FOSS4G Korea 2020
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Using FOSS to estimate and predict the Land Surface Temperature

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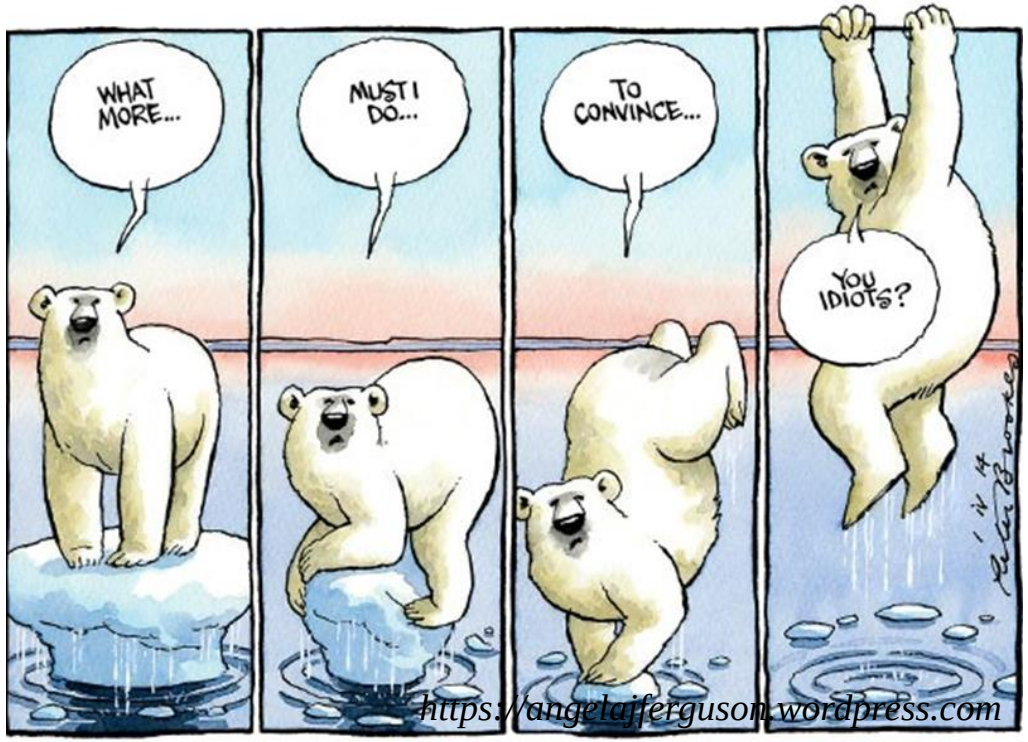
FOSS4G KOREA 2018

Climate Change

- Weather → state of atmosphere at any given instant
- Climate → statistical description of weather over a period of time
- Unplanned urbanization → one of the major reasons of climate change



Global temperature rise

Warming oceans

Sea level rise

Ocean acidification

Increased extreme events

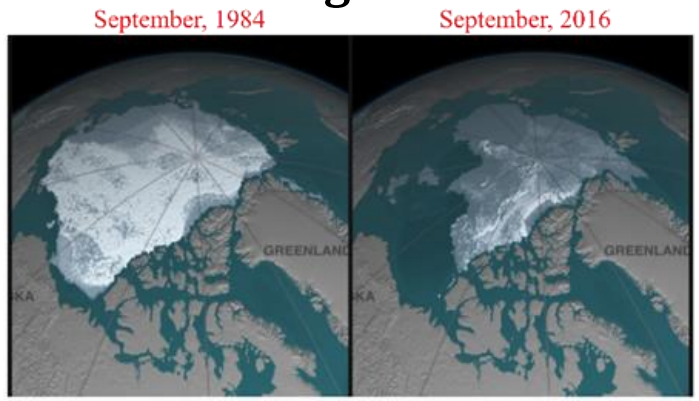
climate.nasa.gov

Evidences

Global temperature rise

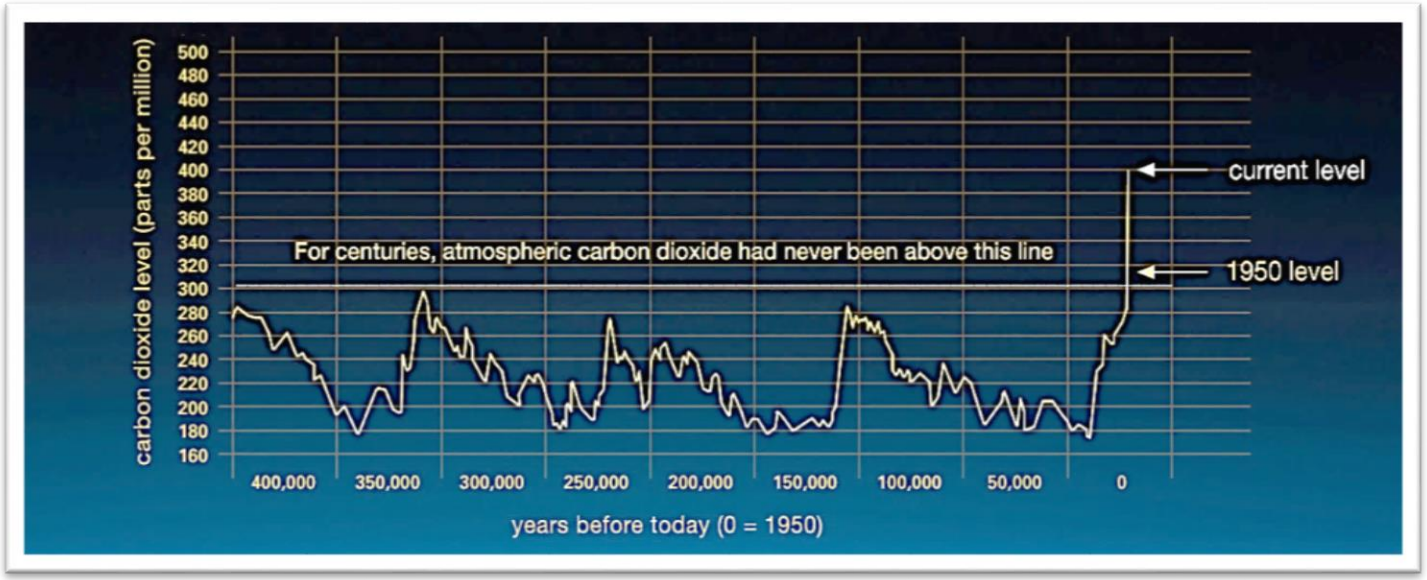
Warming oceans

Shrinking ice sheets



Sea level rise

Extreme events



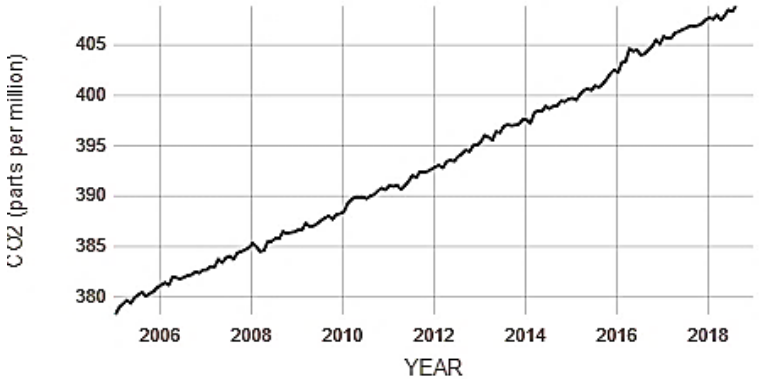
Historical representation of carbon dioxide levels

