Recent Urbanization and its change to climatic conditions of Kanpur Metropolis in Ganga-Yamuna Doab region of India

Himanshu Gandhi[1], Dr. Gautam Hal[2], Dr. Vikram Gaurav Singh[3]

Research Scholar, Assistant Professor, Coordinator
Department of Geography
C.S.J.M. University, Kanpur, India

Abstract: As due to migration, now-a-days the population of cities is increasing due to which urbanization is taking place which in turn changing the Land forms of this region drastically and which effects Land Surface Temperature (LST) and also heat of this region which effects lives of different species. The current study of recent decades examines the impact of urbanization on Land Use Land Cover which is changing and this changes the Land Surface Temperature and heat Intensity of Kanpur Metropolis which is located on the bank of the river Ganga which occupies the area of Kanpur Nagar District with the Yamuna River serving as the region's southern boundary due to it's urban sprawl. As the urbanization and climate change directly depends on Land Use Land Cover change and UHI intensity respectively so for which these factors are carried out by using Landsat 5, 7 & 8 data for the years 1991, 2001, 2011 & 2021 having projection WGS_1984_UTM_Zone_44N with 30m spatial and thermal resolution. The study shows that urbanization intense the built-up areas and lowers down the vegetation and agriculture area however it supports shrub land areas and mixed water bodies settlements. The study also includes factors of human comfort (Discomfort Index) and ecological evolution (Urban Thermal Field Variation Index) for better understanding of impact of urbanization and climate change on human and other species. The all kind of work is carried out through Geospatial technologies (using ArcGIS and ERDAS Imagine). The work also gives some ideas about strategies for sustainable development in the Ganga-Yamuna doab region of India.

Keywords: Landsat, LULC change, UHI Intensity, Discomfort Index, Urban Thermal Field Variation Index, sustainable development

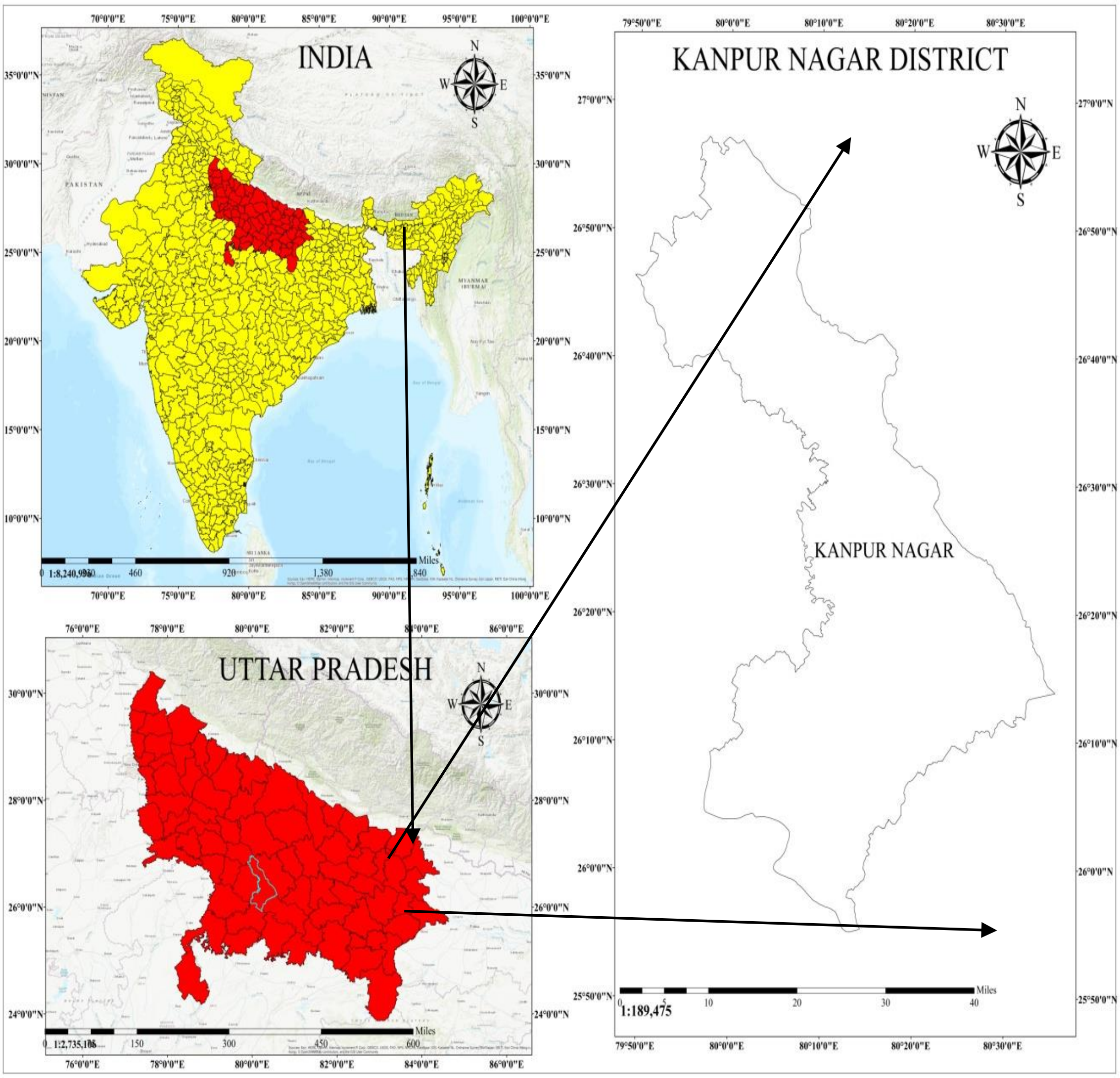
Introduction: Urbanization is an index of transformation from traditional rural economies to modern industrial one (Pranati Datta, 2006) which is mainly driven by population growth and large scale migration (Sudhira et al., 2004). The more than half of the world's population (55%) currently residing in urban areas and this number is expected to rise upto 68% by the year 2050 in today's more connected and globally oriented world (UN, 2019). In urban areas Land Use Land Cover (LULC) is changing by the rising demands for food, energy, water, fiber, and shelter due to the expanding human population. Urbanization drastically changing the natural landscape around the world by converting naturally permeable land surfaces into impervious ones (urban landscape) (Scott J. McGrane, 2016; Paul et al. 2021). A change in the natural terrestrial cover affects the earth's surface's radiative and non-radiative properties, carbon dynamics, and biogeochemical processes, which in turn alters the local environment (Duveiller et al., 2018). A number of climatic conditions problems are brought by the conversion of natural terrestrial cover into built-up land-use (urban landscape) (Jed Collins 2019; M. Hanif et al., 2019) at various temporal and spatial scales (Pawan Thapa, 2021). An increase in land surface temperature (LST), and urban heat islands (UHI) intensity is one of the climatic conditions based on Land Use Land Cover (LULC) change (Amit Kumar et al., 2021; B.P. Kumar et. al., 2023) at the level of micro-thermal and micro-climatic zones (K.A.S. Mislan & B. Helmuth, 2008; K.K. Singh et al., 2018). So, it becomes necessary to understand land cover changes for sustainable development and better quality of life in cities (Yong Xu et al., 2017). The land cover change can be easily detected based on Coarse to sub-pixel classification (Zhang et al., 2006;Weng et. al., 2008; Feng Ling et al., 2011; J.L. Silvan-Cardenas & Le Wang 2014; A. MacLachlan et al., 2017; Y. Xu et al., 2017; Qiong Hu et al., 2021) for its observation, monitoring and characterization (Zhe Zhu et al., 2022). The various classification based on Coarse to sub-pixel classification gives an idea about different sensible and latent heat fluxes (Hui Li et al., 2017; Dan Li et al., 2020) and these land indices also provides rapid surface heat island detection due to their characteristics (Nagihan Aslan and Dilek-Koc-San, 2021) and with such land cover changes LST interacts with to characterize the thermal behavior of the land surfaces (G. Duveiller et al., 2018; Z.L. Li et al., 2018; Glynn C. Hulley et al., 2019) to Urban Heat Island (UHI) Intensity (Chaobin Yang et al., 2017; Suvamoy P. et al., 2020).

