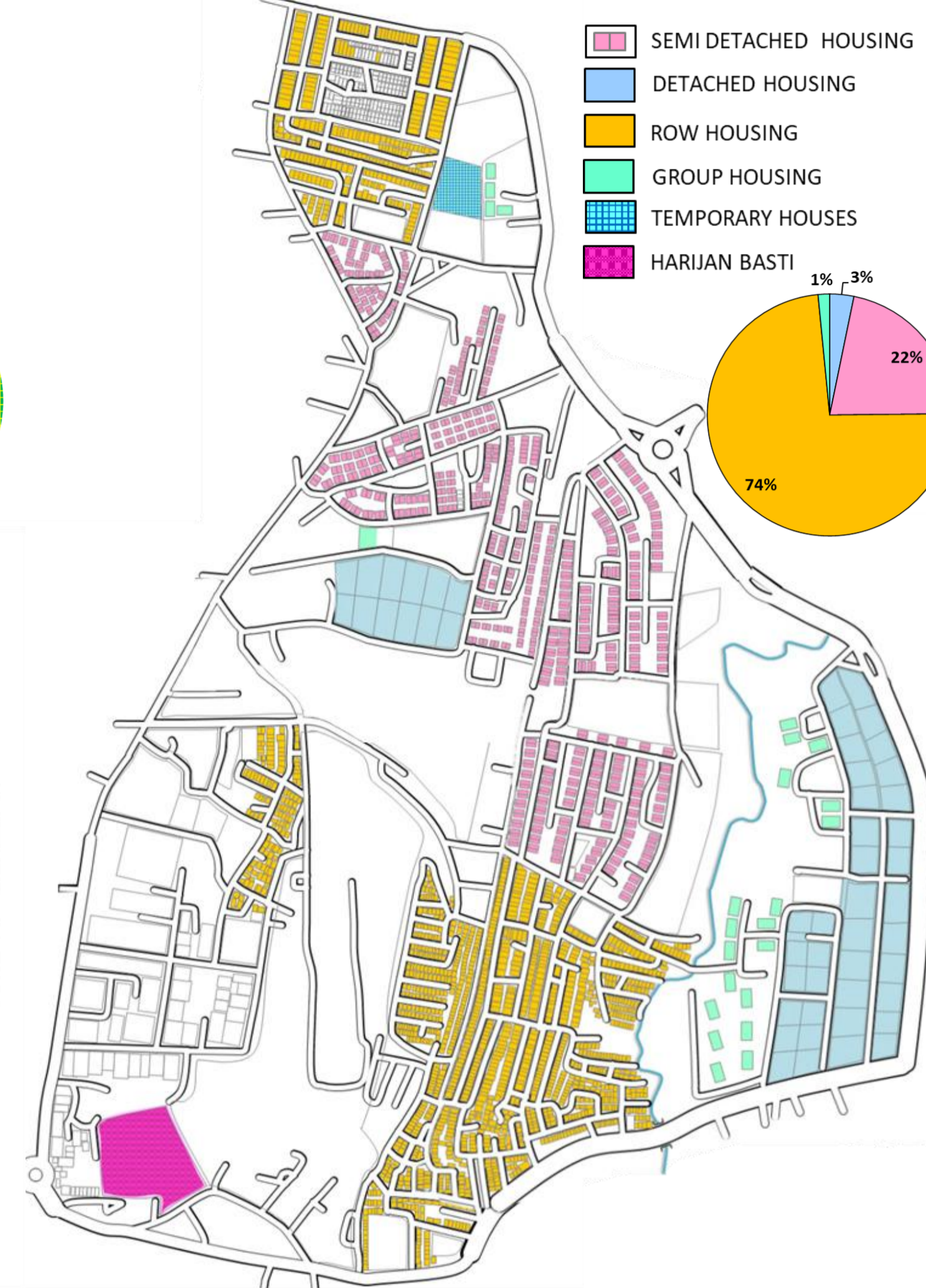


Fig: Heat Map of Neighbourhood

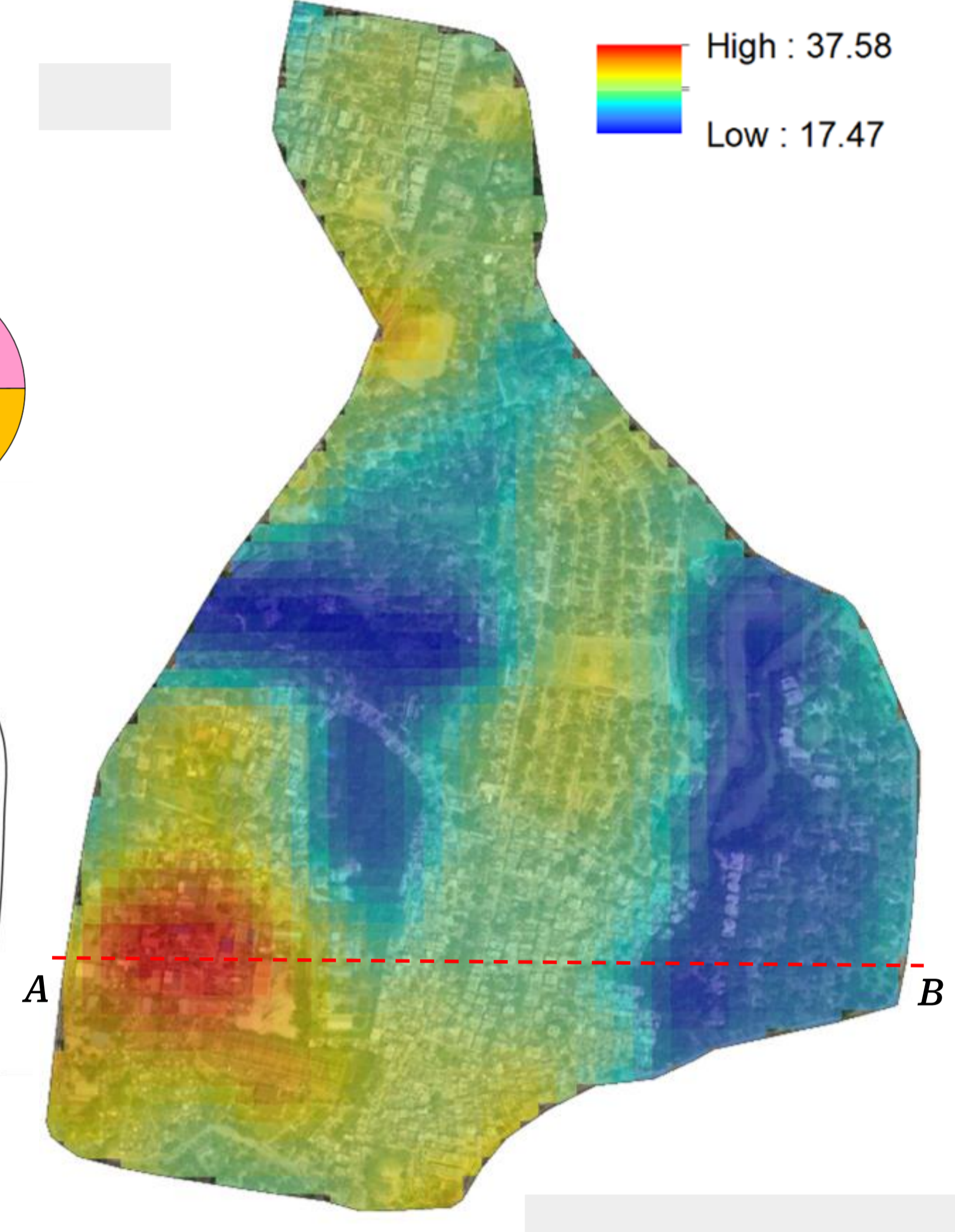


Fig: Temperature based on Green Typology

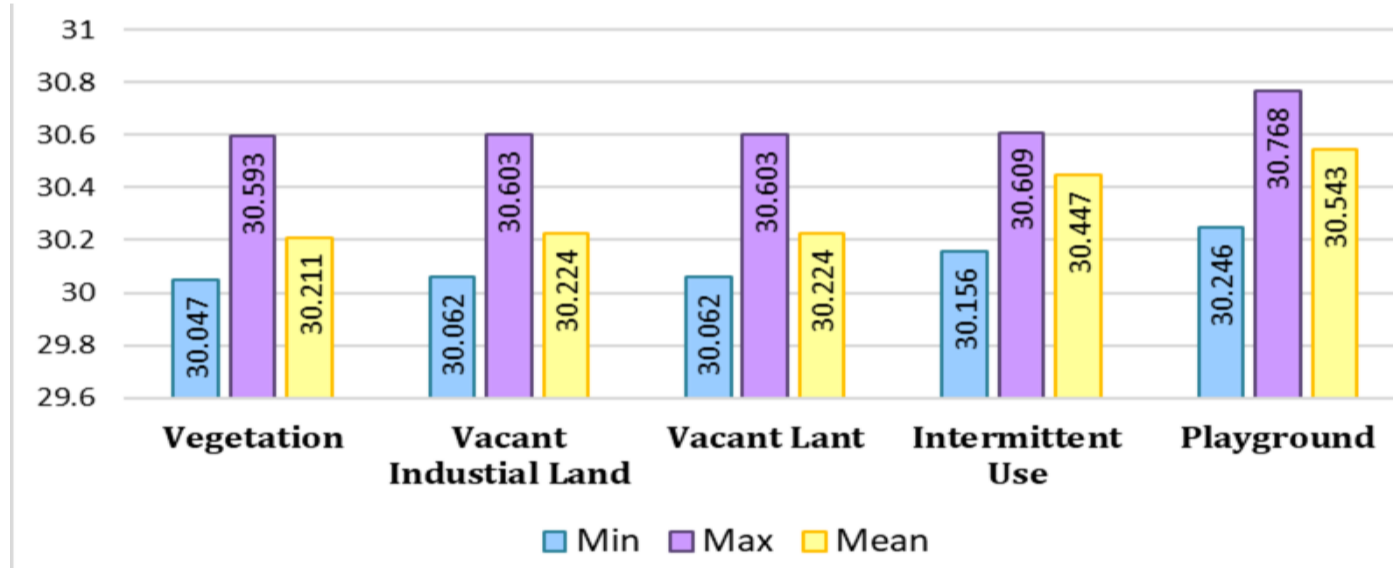


Fig: Temperature based on Housing Typology

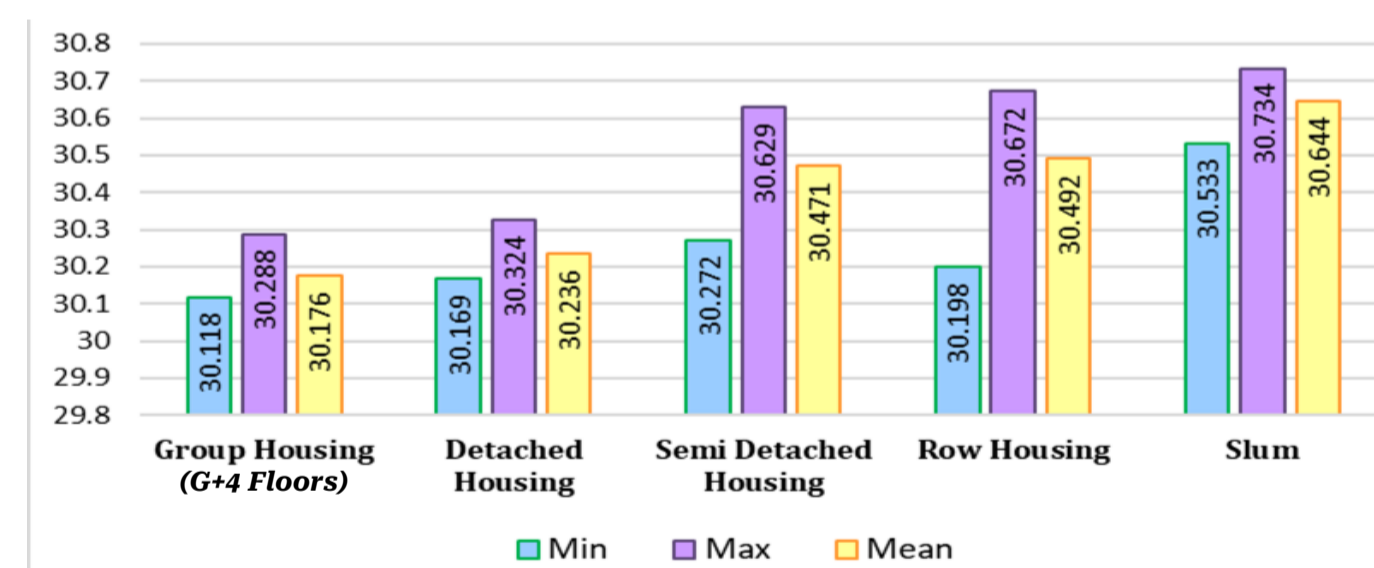


Fig: Cross Section -Spatial Variability of Urban Heat Island in Golmuri Neighbourhood