Ocean acidification

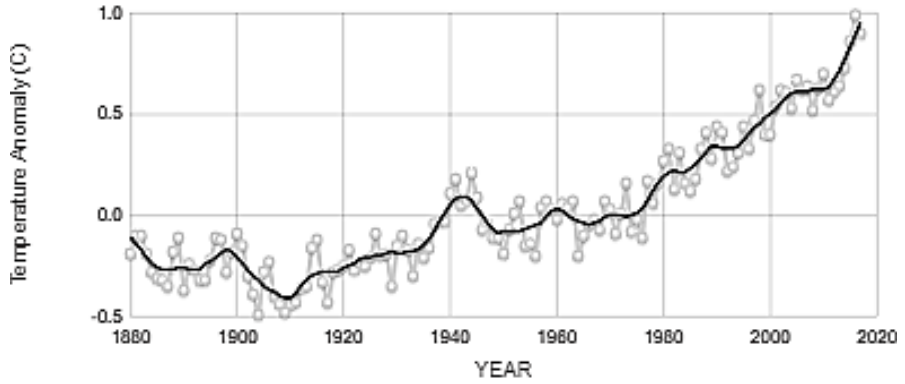
(Source: climate.nasa.gov)

• Vital Signs •

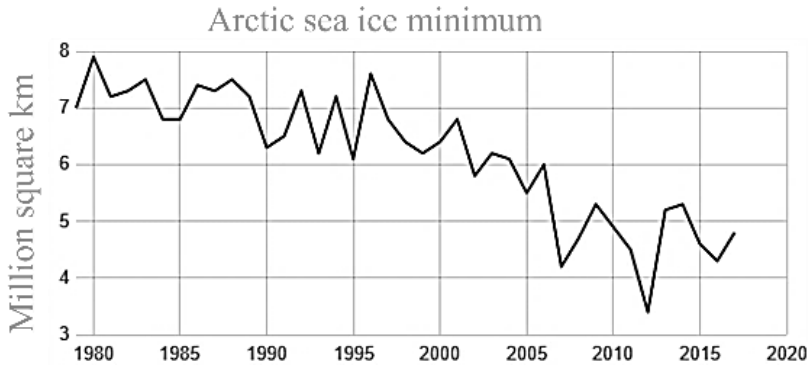
Carbon Dioxide

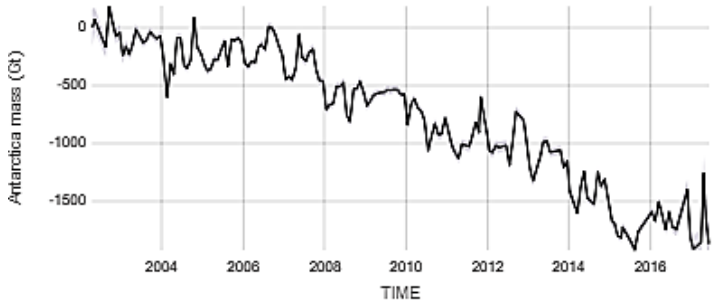


Global Temperature



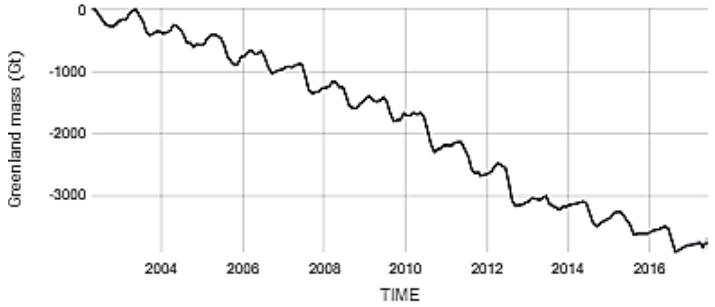
Arctic Sea Ice





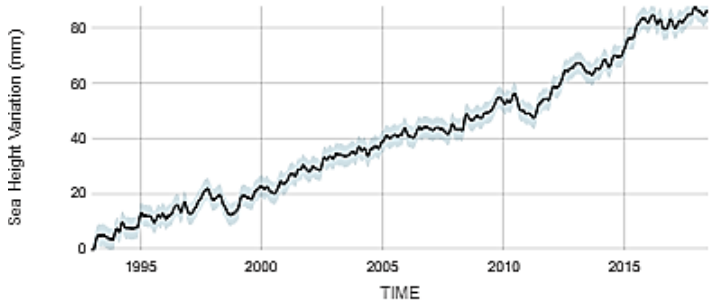
Source: climate.nasa.gov

Antarctica Ice Sheets



Source: climate.nasa.gov

Greenland Ice Sheets



Source: climate.nasa.gov

Sea Level

(Source: climate.nasa.gov)

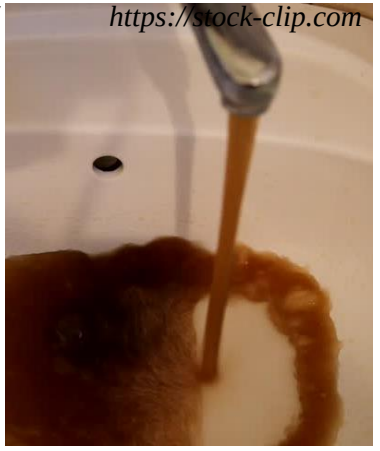
Urbanization

"Escalation in concrete area of towns or cities as a result of augmented demographic pressure"

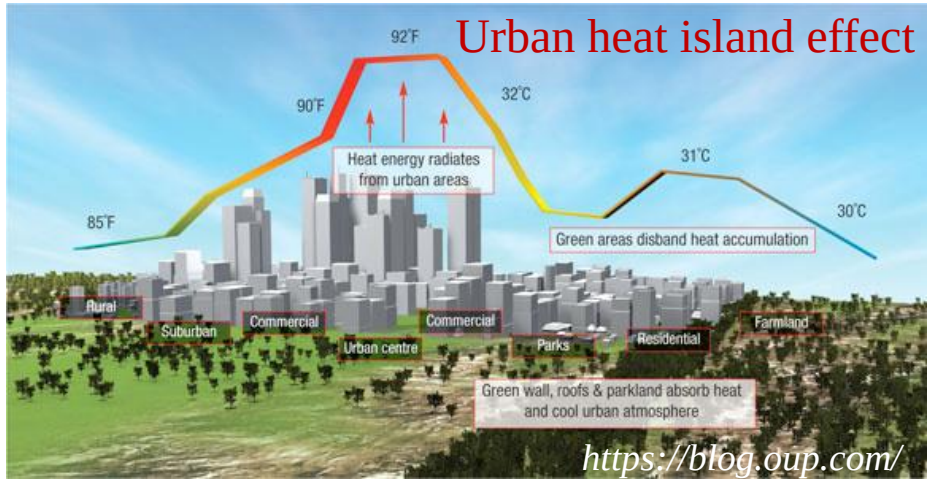
- Urban population → 55% (2016) and 68% (by 2050) (UN DESA, 2018)
- Crucial as it defines GDP per capita and defines how much economically sustainable a city is
- Impacts → Urban sprawl, Environmental impacts, poor quality of water, climate change, increased pollution levels, indecorous waste management, global warming, urban heat island, etc.