As the term "urban heat island" (UHI) intensity describes the phenomenon of sensible heat storage (ΔQ_S) due to which cities experience warmer climatic conditions than the nearby rural and this relates to the arrangement and pattern of land-use types, as well as landscape features (Qingjian Zhao et al., 2019; Alademomi Alfred S. et al., 2020). The composition of LULC in urban areas affects the thermal conductivities of urban surfaces (Mustafa Hamoodi et al., 2017; Ayansina Ayanlade et al., 2021) affects human comfort (S. Patel et al., 2023). The amount of vegetation present within a city (Lei Zhang et al., 2022), anthropogenic discharge from human activities and built-up density affects ecological system and reflects ecological environment (Dingrao Feng et al., 2020; Tiantian Li et al., 2022). The urban canopy, which is the layer between the ground and building rooftops, and which is strongly influenced by surface, morphological, and anthropic parameters (Florent Renard et al., 2019; Junyan Yang, 2020) which in turn gives three distinct UHI types and on the basis of sensible heat flux (Δf_S) quantity that are typically distinguished as: 1. canopy UHII, 2. boundary-layer UHII, and 3. surface UHII which reflects climatic conditions at microscale level (Bakul B. et al., 2018; L.R. Rodriguez et al., 2020). The study of urban climatic conditions is based on the measurement of land-surface temperatures (LST), which directly affect air temperature (M. Naserikia et al., 2023) by energy exchange and forms the Urban Heat Island effect (Nidhi Singh et al., 2020; C.R. Almeida et al., 2021; Manju Mohan et al., 2022). Currently, researchers from all over the world uses satellite thermal images, particularly high resolution images, to study thermal anomalies like UHI intensity in urban areas (A.C. Teodoro and A. Goncalves 2021; M. Zargari et al., 2024). These images have the advantage of offering a repeatable dense grid of temperature data over an entire city and even distinct temperatures for particular areas (Yunfei Li et al., 2020; Eric Krause, 2022; W. Morrison et al, 2023).

Objectives:

- To analyze the land use land cover on decadal basis for past 30 years.
- To analyze the pattern of LULC change
- To analyze the effect on climatic condition (UHI Intensity) caused by Urbanization
- To analyze the consequences caused by this climatic condition

Study Area:



Location of Kanpur Nagar District in India

The study area includes the Kanpur Metropolis region and it's surroundings as due to its urban sprawl. The study area covers the region between latitudes 25°55'N to 27°N and longitude 79°30'E to 80°35'E. The region experiences fast urbanization due to its location and geography as the most of the region is plain and fertile as it is made up of Ganga-Yamuna doab as the river Ganga and river Yamuna forms the study area's north-east and south-west boundaries, respectively.

Data:

From the US Geological Survey's website, https://earthexplorer.usgs.gov/, path 144 and rows 041 and 042 of Landsat5, Landsat7, and Landsat8 data are downloaded. The data are then mosaiced, and ArcMap 10.8 software is used to extract data for the region.

Specifics of the used satellite images

Satellite	Sensor	Acquisition date	Path and row	Spatial resolution	Thermal resolution	Cloud Cover
Landsat 5	TM	16 March 1991	144/041 & 144/042	30 m	120(30)m	<10%
Landsat 7	ETM+	03 March 2001	144/041 & 144/042	30 m	60(30)m	<10%
Landsat 5	TM	07 March 2011	144/041 & 144/042	30 m	120(30)m	<10%