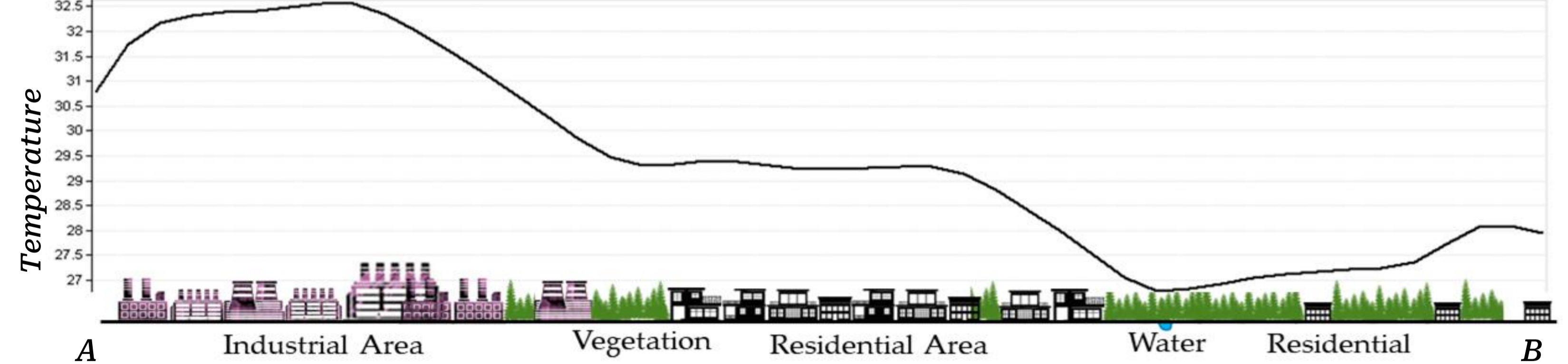


Fig: Playground



Fig: Vacant Industrial Land



Fig: Semi Detached House



Fig: Group House



Vegetation has lowest temperature, followed by vacant industrial land where as playground has higher due to lower albedo and limited evapotranspiration.