https://en.wikipedia.org/


http://www.miss-ocean.com/


https://stock-clip.com


https://campuspress.yale.edu/



https://blog.oup.com/


https://www.sciencedaily.com/

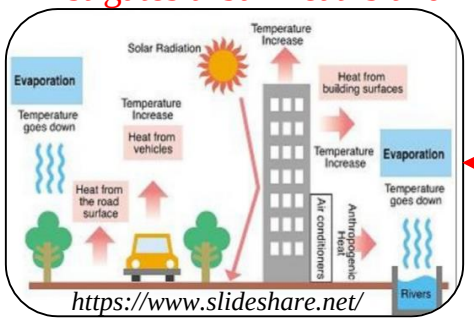
Land use / Land cover

- Land Use/ Land Cover (LULC) changes affects rate of evaporation, surface albedo, storage of heat, moisture content of soil, wind turbulence, solar radiation and surface temperature

Affects health of residents

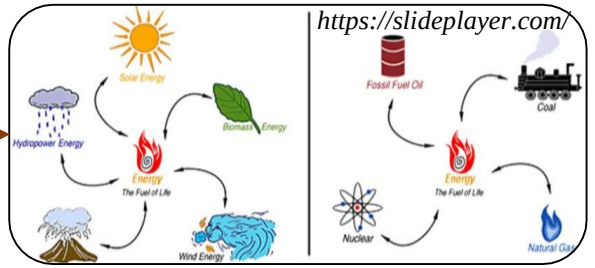
http://jalaloadedshuks.blogspot.com/

Instigates urban heat island



https://www.slideshare.net/

Alters natural flow of resources

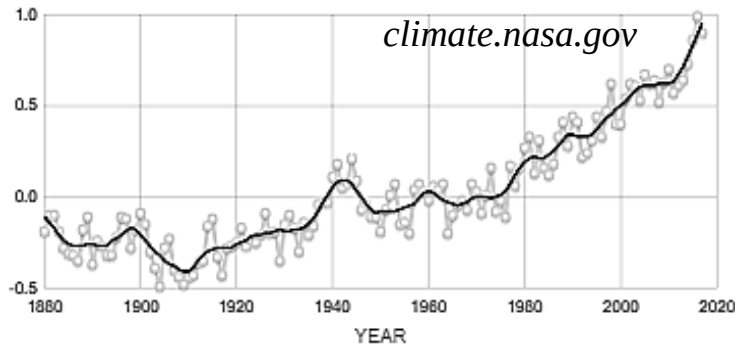


https://slideplayer.com/

Degraded air quality

https://www.financialexpress.com/

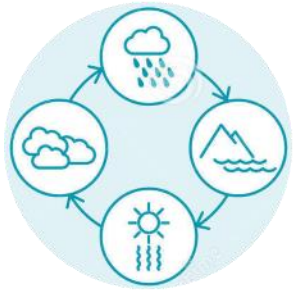
Land Surface Temperature (LST)



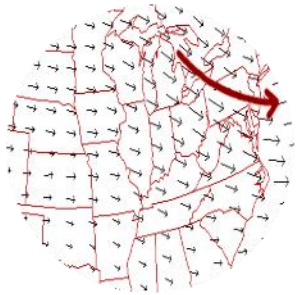
"Radiative skin temperature of earth as viewed from sensors"

- Basic element of thermal behavior of earth
- Basic parameter to comprehend environment and climate change