Landsat 8	OLI/TIRS	02 March 2021	144/041 & 144/042	30 m	100m	<10%

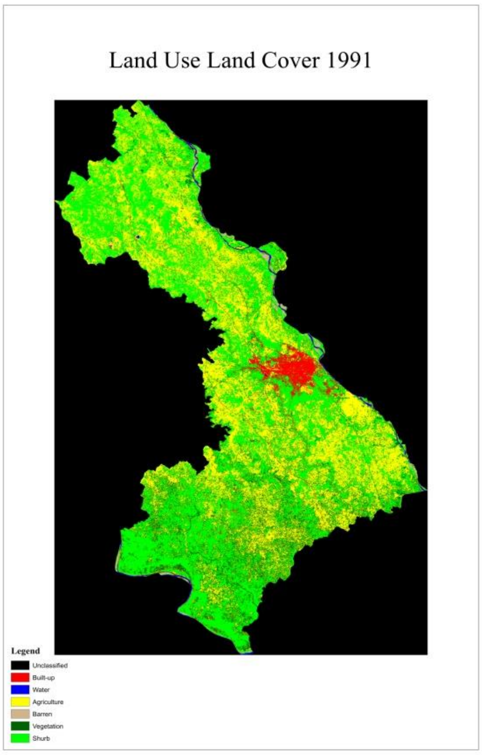
Table-1 Used Data

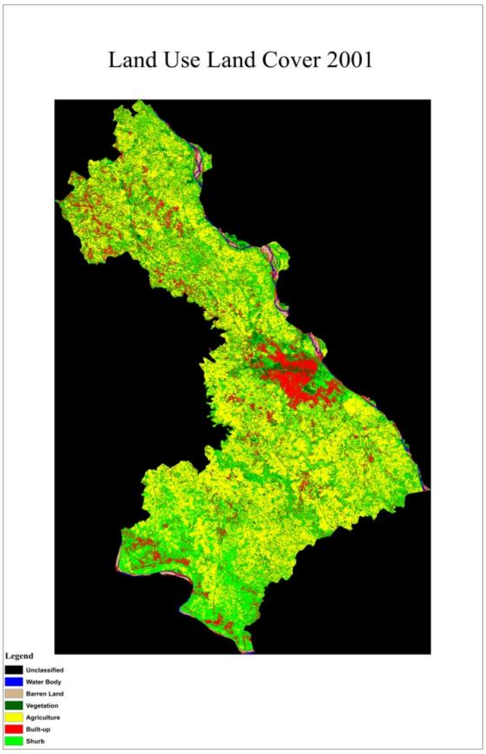
Methodology:

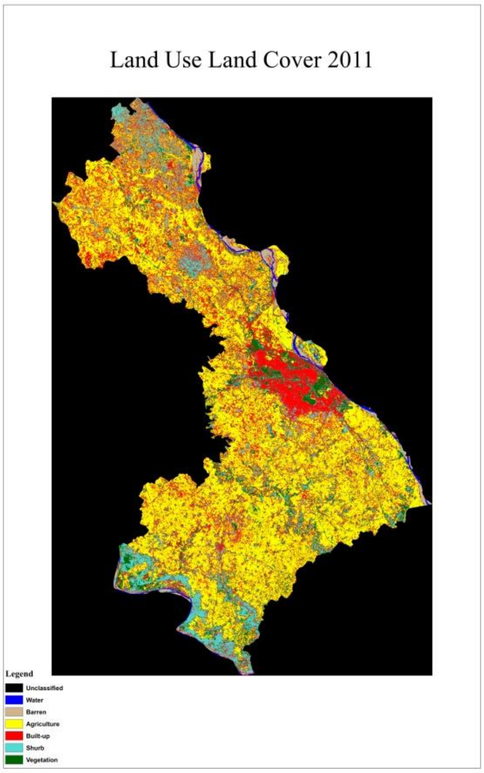
The Land Use Land Cover classification is carried out by stacking the spectral bands of different satellite for particular region keeping in view that each classes should be mutually exclusive, exhaustive and hierarchical (Jensen, 2005; C. Kim, 2016) and neighborhood analysis (J. Im. et al. 2008) with spatial resolution of 30m and each pixel carries the area of $30^{x}30=900m^2$. The Land Surface Temperature (LST) and the climatic conditions formed by it (R. Azmi et al., 2021; M. Naserikia et al., 2023) are carried out using thermal bands of specific resolution with existing resolution (Y. Back et al., 2021; H.M. Imran et al., 2022) and neighborhood analysis (N. He and Guanghao Li, 2021). The human discomfort and ecological evolution are also carried out using thermal bands of specific resolution with existing resolution (Y. Yan et al., 2021) and neighborhood analysis (Z. Yang et al., 2019; C.R. Almeida et al., 2021).

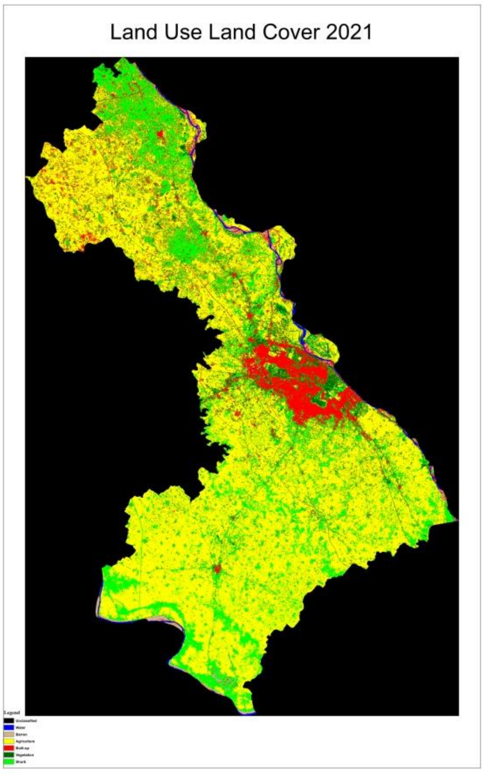
Result:

The procedure descript in the methodology for Land Cover classification is applied and the final result found as follow:









The Land Use Land Cover maps which shown above has the Kappa Coefficient 0.68, 0.73, 0.69, 0.78 for the years 1991, 2001, 2011 and 2021 respectively.

1. The procedure descript in the methodology for Land Surface Temperature (LST) is applied and the final result found as follow:

The procedure described in Methodology section for Retrieving Land Surface Temperature (LST) have been used, and the following results for 1991, 2001, 2011 and 2011 have been discovered using the projection WGS_1984_UTM_Zone_44N