Group housing has lower temperature as it has higher vegetation cover and detached and semi detached has higher share of vacant land.

Fig: Existing Bus Stop



Fig: Street section (1) of Semi Detached Housing

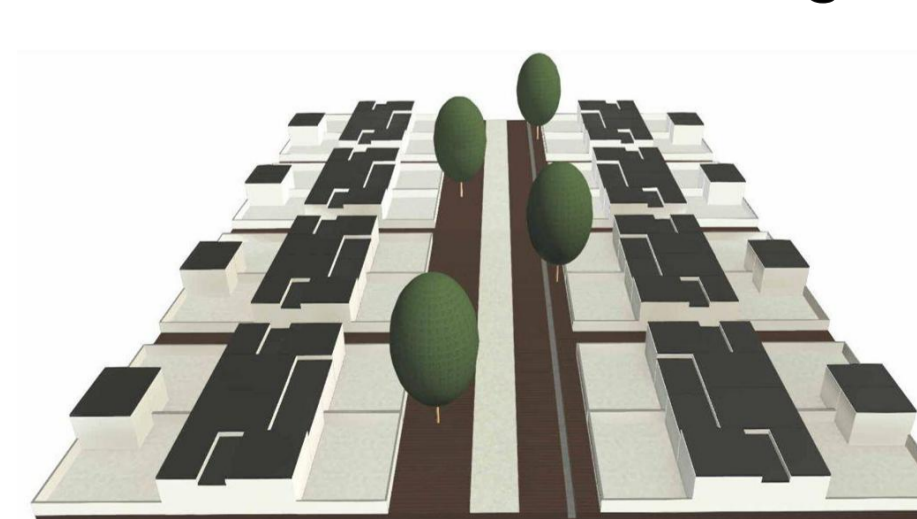


Fig: Street section (2) of Sub-Arterial Road



Road 1 has higher vacant land & the roof is covered with Tar which increases temperature.

Road 2 has 15 m wide median which hardly has any landscape. Thus it increases temperature.

## Causes of Urban Heat Island

Industrial areas of TATA STEEL and Adityapur Cause	Commercial areas of Sakchi and Bistupur Cause	Residential areas of JNAC Cause
Anthropogenic heat	Anthropogenic heat	Increased energy use
Roofing material (i.e metal sheets)	Roofing material (i.e metal sheets)	Urban geometries that trap heat
Lack of vegetation	Lack of vegetation	Poor vegetation and roofing
Lack of buffer zone from industrial to residential zone	Widespread use of impermeable surfaces	Roofing material

*Table: Scale of Interventions*

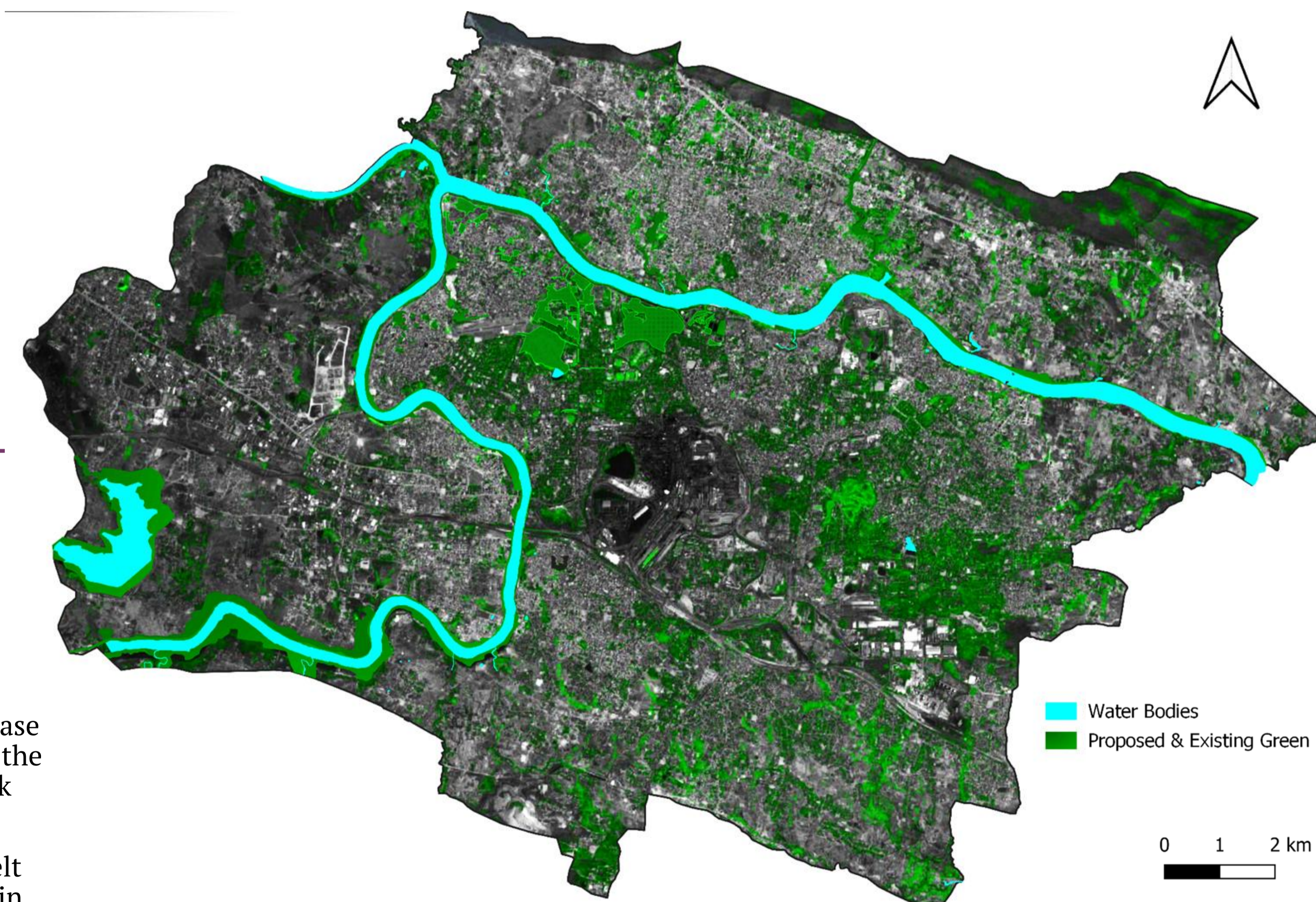
ASPECT	BUILDING SCALE	BLOCK SCALE	NEIGHBOURHOOD SCALE	CITY SCALE
<b>Urban Climate Effect</b>	Heat absorption and radiation, shading and ventilation	Street Canyon dynamics, Heating and Cooling, Pollutants circulation	Local heat Island, park cool island effects	Urban impact on weather patterns - air, circulations etc
<b>Relevant Actors</b>	Building owners, landlord, tenants	Residents' committee, real estate developer	Neighbourhood Association, real estate developer	Urban Planner, Architects, Governments, TUISL
<b>Intervention</b>	Cool roof, passive building design, green building elements	Public space design, building arrangements, greening	Street trees, traffic medians, private lands, pocket parks	Building codes (cool roof, material, color mandates), Incentives (FAR)



*Table: Proposals for different aspects*

ASPECT	IMPLEMENTATION	COOLING THROUGH	CO-BENEFITS
<b>Green</b>	Parks, unsealing of soil, and creation of more permeable surfaces, green roofs, living walls, vertical gardens	Shading effect, insolation evaporative cooling	Storm water retention, low energy, recreation, biodiversity, groundwater recharge
<b>Blue</b>	Ponds, lakes, fountains, canals, re-naturalization, etc.	Evaporative cooling, increased ventilation	Recreation, biodiversity
<b>White</b>	Bright (reflective) materials	Reduced heat absorption through the reflection of solar radiation	Building energy savings, easy implementation