- Alters


Water Cycle


Crop Pattern


Wind Pattern

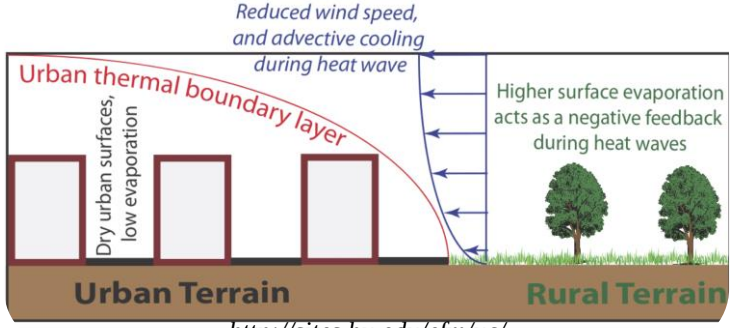

Rainfall


Ecology


Biodiversity

- Useful for variety of applications

Urban climatology



http://sites.bu.edu/efm/uc/

Estimation of GHGs


http://www.screamingpower.ca/

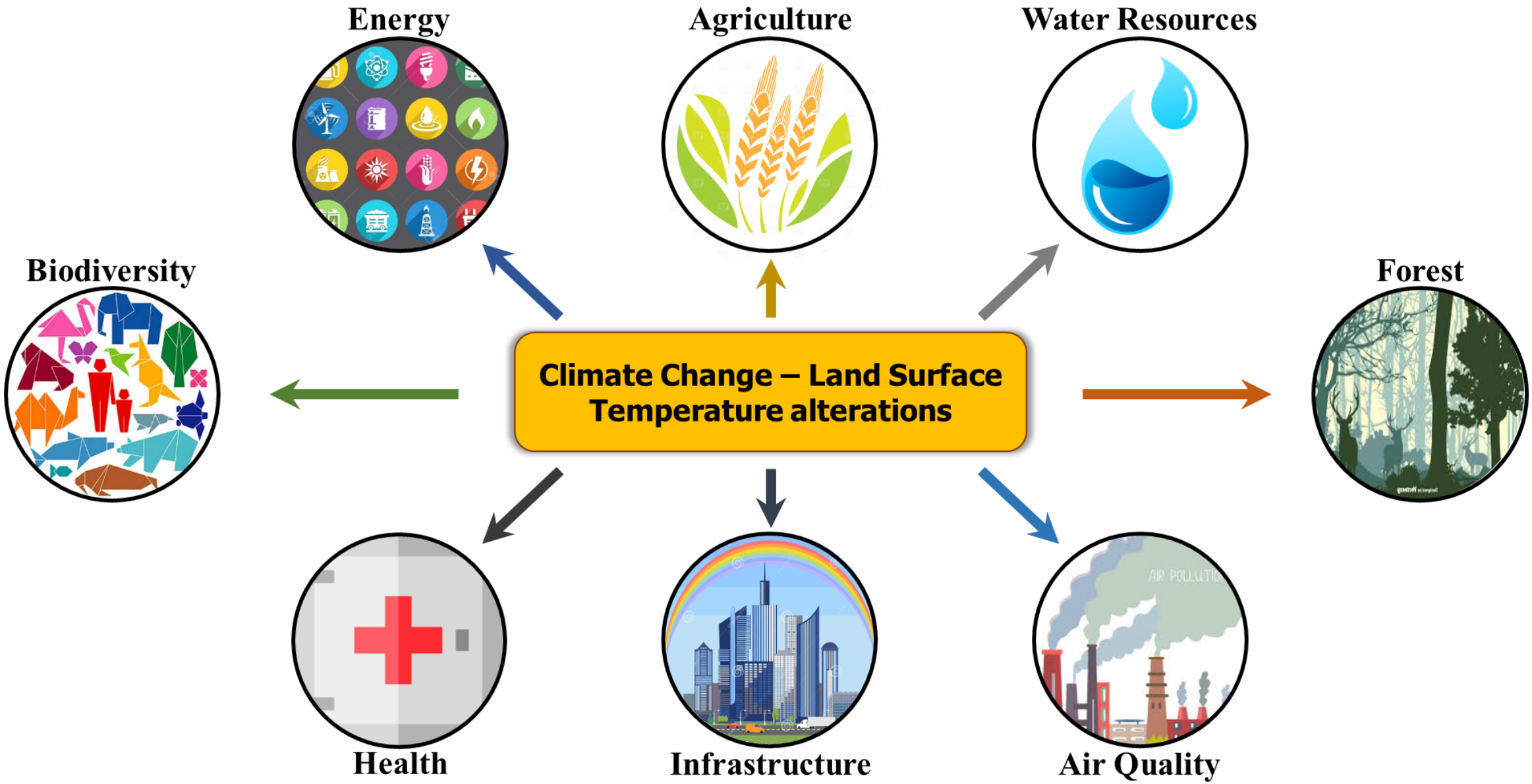
Vegetation Monitoring


http://hummingbirdaerialsurveys.com/

Urban heat island study

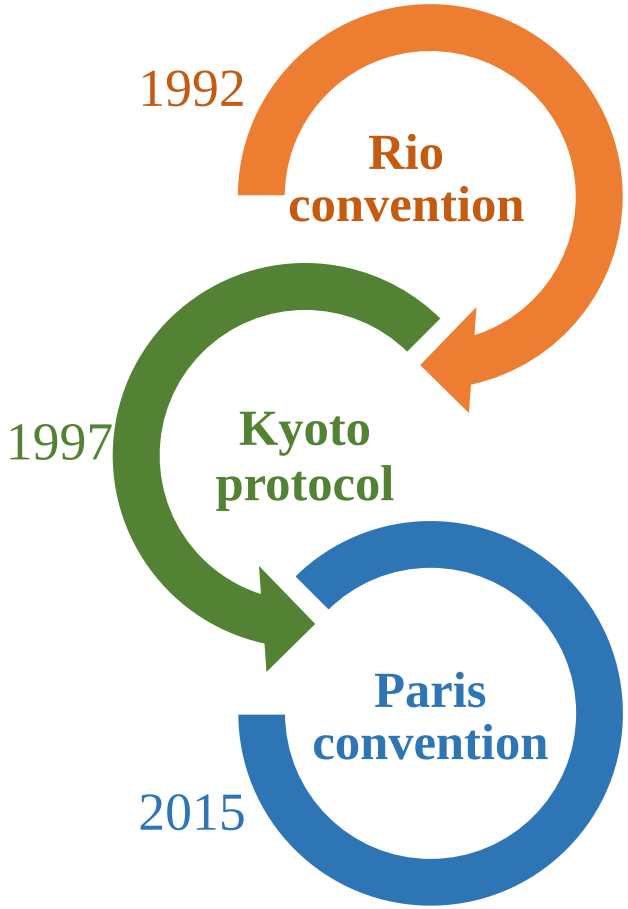
https://www.youtube.com/watch?v=jHXw_eZLhII

Motivation


Energy
Agriculture
Water Resources
Biodiversity
Forest
Climate Change – Land Surface Temperature alterations
Health
Infrastructure
Air Quality

Motivation

- UNFCCC (United Nation Framework Convention for Climate Change), since 1992, tries to tackle these issues by organizing various International conventions



Signed by 154 nations to reduce emissions within 10 years to avoid global warming

Legally bounded developed nations to reduce the emissions by 5.4% by 2010

Signed by 195 nations and the main aim was to restrict the global temperature rise to 1.5-2ºC

(United Nation Climate Change, 2018; Marshall, 2009)

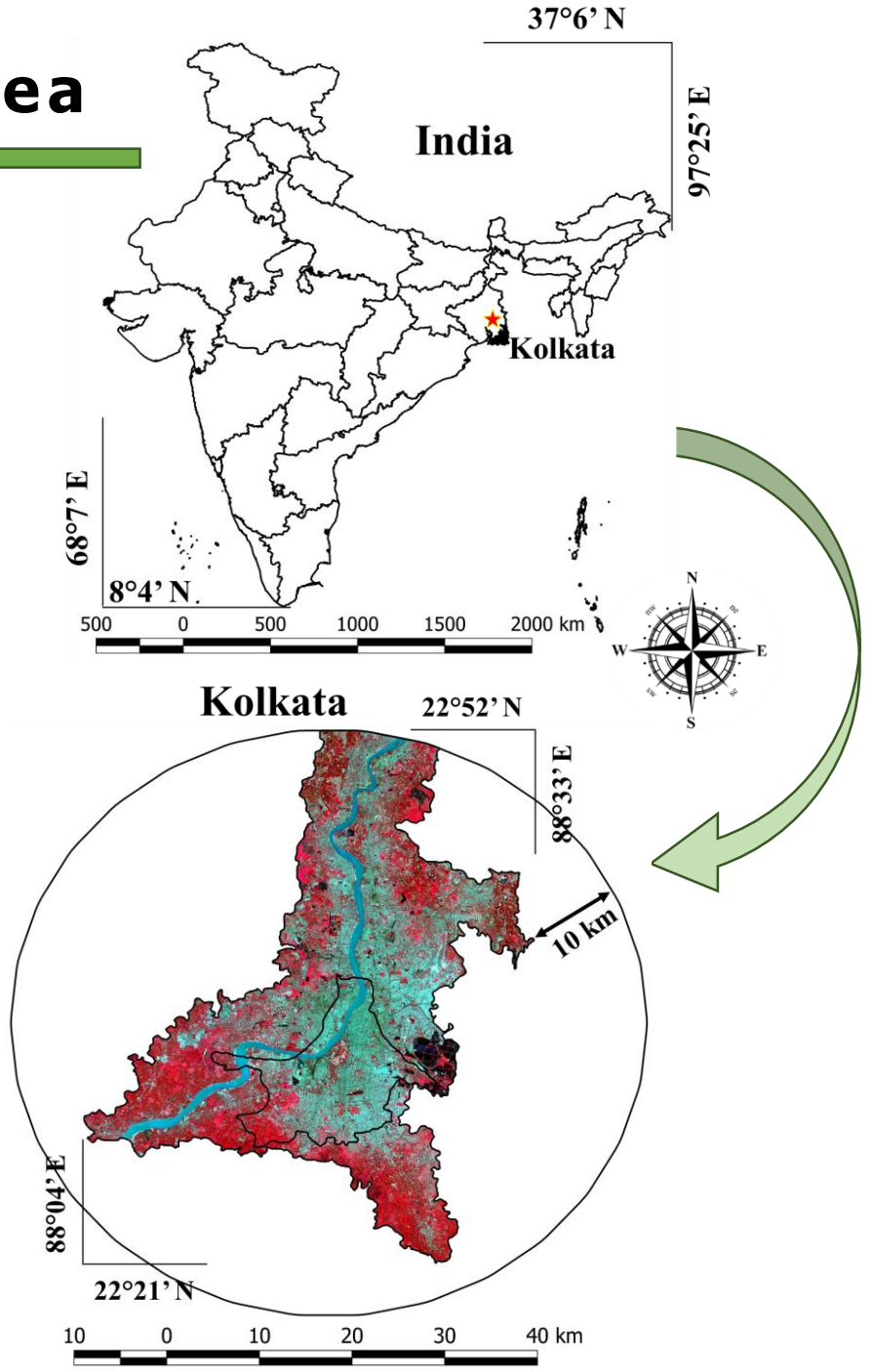
The main objective of this study is to showcase the performance of FOSS in analysis of and forecasting LST over urban areas. Following sub objective needs to be performed for achieving this.