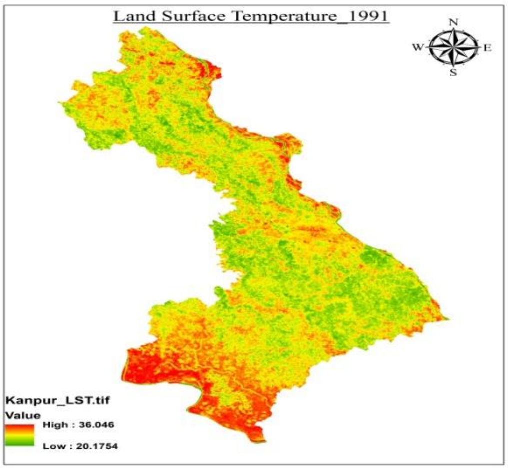


Figure 2.1

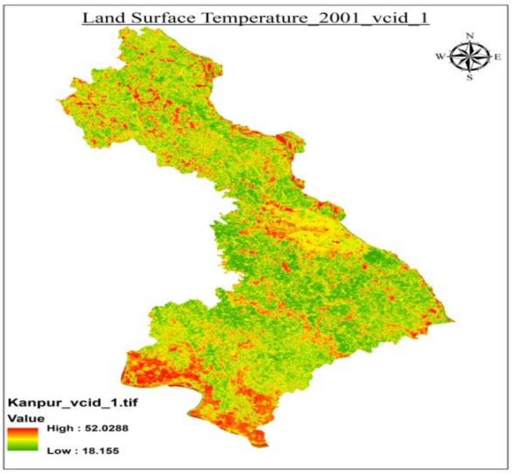


Figure 2.2

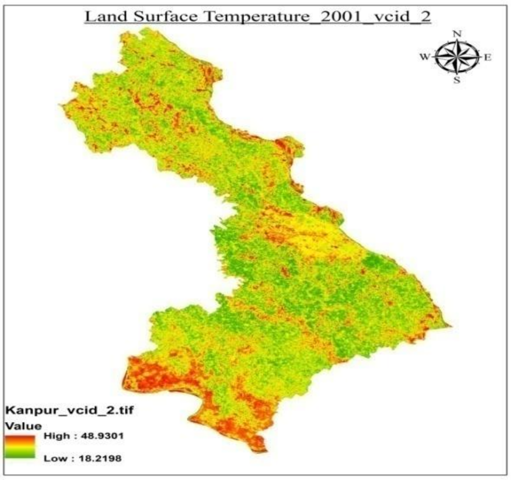


Figure 2.3

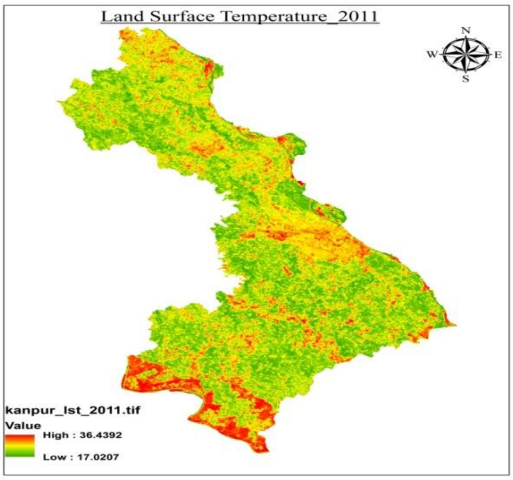


Figure 2.4

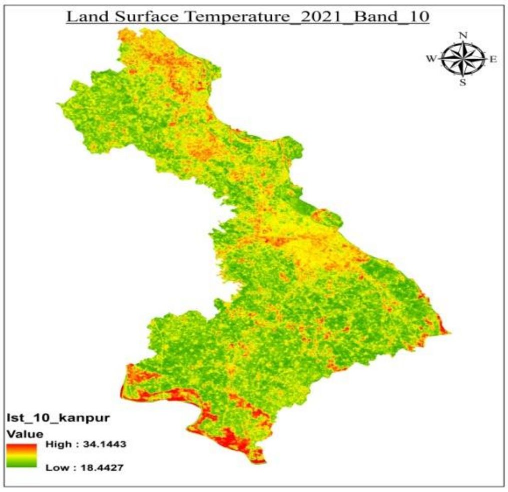


Figure 2.5

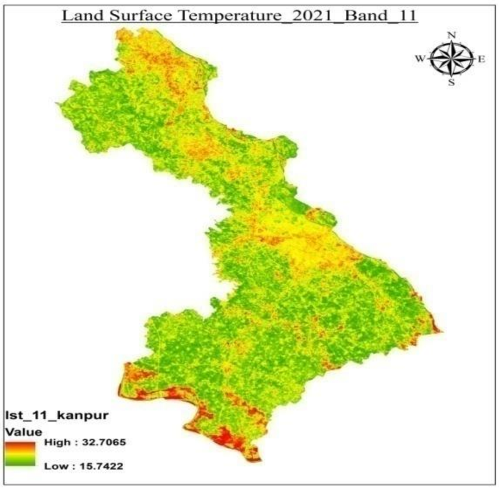


Figure 2.6

2. The procedure descript in the methodology for Climatic Condition (UHI Intensity) is applied and the final result found as follow:

The procedures described in Methodology section for Retrieving UHI Intensity have been used, and the following results for years 1991, 2001, 2011 and 2021 have been discovered using the projection WGS_1984_UTM_Zone_44N