*Table: Proposals for Green Area in Jamshedpur Urban Agglomeration*

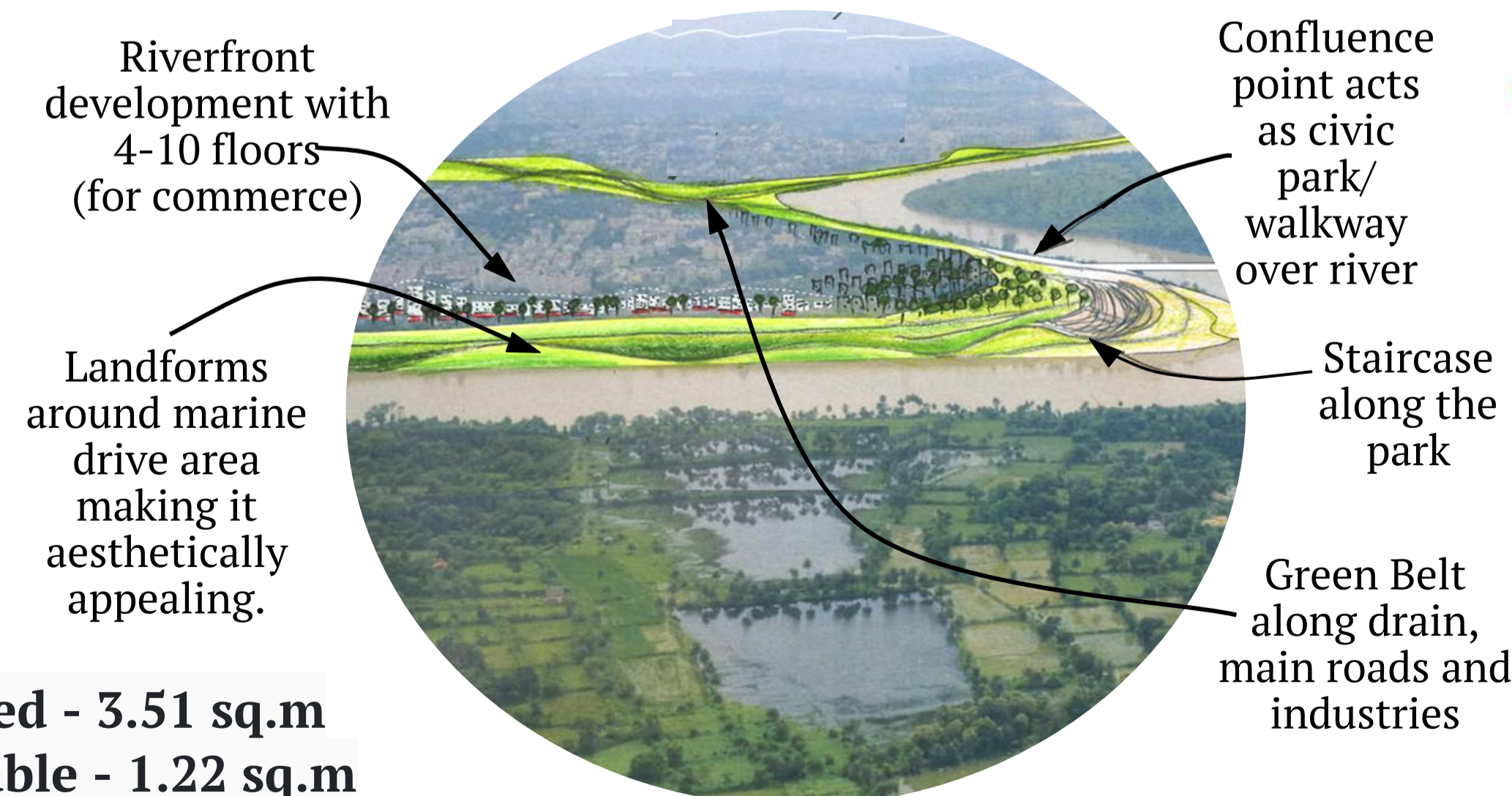


*Table: Organised green area requirement as per URDPFI guidelines*

Park Hierarchy	Required	Existing
Housing Area	130 Ha	1.3 Ha
Neighbourhood	87 Ha	3.25 Ha
Community	65 Ha	21.83 Ha
District	75 Ha	25.02 Ha
Sub city	100 Ha	107 Ha
<b>Total</b>	<b>457 Ha</b>	<b>158.4 Ha</b>

Per Person Organised Green spaces required - 3.51 sq.m  
 Per Person Organised Green spaces available - 1.22 sq.m

*Table: Proposals for River Confluence (Dumuhani)*



Per Person Organised Green spaces proposed - 2.31 sq.m  
 Total Green Proposed - 12,00,000 sq.m