1	Analysis of Land Use/ Land Cover (LULC) using Gaussian maximum likelihood algorithm
2	Quantification of Land Surface Temperature (LST) using Radiative Transfer Equation algorithm
3	Understanding the relationship between changes in LST with alterations in LULC
4	Developing a relationship to forecast Land Surface Temperature using regression analysis

STUDY AREA: Kolkata Metropolitan Area

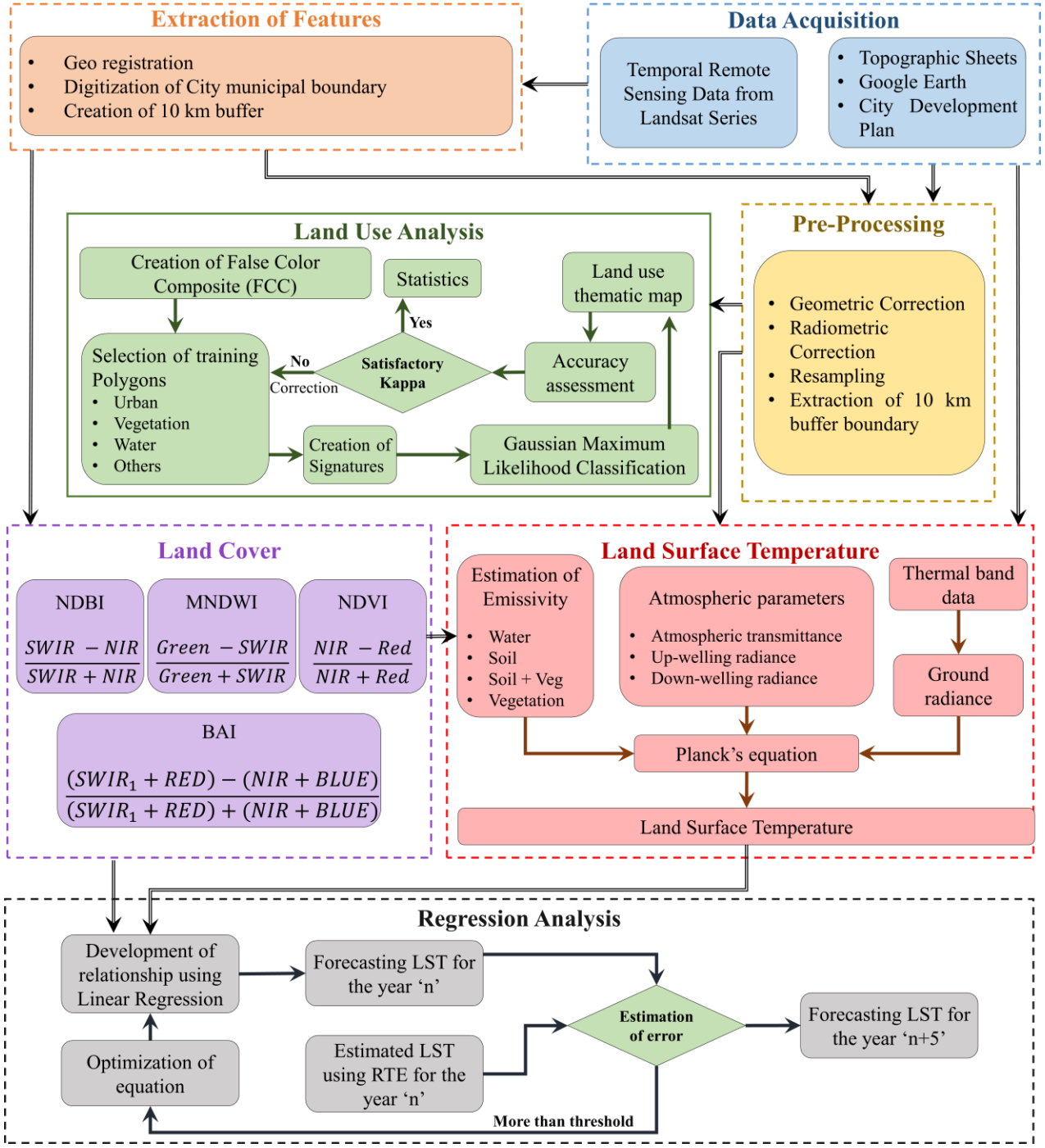
- Also known as Greater Kolkata and is one of the oldest metropolitan cities in India
- Incorporates 5 municipalities – North 24 parganas, South 24 parganas, Nadia, Howrah, Hooghly
- Serves as home to 14.11 million (Census, 2011)
- Third most populous city in India and eighth largest urban agglomeration globally

Area	**1886.67 km^2 (Population density: 7480/km^2)**
Temperature	Winters minimum (Dec – Jan): 9ºC – 11ºC Summer maximum (May – June): > 40ºC Annual mean: 24.8ºC
Annual Rainfall	1582 mm/year (Monsoon: June – Sep)
Elevation	1.5m – 9m



Data & Method

1. SOI Toposheets
2. CDP
3. GPS
4. Google Earth and GPS
5. OSM
6. Landsat series
7. ASTER



Free and Open Source Software/Data Used

Software

Data

Google Earth

- Virtual earth system formed by satellite imagery, maps, terrain, 3D buildings, etc
- Used for
  - Creation of GCPs
  - Geo-referencing the satellite data
  - Validation of Landuse maps

Bhuvan

- Web mapping service application developed with the help of open layers and embedded map data
- Used for
  - Creation of GCPs
  - Geo-referencing the satellite data

GRASS GIS and Quantum GIS

- GRASS GIS: Mainly used for image processing, raster and vector data management, visualization, spatial modelling etc.
- QGIS: Helps in visual interpretation, manage, edit, analyze data, and compose geospatial maps
- Used for
  - Creation of Landuse/Landcover maps and LST estimation
  - Extraction of output maps

RStudio

- RStudio is an integrated development environment for R, a programming language for statistical computing and graphics
- Used for
  - Statistical analysis
  - Graphical representations