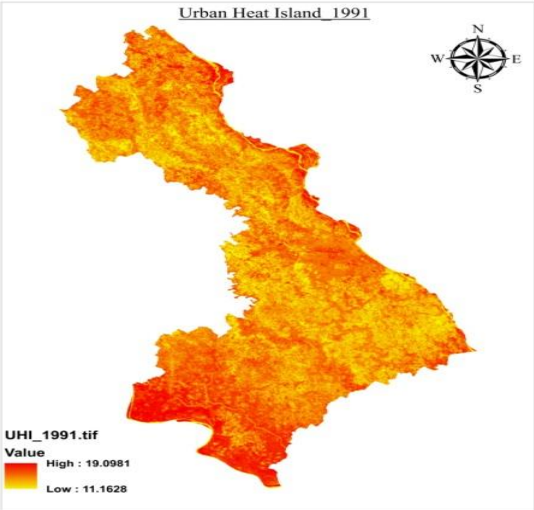


Figure 3.1

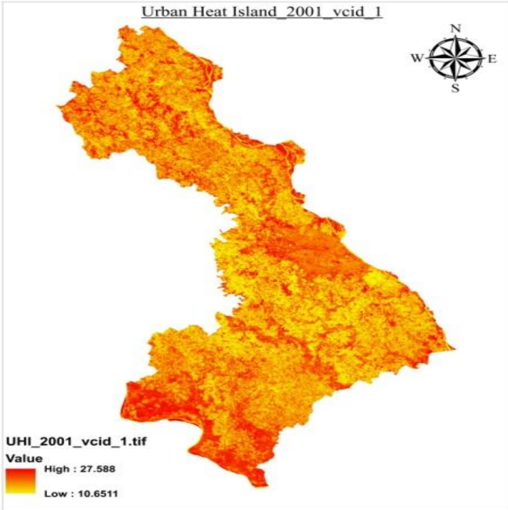


Figure 3.2

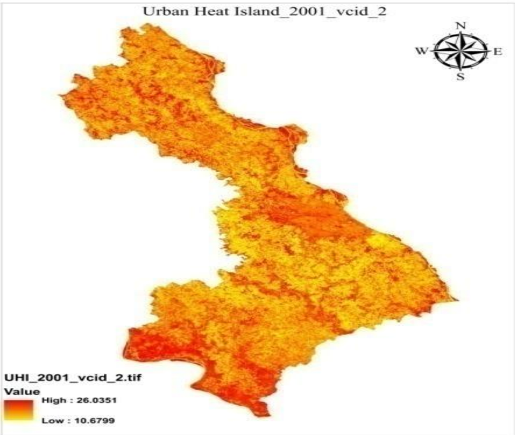


Figure 3.3

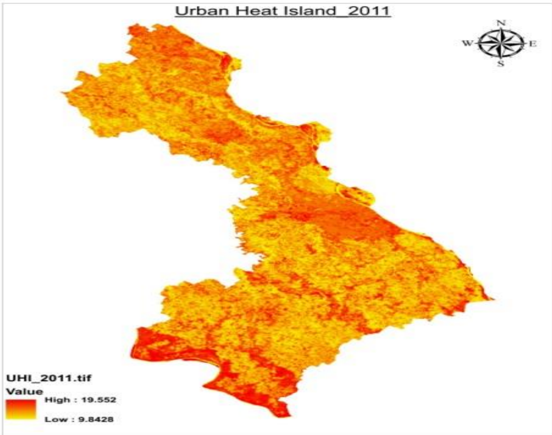


Figure 3.4

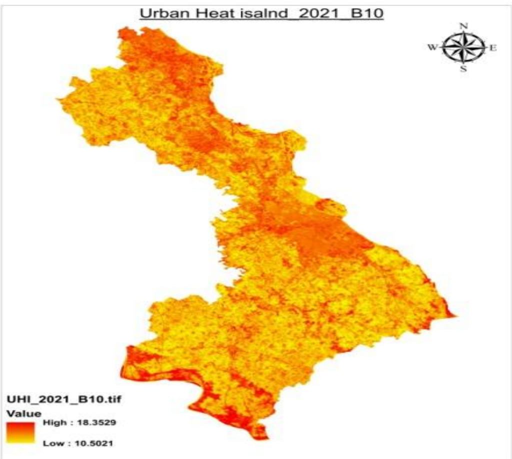


Figure 3.5

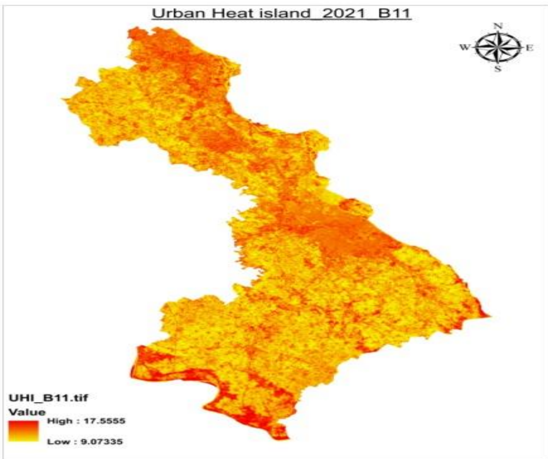


Figure 3.6

3. The procedure descript in the methodology for Human Discomfort and Ecological Evolution is applied and the final result found as follow:

The Discomfort index is retrieved for the following years: 1991, 2001, 2011, and 2021.and displayed as maps having projection WGS_1984_UTM_Zone_44N

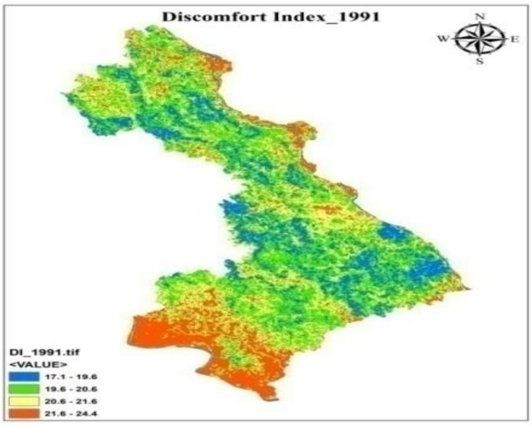


Figure 4.1(a)

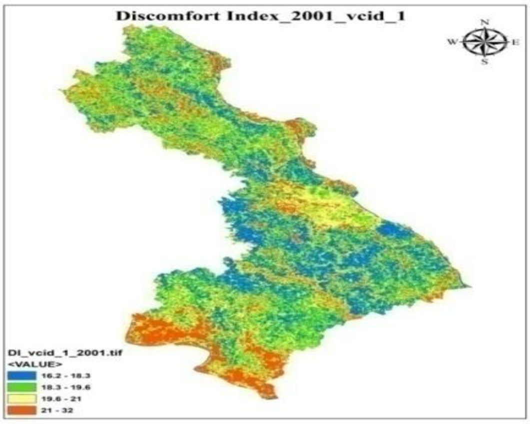


Figure 4.1(b)

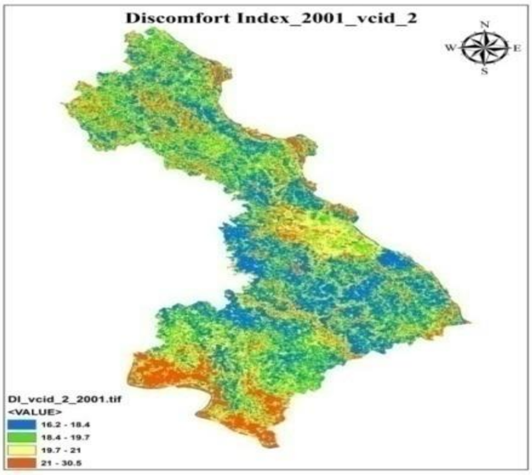


Figure 4.1(c)