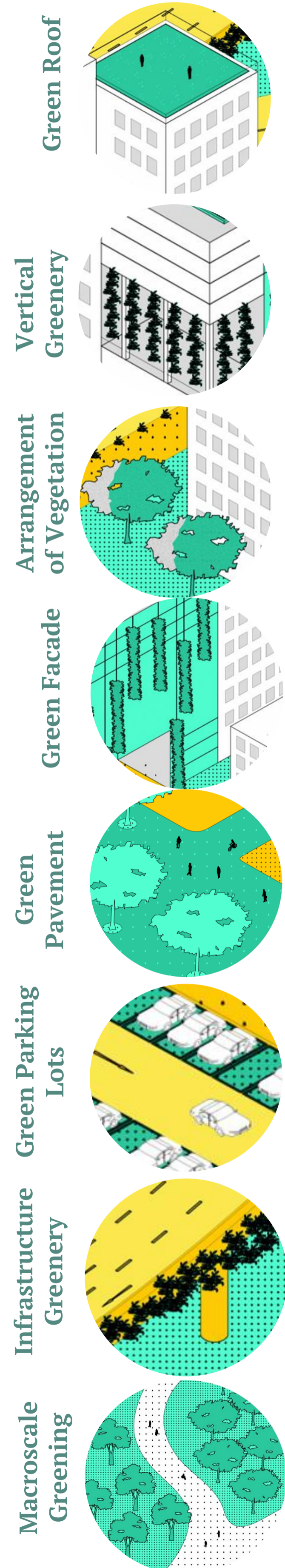
PROPOSAL FOR GREEN

Building

Block

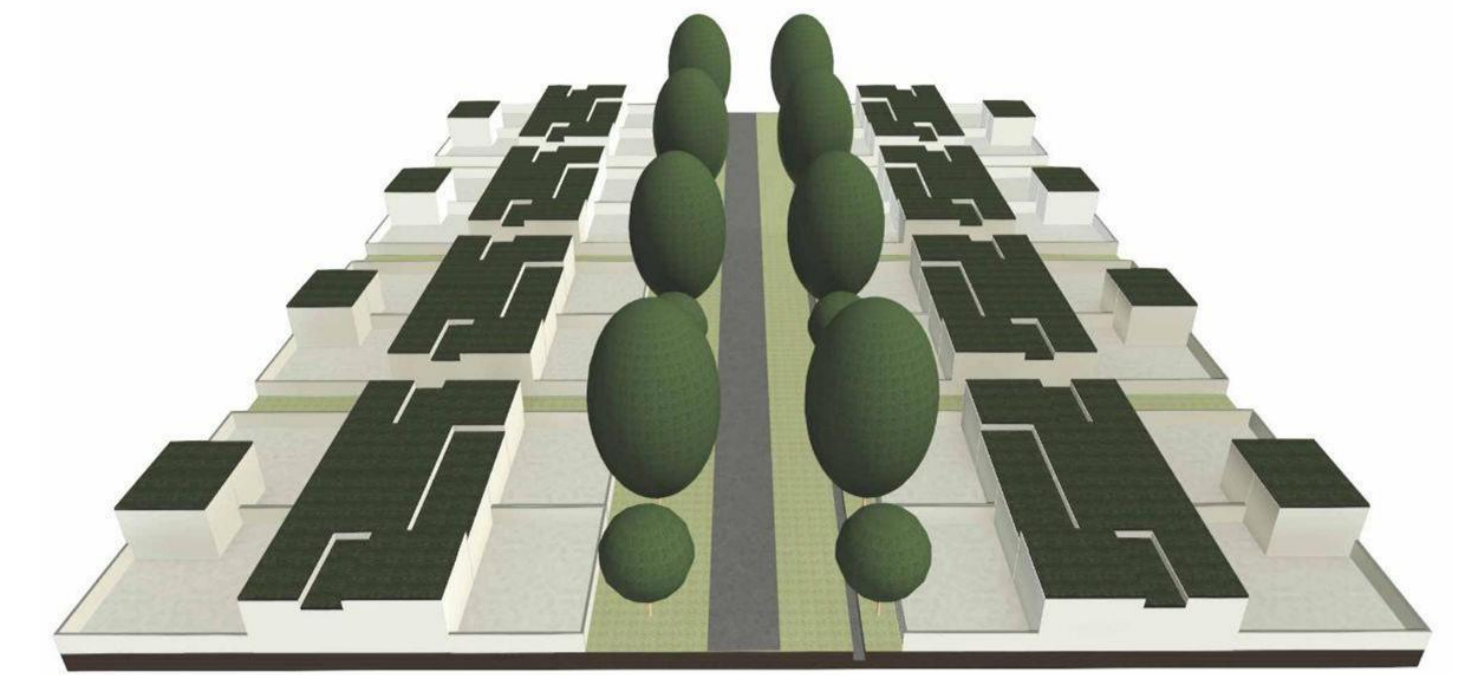
Neighbourhood

Illustration



Tropical Climate	UHI Effect	Urban Planning	Techniques (as per papers)
Elevated position of the sun along the year producing intense vertical radiation.	Urban heat accumulation reduction. Air temp. is influenced by evapotranspiration. Reduction in building energy consumption.	Implementation should be aided by the development of building codes and energy efficiency guidelines.	Green roofs lower urban air temps by 0.5-1.7°C at ground level. (Peng and Jim 2013). Reduction of energy consumption can be close to 10% (Refahi and Talkhabi 2015),
Water access can be provided naturally through atmospheric precipitation.	Reduction of the external surface temperature. Pedestrian thermal comfort. Energy consumption for cooling reduces.	Adequate greenery systems accordance to building structure, the maintenance required and safety.	Reductions between 10-31% energy cooling load. (Wong et al. 2009).
Reducing direct exposure to sun radiation.	Vegetation can absorb the incoming solar radiation and reduce heat accumulation in urban materials.	Prioritize thermal pleasure by creating asymmetrical thermal environments with dominant cool spots.	Tree-shadowed streets can lower air temperatures by 0.9-2.6°C (Gillner et al., 2015).
Reducing solar exposure isolates building thermal impact from warm exteriors.	Facade temperature reduced. Temperature inside the building remain more stable. Benefits of thermal comfort for pedestrians.	Implementation should be aided by development of building codes and energy efficiency guidelines.	6.2% decrease in energy consumption and a potential 0.5-1°C reduction in outdoor temperature near the facade. Pan and Xiao (2014)
Greenery here grows with little maintenance due to the sufficient access to water.	Reduction of urban heat accumulation by decreasing pavement temperature. Influencing pedestrian's thermal comfort and UHI.	Implementation efforts on areas/pavements with minimal shading, as heat accumulation increase in such conditions.	Utilizing grass pavements can reduce temp., pavements cover approximately 30-45% of urban areas (Flower et al., 2010).
Elevated position of the sun along the year, and the high growth of vegetation in humid tropics.	Use of vegetative elements/soils with higher albedo has the effect of reduces heat compared to conventional dark asphalt at parking lots.	Should be focused on parking lots with little shading where heat accumulation could be higher.	Traditional asphalt pavement absorbs heat, but new green parking lots offer improved thermal performance. (Gibbons 1999).
Shadowing green elements beneficial to improve outdoor thermal comfort than greenery.	Reduction of the urban heat by decreasing surface temp. influencing pedestrians' thermal comfort.	Development of small green urban areas located strategically or grouped around buildings.	Greenery enhances thermal comfort, reduces air pollution, and enhances psychological well-being during heat stress. (Laforteza et al., 2009).
The potential growth of vegetation and the low irrigation needs for maintenance.	Assure a better thermal perception and provides coolness to nearby urban areas.	Implementation of macroscale urban greening.	The temperature difference between urban and park areas has been found to be from 1.5-4°C (Jonsson 2004).

Fig: Proposal for Road 1 (Neighbourhood - Golmuri) Building and Block Level



The black tar roof should be covered with green roof of with a light shade roof to reflect the heat. Also trees to be planted at regular interval to provide shading.

Fig: Proposal for Road 2 (Mango) City Level



Green roof over commercial buildings and median should be planted with quick growing trees. Eco-friendly landscaping - green footpath.

Fig: Green Corridor Design.

The vegetation arrangement along transport corridors to provide shade to road surface.