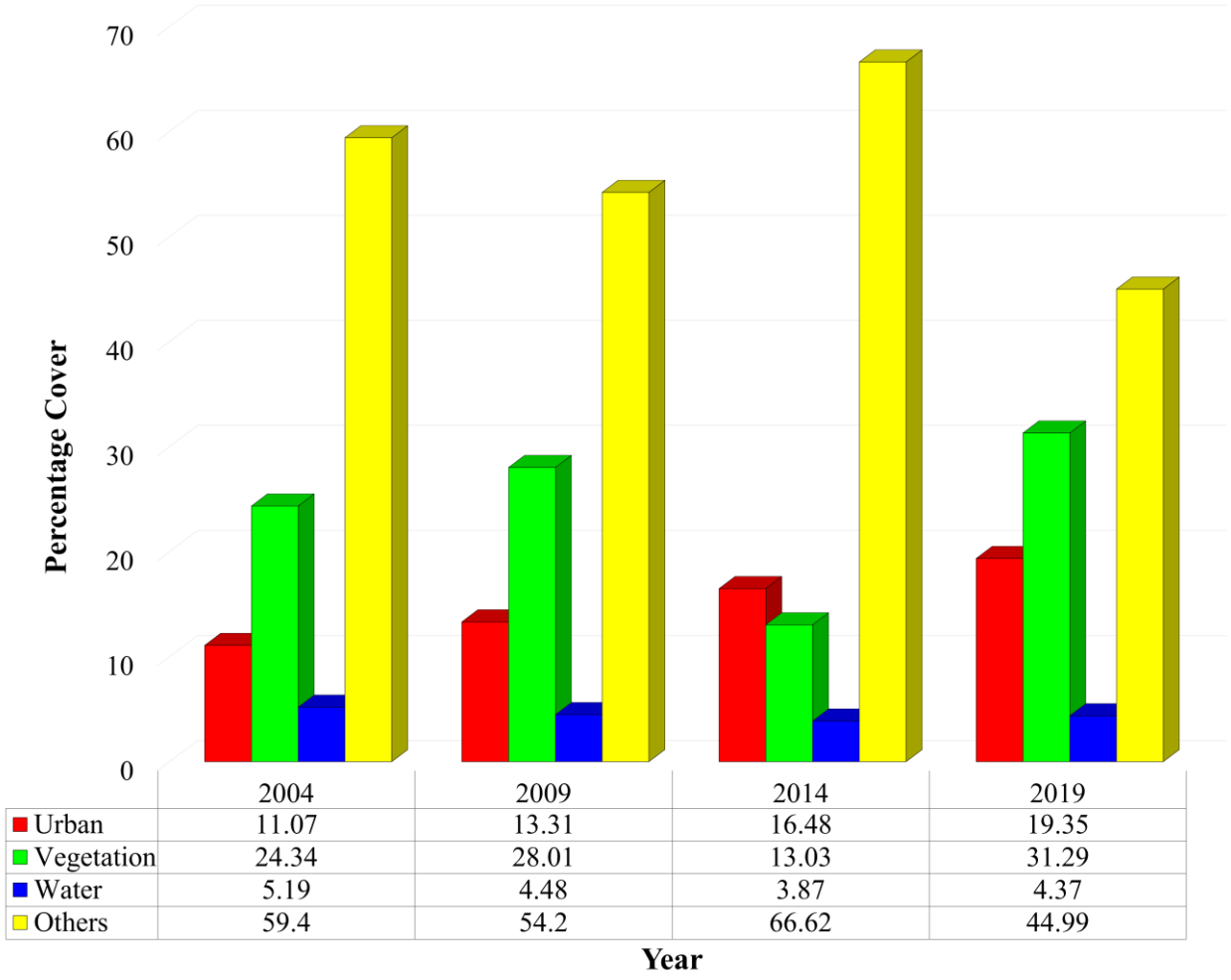
Survey of India Toposheets

- Provides topographic and open series maps that contains natural and anthropogenic geographic features since 1767
- Used for
  - Geo-referencing the satellite data

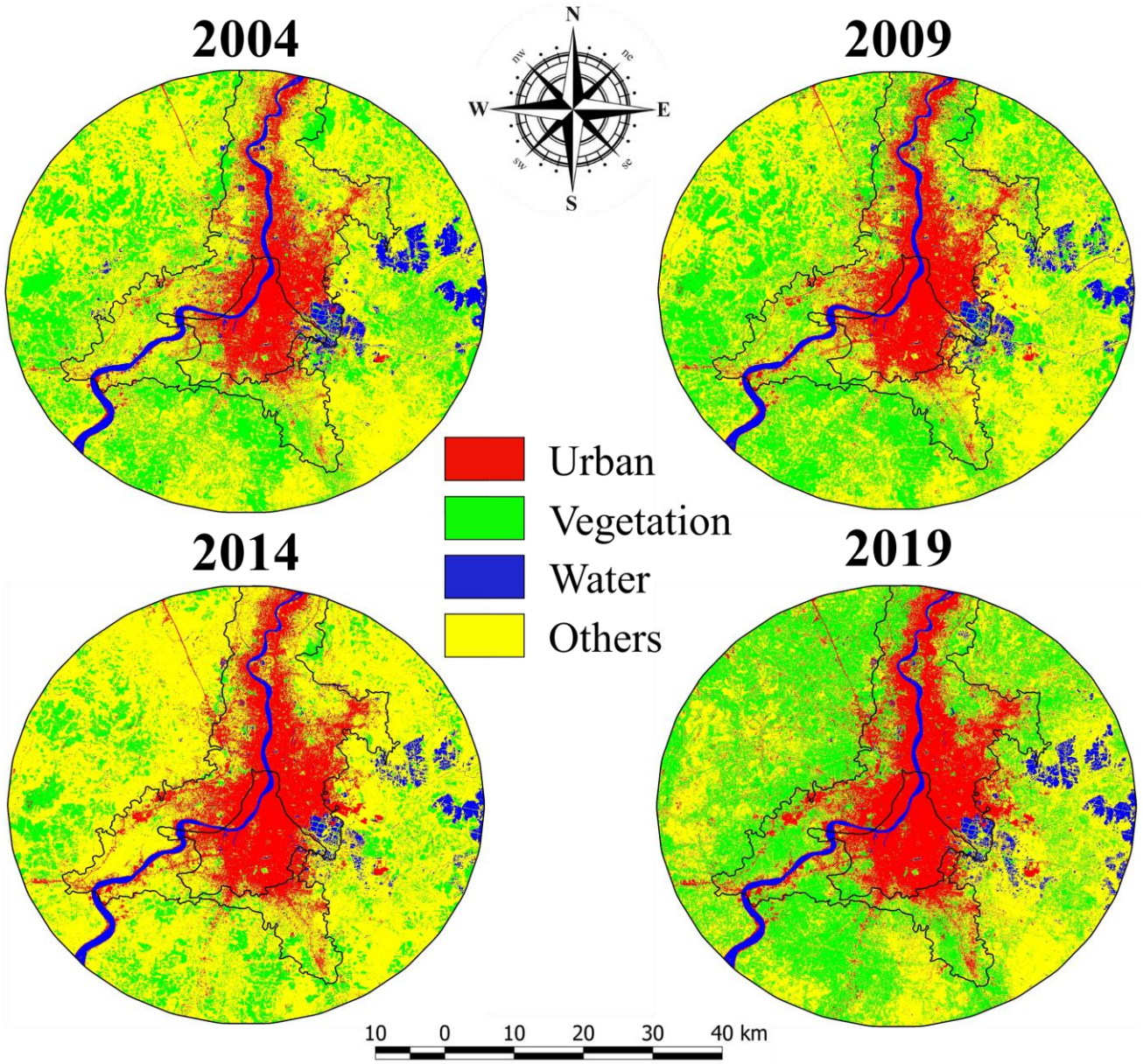
Satellite Data

- It is longest running program for acquisition of satellite imagery of earth.
- Provides data with good resolution (spatial, spectral and temporal) at no cost.
- Used for
  - Obtaining raw satellite data for 2004, 2009, 2014 and 2019 over the study area