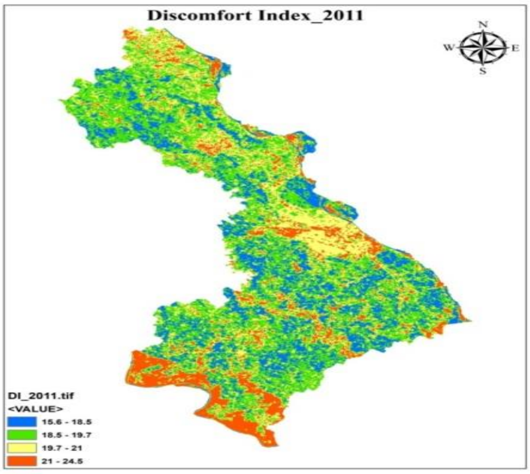


Figure 4.1(d)

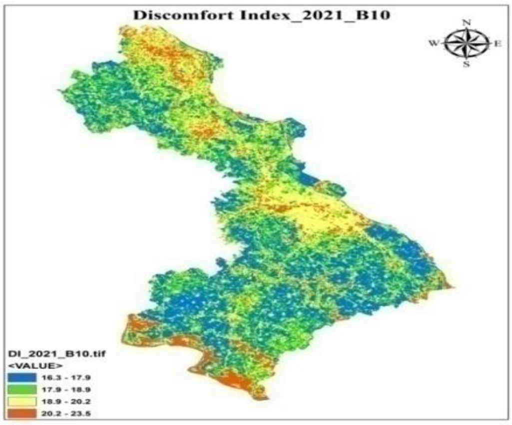


Figure 4.1(e)

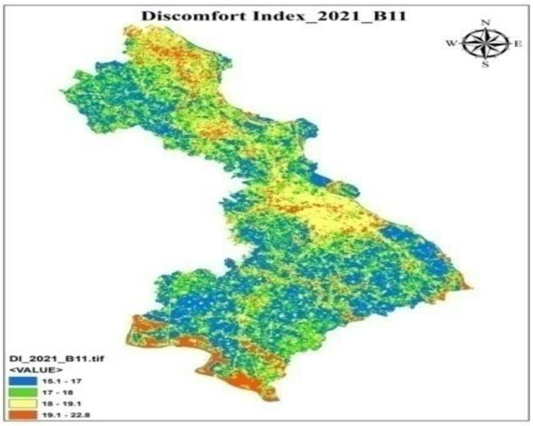


Figure 4.1(f)

The study area region's UTFVI for 1991, 2001, 2011, and 2021 are retrieved, and they can be provided with projection WGS_1984_UTM_Zone_44N

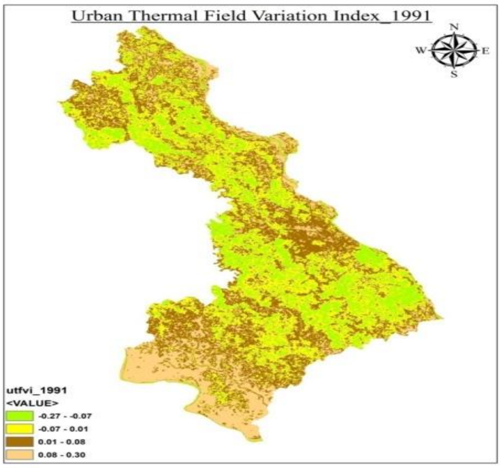


Figure 4.2(a)

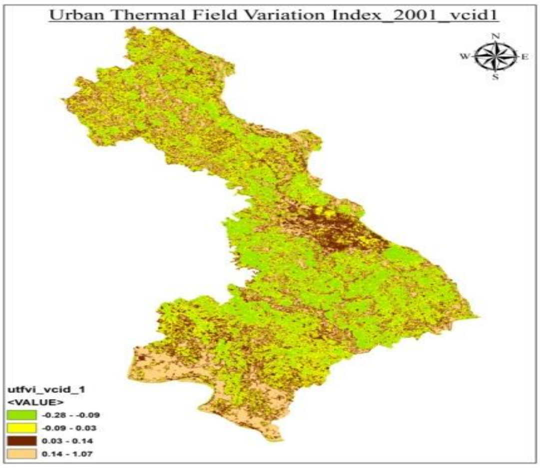


Figure 4.2(b)

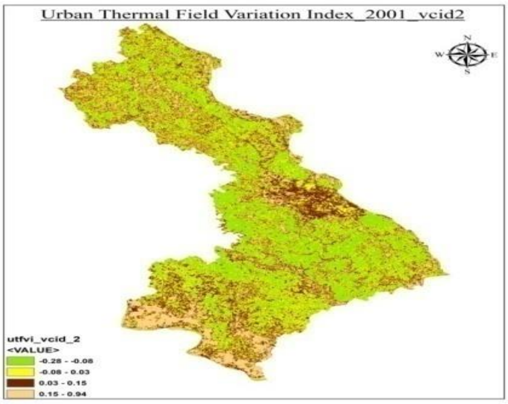


Figure 4.2(c)

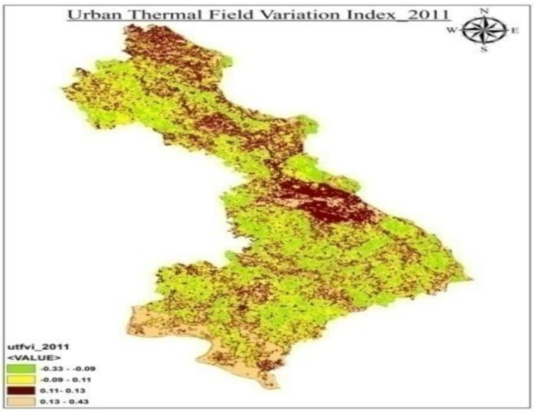


Figure 4.2(d)

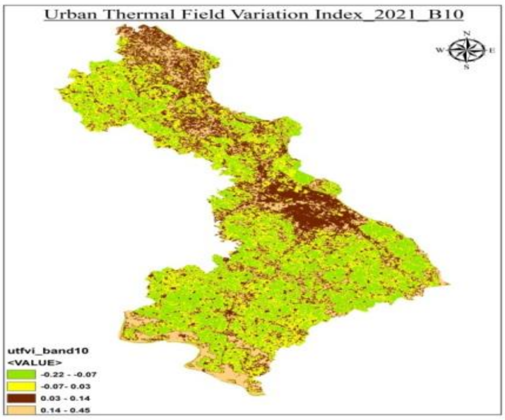


Figure 4.2(e)