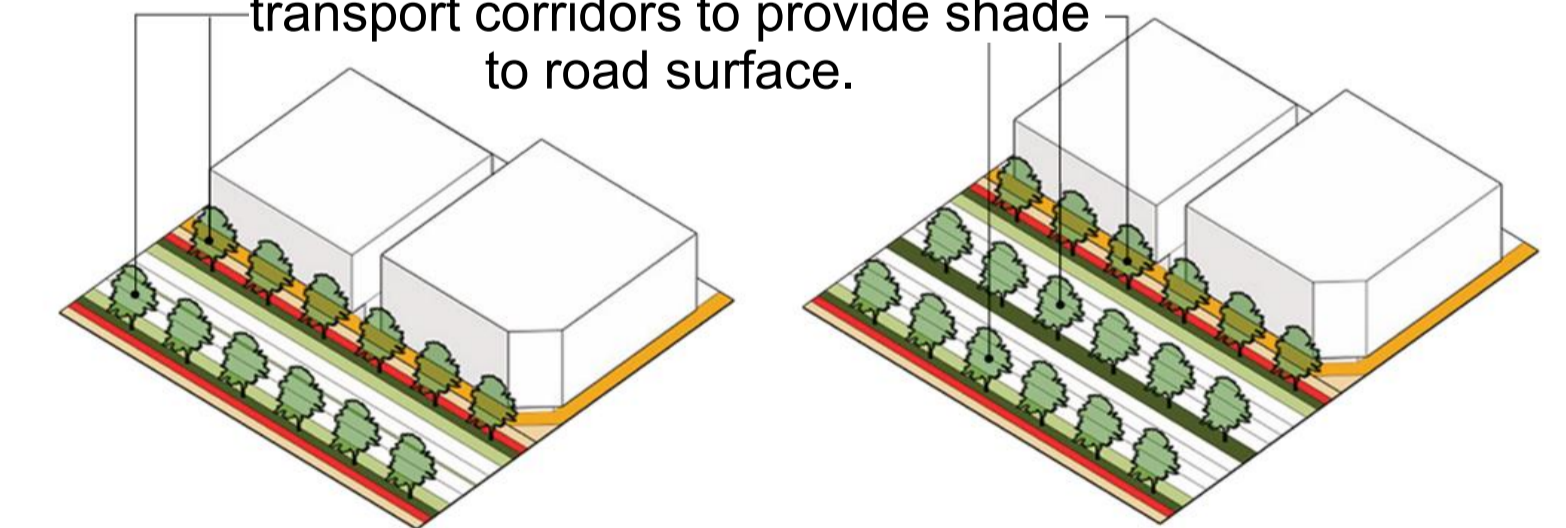
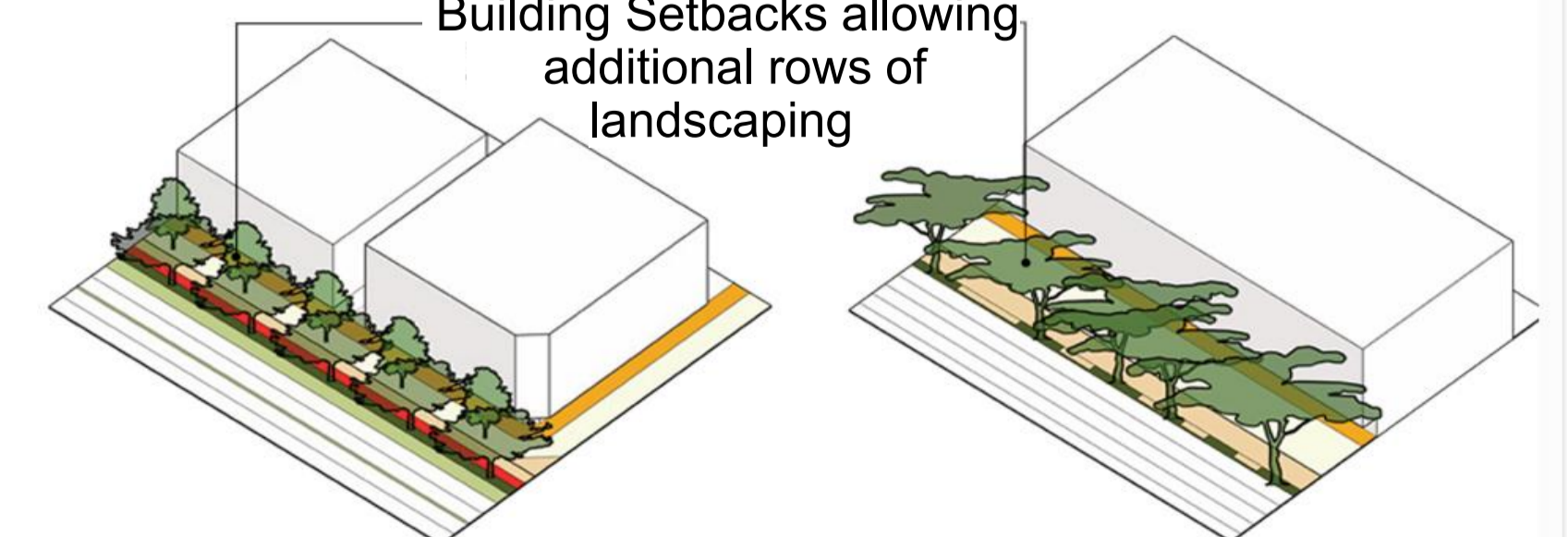


Fig: Planting at Setbacks

Building Setbacks allowing additional rows of landscaping



**BLUE**

		Tropical Climate	UHI Effect	Urban Planning	State Of Art
Neighbourhood	Cool Sinks	Mitigating surface overheating positively impacts urban climate and energy usage.	Water masses absorb thermal energy from incoming solar radiation due to heat capacity. Water evaporation absorbs solar energy, reducing heat accumulation lowering UHI.	The planning of new developments consider the possibility of strategic natural water accumulation.	Several smaller lakes equally distributed within the urban area have a smaller temperature effect, but collectively influence a larger area. <i>(Theeuwes et al. 2013)</i>
	Blue Green Spaces	Water access can be provided naturally through atmospheric precipitation.	Water (blue) and vegetation (green) strategies can affect climate variables differently. Water can have a nocturnal warming effect during certain periods of the year.	Ad-hoc urban design protect and enhance the wellbeing of inhabitants by optimising ecosystem services.	Green and blue strategies provide mutually dependent environment - synergistic cooling and other valued ecosystem services <i>(Gunawardena et al. 2017)</i> .
City	Wetland Construction	Can provide shadowing and be a reservoir of regional undisturbed climate. It will act as a sink of CO2 and other greenhouse gases.	Water has negligible diurnal temperature variation compared to land surface and thus it does not accumulate heat during daytime hours.	Not only development of natural areas should be considered for thermal comfort but also their surrounding for extended effects.	Preserve wetlands for both ecological and urban heat island mitigation benefits.
	Water Catchment	Changing characteristics of surface to avoid overheating can contribute positively to the urban climate.	Large water masses can absorb thermal energy from the incoming solar radiation. Extending water catchment areas can increase the non-heated surfaces	Different agents should be involved in the design and implementation in relation to other requirements such as water supply.	The cooling effect depends on the size and distribution of individual water catchments.

Fig: Visualization Of Wetlands and Details of increased benefits for urban living environment