Results: Land use analysis

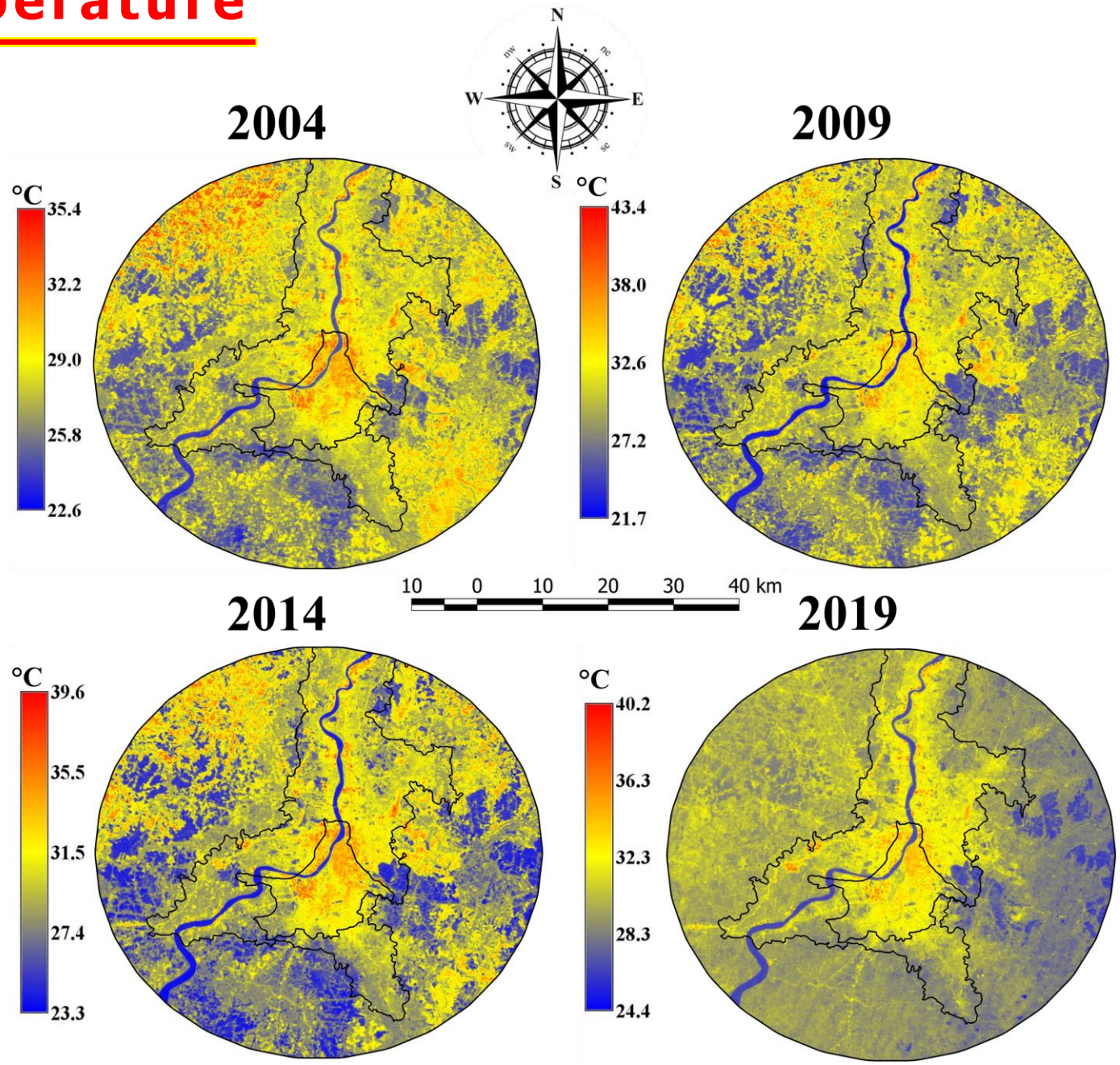


	2004	2009	2014	2019
Urban	11.07	13.31	16.48	19.35
Vegetation	24.34	28.01	13.03	31.29
Water	5.19	4.48	3.87	4.37
Others	59.4	54.2	66.62	44.99