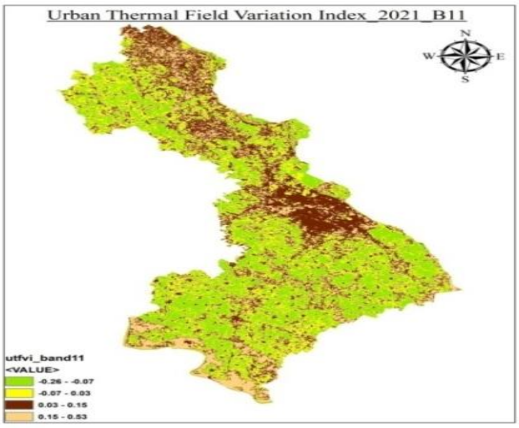


Figure 4.2(f)

Findings: The Land Surface Temperature which is the initial property of urban climate phenomenon depends directly upon Land Use Land Cover (LULC) change of the region (S. Pal et al. 2017; A. Kafy et al. 2021) and vice-versa (P.P. Gogoi et al., 2019) due to different sensible and latent heat fluxes (Hui Li et al., 2017; Dan Li et al., 2020; Z. Qian et al., 2023) and vice-versa (S. Tariq et al., 2023) which influences urban climatic condition (UHI intensity) proportionally. As the built-up area and barren land increases the Land Surface Temperature (LST) also finds to increase which influences urban climatic condition (UHI intensity) proportionally because there is large sensible heat fluxes in comparison to latent heat fluxes which prevents cooling (N. Rashid et al., 2022; M. Rendana et al., 2023). While in Agricultural, Vegetation and Water Bodies area the Land Surface Temperature (LST) decreases due to evaporation and evapo-transpiration processes which decrease urban climatic condition (UHI intensity) proportionally due to availability of latent heat fluxes which provides cooling (N. Rashid et al., 2022; M. Rendana et al., 2023). The better results finds in mixed use of land or shrub land regions because over this type of land the Urban Heat Island intensity decreases drastically caused by mixed effect of permeable and impermeable surfaces effecting sensible and latent heat fluxes of the region (P. Rao et al., 2023; H. Gandhi et al., 2023).

As climatic conditions of region directly influenced by Land Surface Temperature, the influenced climatic conditions influences human health (H.M. Moda et al., 2019; Nidhi Singh et al., 2020) and ecological evolutions (Liu, L., Zhang Y., 2011; Renard Florent et al., 2019) which can be measured by the Discomfort Index (DI) and (José Antonio Sobrino and Itziar Irakulis, 2020) Urban Thermal Field Variance Index (UTFVI) (Tomlinson et al. 2011; Kafy et al., 2021; Md. Nazmul Huda Naim et al., 2021) using recent development and methodology of remote sensed thermal data (Hui Shi et al., 2021) tells that as Urban Heat Island (UHI) Intensity increases there is found drastic increase in Human Discomfort and Ecological Evolution. However, there is slightly opposite trends finds in between Human Discomfort and Ecological Evolution (N.E. Clark et al., 2014; H. Gandhi et al., 2023).

However, the endeavors taken by Government of Uttar Pradesh for trees planting schemes and built up of Green and Blue Space in this region reflects advantages as it lowered down the Land Surface Temperature (LST) in this region as additional forest and tree cover reduces urban heat by squeezing CO_2 and becomes carbon sink (S. Ashutosh et al., 2019). As this process took place which made favorable climatic conditions by reducing UHI intensity and this reduced UHI intensity reduced Discomfort Index (DI) and Urban Thermal Field Variation Index (UTFVI) which can be seen in results for the years 2011 and 2021.

Conclusion: Recent Urbanization causes significant Land Use Land Cover changes due to human settlement pattern which effects thermal properties such as LST and UHI Intensity of the region. The thermal properties of a land and its related climatic conditions affect human health and the ecological evolution. As thermal intensity increases the human discomfort index and ecological evolution also increases which reflects negative impact on local environment.

So, we must be careful about Land Use/Land cover thermal properties and should other people make aware about it so that we can lower down Urban Heat Island Intensity in this region. As we came to know that shrub land areas lowers the Urban Heat Island Intensity so we must plant trees on the top of roofs and around the buildings and should make endeavors to make Green space and Blue space and should protect them for our future generations in this region.

Acknowledgement:

The authors are grateful to the University Grants Commission (UGC) and Principal of D.B.S. Degree College, Kanpur for providing the necessary facilities for the successful completion of this research. The first author wishes to acknowledge the support received from the Council of Scientific & Industrial Research (CSIR), New Delhi, India for providing grant under CSIR NET-JRF fellowship (Ref No.455/CSIR-UGC NET DEC. 2016).

Conflicts of Interest: There is no conflict of interest at all by all authors.

References:

- Almeida C.R. et al. 2021 Study of the Urban Heat Island (UHI) Using Remote Sensing Data/Techniques: A Systematic Review, Environments, 8(10), 105. DOI: 10.3390/environments8100105
- B. Bakul et al. 2018 Studying Surface and Canopy Layer Urban Heat Island at Micro-scale Using Multi-Sensor Data in Geographic Information System. International Journal of Applied Geospatial Research, 9(4), 36-56. DOI: 10.4018/IJAGR.2018100103
- Back Y. et al. 2021 A rapid fine-scale approach to modeling urban bioclimatic conditions. Science of Total Environment, 756, 143732. DOI: 10.1016/j.scitotenv.2020.143732
- Clark N.E. et al. 2014 Biodiversity, cultural pathways, and human health: a framework. Trends in Ecology and Evolution, 29(4), 198-204. DOI: 10.1016/j.tree.2014.01.009
- Datta Pranati 2006: Urbanization in India, European Population Conference
- Gandhi H et al. 2023 Dynamics of Land Cover Indices and Their Relation with Urban Biophysical Components of Kanpur Metropolis in the Ganga-Yamuna Doab region of India, International Journal of Creative Research Thoughts, 11(8), e849-e868
- Gandhi H et al. 2023 Necessity and Techniques of Mitigation of Urban Heat Island (UHI) Intensity of Kanpur Metropolis in Ganga-Yamuna Doab Region of India. International Journal of Creative Research Thoughts, 11(8), e835-e848
- Gogoi P.P. et al. 2019 Land use and land cover change effect on surface temperature over Eastern India. Scientific Reports, 9; 8859. DOI: 10.1038/s41598-019-45213-z
- H. Ne and Guanghao Li 2021 Urban neighborhood environment assessment based on street view image processing: A review of research trends, Environmental Challenges, 4. DOI: 10.1016/j.envc.2021.100090
- Hu Qiong et al. 2021 Integrating coarse resolution images and agricultural statistics to generate sub-pixel crop type maps and reconciled are estimate. Remote Sensing of Environment, 258, 112-365, doi: 10.1016/j.rse.2021.112365