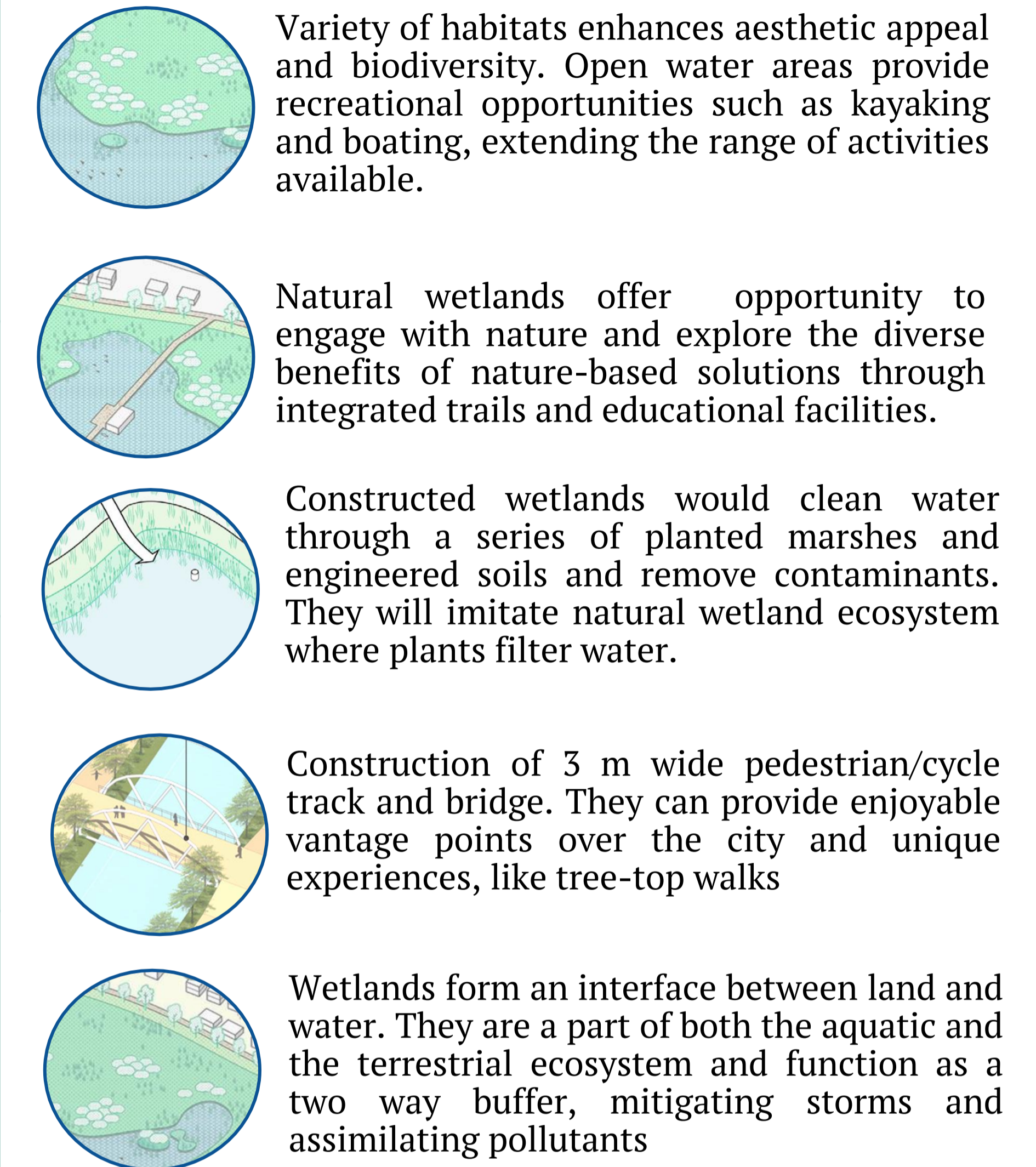
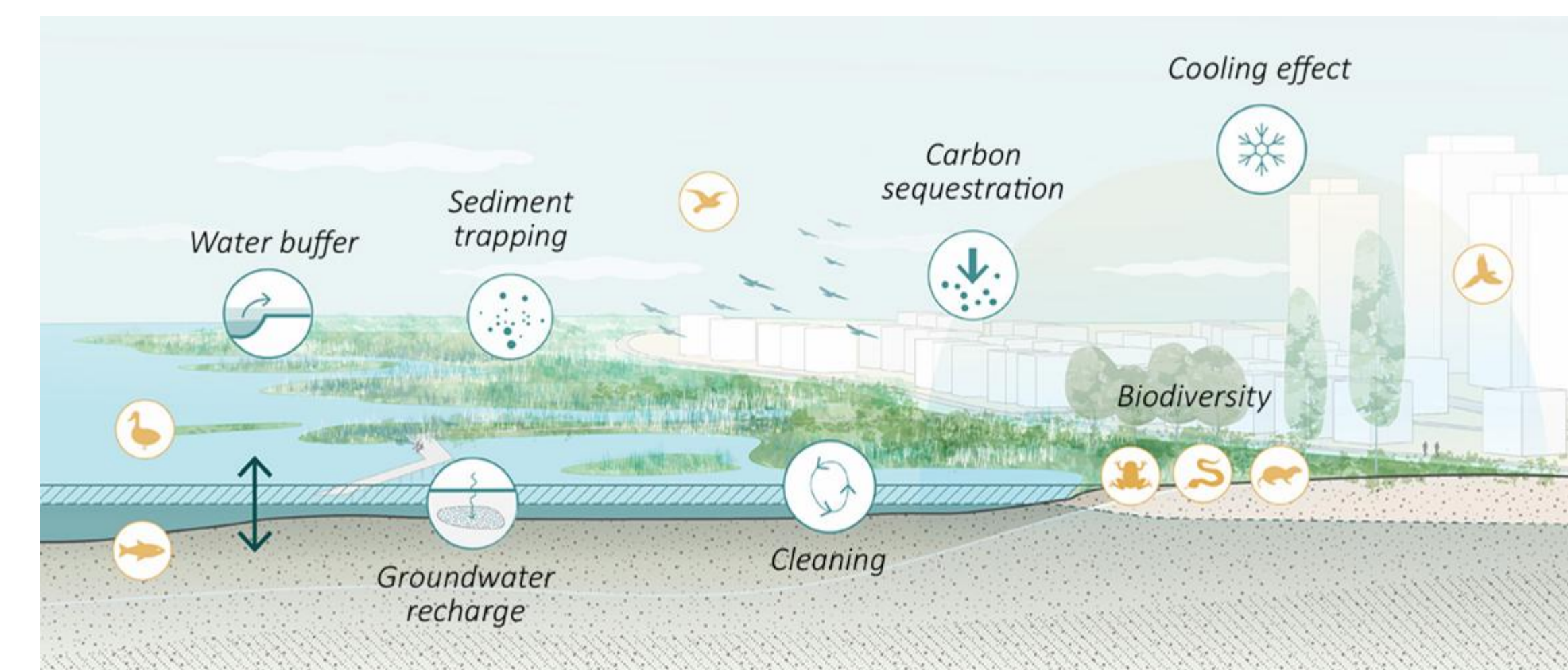


Fig: Constructed Wetland Process

Fig: Productive Landscaping, Confluent section (including floodable islands) and terracing of Buffer area.


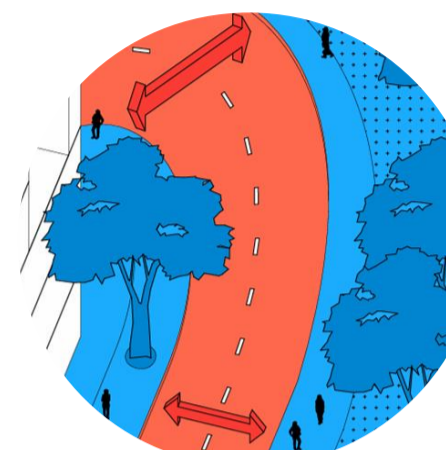
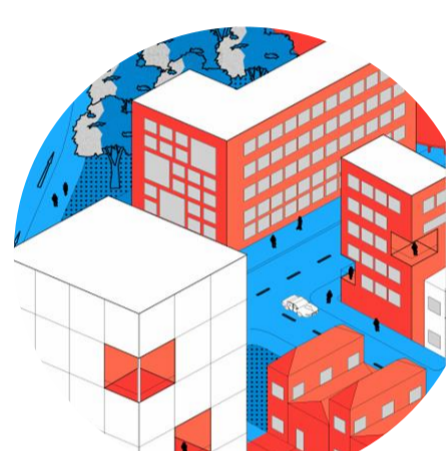
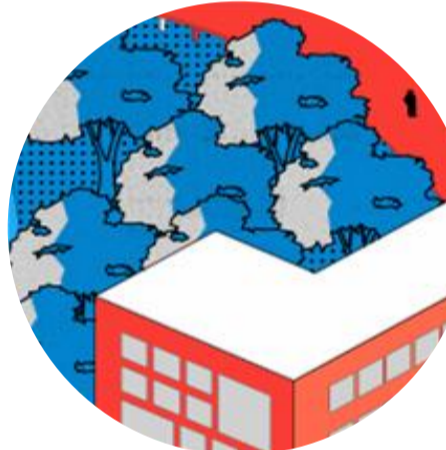


At the confluence point, we propose to open up the Drain with a delta designed to create a set of floodable islands that serve as a layer of water-bioremediation as it enters Subarnarekha. During dry season, these floodable islands can become destination points for boats and tourist flows.



Constructed inland wetlands in urban areas mitigate anthropogenic impacts, sequester carbon, aid climate adaptation, and purify various sources of pollution. Temperature reduction, Water quality and sediment management, Biodiversity, Pluvial and riverine flood risk reduction, Carbon storage and sequestration, Tourism and recreation are some of the benefits of Wetlands.