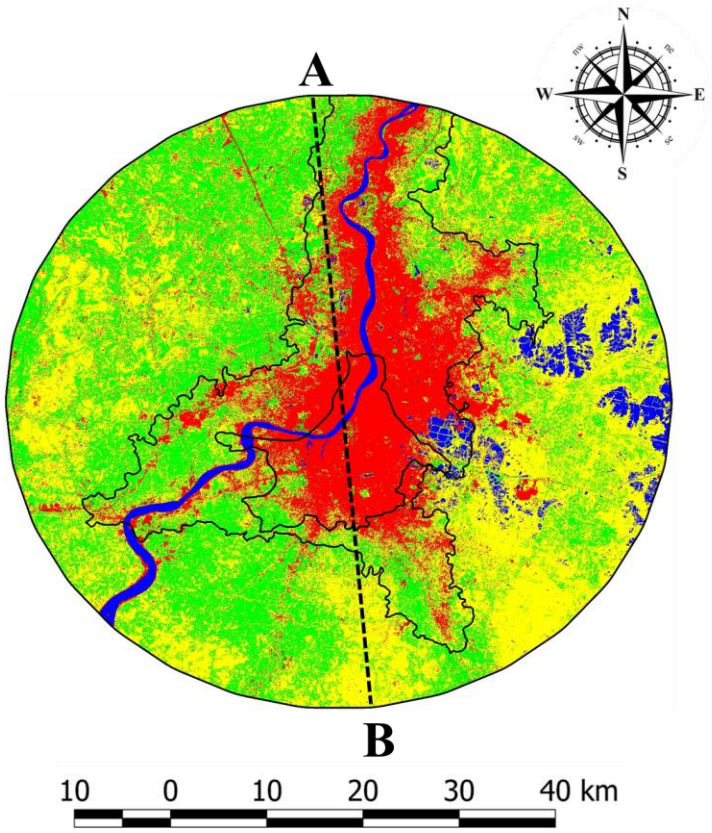


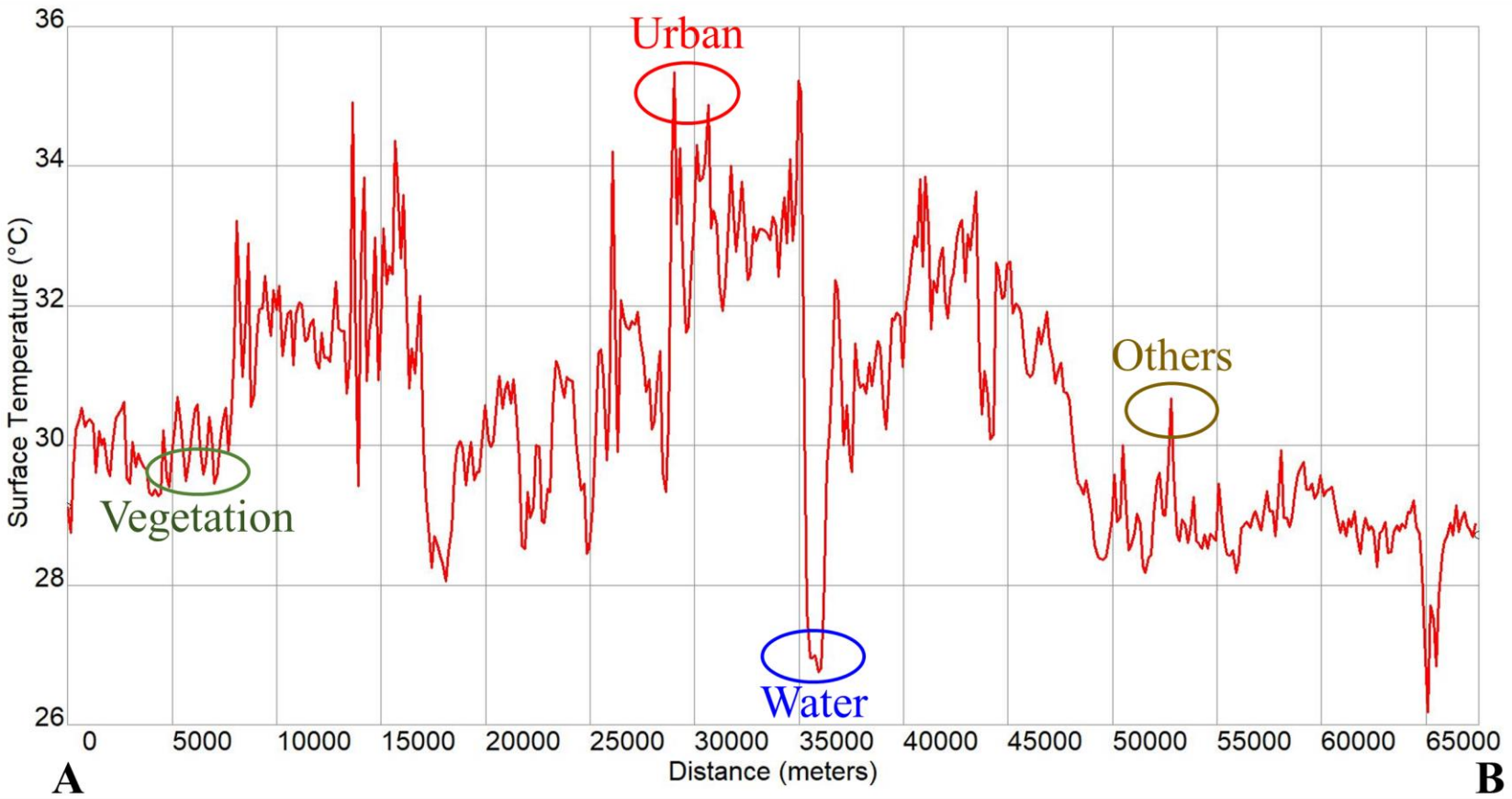
Results: Land surface temperature

Year	Land use class	Min. Temp. (˚C)	Max. Temp. (˚C)	Mean Temp. (˚C)	Standard Deviation	Coefficient of variation (%)
2004	Urban	23.89	35.38	29.23	1.39	4.74
	Veg.	23.03	32.60	26.35	1.07	4.06
	Water	23.03	34.99	25.50	1.37	5.36
	Others	22.60	34.59	28.22	1.48	5.23
2009	Urban	22.17	43.41	31.91	2.27	7.12
	Veg.	23.03	37.72	27.37	1.79	6.54
	Water	21.73	40.40	25.67	2.25	8.77
	Others	23.03	40.78	30.56	2.17	7.10
2014	Urban	23.54	39.61	31.17	1.93	6.20
	Veg.	23.46	34.70	26.19	1.40	5.36
	Water	23.29	36.29	25.32	1.35	5.34
	Others	23.50	37.78	29.25	2.02	6.90
2019	Urban	25.79	40.24	31.53	1.46	4.63
	Veg.	26.42	35.99	29.43	0.73	2.50
	Water	25.87	34.43	27.20	0.80	2.95
	Others	24.35	36.18	29.44	0.98	3.32



Results: Temperature profile graph





Presence of urban and others category → higher temperature

Presence of water bodies and vegetation → lower temperature

Results: Regression Analysis

Equations obtained from test data

LST(2004) = 29.43 + 1.32*NDBI(2004) - 9.10*NDVI(2004) - 14.73*MNDWI(2004) + 10.48*BSI(2004)
LST(2009) = 31.92 + 3.69*NDBI(2009) - 11.21*NDVI(2009) -16.96*MNDWI(2009) + 15.38*BSI(2009)
LST(2014) = 31.90 + 21.13*NDBI(2014) - 14.81*NDVI(2014) - 32.25*MNDWI(2014) + 30.82*BSI(2014)
LST(2019) = 32.07 + 9.39*NDBI(2019) - 7.19*NDVI(2019) - 24.46*MNDWI(2019) + 20.75*BSI(2019)

Model estimated vs calculated

LST	Error parameters	
	MAE	MPE
2004	0.86	3.10%
2009	1.23	4.14%
2014	1.02	3.50%
2019	0.78	2.61%

Predicted using regression equation

LST	Using equation of	Error parameters	
		MAE	MPE
2009	2004	2.16	6.99%
2014	2009	1.74	6.23%
2019	2014	1.92	6.43%

The equation obtained for 2019 can be used to predict LST for 2024

MAE: Mean Absolute Error
MPE: Mean Percentage Error

Conclusion

- There exist a **relationship** between **LULC** changes and climate change in terms of **LST**
- LULC dynamics demonstrated rapid change in **core** as well as **buffer** area
- Urban area has increased by **74.75%** during the study period
- City experienced growth in **center, south-west, north-east and east** direction
- Major concentration → **Banamalipur, Newtown, Rajarhat, Andul and Howrah**
- Quantification of LST illustrated a rise in mean LST by **2°C**
- **Urban** area and **others** category shows **high** surface temperature while **vegetation** shows **moderate** and **water body** shows **minimum**
- **Water body** and **vegetation** helps in regulating the **microclimate**
- **Regression analysis** was tested and validated to **forecast Land Surface Temperature**
- It was observed that **linear regression** is providing **promising** relationship for forecasting LST
- Whole analysis was performed using **free and open source software**
- Formulation of strict policies → **Sustainable development**

Acknowledgement

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सत्यमेव जयते
Goverment Of India

GOVT. OF WEST BENGAL

INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR
भारतीय प्रौद्योगिकी संस्थान खड़गपुर
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सत्यमेव जयते
Department of Science and Technology (DST)
DST

USGS

इसरो isro

And time is running out to deal with climate change

Thank you!!!