- Hua Shi et al. 2021 Urban Heat Island and Its Regional Impacts Using Remotely Sensed Thermal Data- A Review of Recent Developments and Methodology. Land Surface Monitoring Based on Satellite Imagery, 10(8), 867. DOI: 10.3390/land10080867
- Im J. et al. 2008 Object-based change detection using correlation image analysis and image segmentation. International Journal of Remote Sensing, 29(2), 399-423. DOI: 10.1080/01431160601075582
- J.L. Silvan-Cardenas & Le Wang 2014 On quantifying post-classification subpixel land cover changes. ISPRS Journal of Photogrammetry and Remote Sensing. 98, 94-105. Doi: 10.1016/j.isprsjprs.2014.09.018
- Kafy A. et al. 2021 Modeling the relationship between land use/land cover and land surface temperature in Dhaka, Bangladesh using CA-ANN algorithm. Environmental Challenges, 4, 100109. DOI: 10.1016/j.envc.2021.100109
- Kim C. 2016 Land use classification and land use change analysis using satellite images in Lombok Island, Indonesia. Forest Science and Technology, 12(4), 183-191. DOI: 10.1080/21580103.2016.1147498
- Li Z. et al., 2021 Subpixel Change Detection Based on Radial Basis Function with Abundance Image Difference Measure for Remote Sensing Images. Remote Sensing, 13(8), 868. Doi: 10.3390/rs13050868
- Ling F. et al. 2011 Land Cover Change Mapping at the Subpixel Scale With Different Spatial-Resolution Remotely Sensed Imagery. IEEE Geoscience and Remote Sensing. 8(1), 182-186
- MacLachlan A. et al., 2017 Subpixel land cover classification for improved urban area estimates using Landsat. International Journal of Remote Sensing, 38(20), 5763-5792. Doi: 10.1080/01431161.2017.1346403
- Moda H.M. et al. 2019 Impacts of Climate Change on Outdoor Workers and Their Safety: Some Research Priorities. International Journal of Environmental Research and Public Health, 16(18); 3458. DOI: 10.3390/ijerph16183458
- Morrison W. et al. 2023 Simulating satellite land surface temperatures: sensitivity to sensor view angle and assumed landscape complexity. Remote Sensing of Environment, 293, 113579. DOI: 10.1016/j.rse.2023.113579
- Naserikia M. et al. 2023 Land surface and air temperature dynamics: The role of urban form and seasonality. Science of Total Environment, 905, 167306. DOI: 10.1016/j.sciotenv.2023.167306
- P. Suvamoy et al., 2020 Land Use Land Cover Change and Surface Urban Heat Island Intensity: Source- Sink Landscape Based Study in Delhi, India. Environment Development and Sustainability. DOI: 10.1007/s10668-019-00515-0
- Pal S. et al. 2017 Detection of Land Use and Land Cover change and land surface temperature in English bazar urban centre. The Egyptian Journal of Remote Sensing and Space Sciences, 20(1), 125-145. DOI: 10.1016/j.ejrs.2016.11.003
- Patel S. et al. 2023 A comprehensive systematic review: Impact of Land Use/Land Cover (LULC) on Land Surface Temperature (LST) and outdoor thermal comfort. Building and Environment, 249 DOI:10.1016/j.buildenv.2023.111130
- R. Najiba et al. 2022 Impact of landuse change and urbanization on urban heat island effect in Narayanganj city, Bangladesh: A remote sensing based estimation. Environmental Challenges, 8, 100571. DOI: 10.1016/j.envc.2022.100571
- Rao P. et al. 2023 Exploring the land-use urban heat island nexus under climatic change conditions using machine learning approach: A saptio-temporal analysis of remotely sensed data. Heliyon, 9(8), e18423. DOI: 10.1016/j.heliyon.2023.e18423
- Rendana M. et al. 2023 Relationships between land use types and urban heat island intensity in Hulu Langat district, Selangor, Malaysia. Ecological Processes, 12(33), 2371
- Rodriguez L.R. et al. 2020 Analyzing the Urban Heat Island: Comprehensive methodology for data gathering and optimal design of mobile transects. Sustainable Cities and Societies, 55, 102027. DOI: 10.1016/j.scs.2020.102027
- Sudhira H.S. 2004: Urban Sprawl: metrics, dynamics and modeling using GIS, International Journal of Applied Earth Observation and Geoinformation, 5(1), pp. 29-39
- Tariq S. et al. 2023 Impact of land use/land cover (LULC) changes on latent/sensible heat flux and precipitation over Turkey. Theoretical and applied climatology, 153, 3-4, pp. 1237-1256. DOI: 10.1007/s00704-023-04535-Xu Yong et al. 2017 Learning-Based Sub-Pixel change Detection Using Coarse Resolution Satellite Imaginary. Remote Sensing, 9(7) , 709 doi: 10.3390/rs9070709
- Yan Y. et al. 2021 A high-spatial-resolution dataset of human thermal stress indices over South and East Asia, Scientific Data, 229(8). DOI: 10.1038/s41597-021-01010-w
- Yang C. et al. 2017 Mapping the Influence of Land Use/Land Cover Changes on the Urban Heat Island Effect- A Case Study of Changchun, China. Sustainability, 9(2), 312. Doi: 10.3390/su9020312
- Yang Z. et al. 2019 Spatial heterogeneity of the thermal environment based on the urban expansion of natural cities using open data in Guangzhou, China. Ecological Indicators, 104, 524-534. DOI: 10.1016/j.ecolind.2019.05.032

• Zargari M. et al. 2024 Climatic comparison of surface urban heat island using satellite remote sensing in Tehran and suburbs. Scientific Reports, 14:643. DOI: 10.1038/s41598-023-50757-2