## URBAN GEOMETRY

	Illustration	Tropical Climate	UHI Effect	Urban Planning	Techniques
Neighbourhood	Mean Building /Tree Height 	The combination of greenery shade in relation to building geometry is considered to provide the best benefits.	Trees reduce direct solar insolation, both of building facades and tree surroundings. Reduction in UHI and an increase in local thermal comfort is expected together.	Adequate tree heights should be implemented in each area and other issues such as natural lighting should be considered.	Transmissivity of direct solar radiation; Foliated tree crowns: 1.3-5.3% Defoliated tree crowns: 40.2-51.9%. <i>(Konarska et al., 2014)</i>
	Wider Streets 	Water access can be provided naturally through atmospheric precipitation.	The higher the air movement inside a street canyon, higher the release of urban heat. Thermal Comfort improve with increasing wind speed and air pollutants dispersion.	The implementation of street widening should be carried out in new developments.	Air temperatures rose as high as 1.3 °C when ambient wind speed decreased from 4 m/s to 0.5 m/s. <i>(Rizwan et al. (2010)).</i>
City	Urban Density 	Rural-urban comparison using adopt the LCZ framework.	The LCZ scheme allows for the assessment and comparison of UHI magnitude.	LCZ 1, LCZ 2, LCZ 3 (compact high- rise, mid rise and low rise) and LCZ 4 (open high-rise) will dominate development	Preserve wetlands for both ecological and urban heat island mitigation benefits.
	Green Plot Ratio 	Uniform temperature all-year round, high humidity and abundant rainfall.	Increasing the greenery and integrating it into the architectural design can provide cooling to the immediate surrounding environment.	Rates different building typologies by the amount and type of surrounding greenery such as grass, bush/tree.	Groundcover plants and shrubs have higher Leaf Area Index than palms and canopy trees. <i>( Ong, Ho and Ho (2016)</i>

## SURFACE MATERIAL



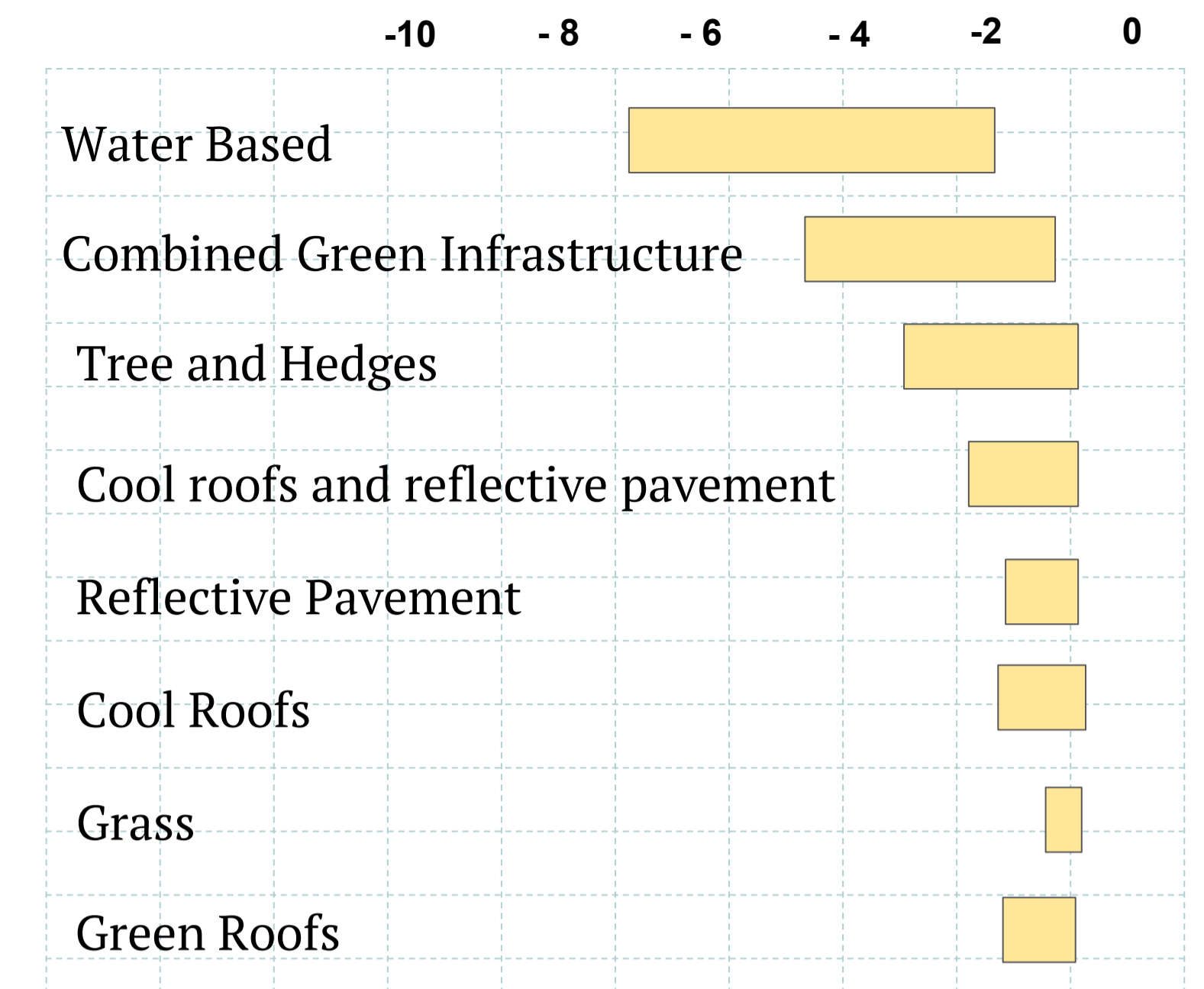
	Illustration	Tropical Climate	UHI Effect	Urban Planning	State Of Art
City	Cool Pavements 	Elevated position of the sun throughout the year, and the potential for lowering the outdoor temperature.	Reducing solar radiation absorbed by the pavements during the day, and releasing absorbed thermal heat into the atmosphere readily.	Lighter coloured asphalt on streets and roads and by the use of cool tiles or special coatings on urban pavements.	Cool pavements are able to keep urban temperatures lower overnight <i>(Asaeda and Ca 1993; Santamouris 2013).</i>
	Permeable Pavement 	Improved stormwater management and outdoor thermal comfort.	Provides benefits pedestrian's thermal comfort allowing reduction of surface temp. It can contribute to pollution control from surface runoff from roads.	Integral part of sustainable drainage systems. Implementation varies greatly across specific designs.	Permeable pavements under wet conditions could give lower surface temperatures than impermeable pavements <i>(Studies in California).</i>

Fig: Decrease in maximum daily temperature (°C )



### Commercial Recommendation

A high H/W ratio is useful in commercial building zones as it is effective in providing shade to the horizontal and vertical surfaces of a street canyon.

Cool roofs or green roofs will be very effective in lowering the daytime temperatures too. Light coloured finishes should be selected for external walls of buildings (especially taller buildings).

### Residential Recommendation

Integrating green cover and water bodies in the planning of the layouts at locations where H/W ratio is higher than 1.

When designing new layouts, urban planners should ensure that roads are fully shaded by the canopy of planned vegetation. For every 7 sq. kilometres of development, 1 sq. kilometre of water body with open lands is recommended.

33 sq. km. of water body and open land is required for proper maintaining of the urban environment and providing thermal comfort.

### Conclusion

Disparities in UHI exposure among different residential areas and socioeconomic groups underscore the importance of addressing environmental justice.

Continuous monitoring and modeling of UHIs will aid in identifying hotspots and informing targeted interventions.