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Impact Assessment of Changing LULC on LST and UHI Pattern. A Case Study of Srinagar City Jammu and Kashmir (2010-2022)

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Abstract

The rapid urbanization of Srinagar city, located in the Himalayan region, has led to significant changes in land use and land cover (LULC), resulting in an increase in the Urban Heat Island (UHI) phenomenon. This study investigates the relationship between Land Surface Temperature (LST) and LULC changes over a decade, from 2010 to 2022, focusing on four key categories: built-up areas, agricultural land, water bodies, and natural vegetation. Using Landsat satellite data, we analysed seasonal variations in LST across these categories and calculated the Urban Thermal Field Variance Index (UTFVI) to assess the ecological impact. The findings reveal a substantial increase in LST, particularly in built-up areas, where maximum temperature increased from 34.6°C in 2010 to 37.19°C in 2022. Additionally, the UTFVI analysis showed a decline in areas with "Excellent" ecological conditions, dropping from 57.91% in December 2010 to 47.24% in December 2022, while areas categorized as "Worst" ecological conditions increased, indicating a worsening UHI effect. These results highlight the growing environmental challenges posed by urbanization in Srinagar city, necessitating urgent sustainable urban planning interventions.

Keywords: Land surface temperature (LST); Urban heat island (UHI); Urban thermal field variance index (UTFVI); Land use land cover (LULC); Urbanisation

1 Introduction

Urbanisation is often described as a phenomenon linked to both economic advancement and demographic shift, leading to changes in the geographical features of a region [1]. This transformation in land cover is happening globally, with a more pronounced impact in developing nations [2]. Approximately half of the world's population is currently residing in urban areas, occupying only 0.1% of the total land area globally [3]. Furthermore, UN projection indicated a 68% increase in the global population by 2050, with majority of growth anticipated in Asian countries [4]. The urban population in India has increased significantly during last three decades, resulting in rapid expansion of urban areas[5]. This rapid increase in urbanisation, contributes to diverse environmental alterations within cities, including changes in ecosystem services and functions, local weather pattern and microclimate[6].

Shift in natural land cover to built-up area results in alteration of surface thermal properties and hence, more heat gets accumulated in the land surfaces[7,8]. This change in thermal properties of land surface leads to increase in land surface temperature (LST) and formation of urban heat island (UHI). The concept of UHI was first proposed in 1818, where surface and air temperature of a specific area exhibit higher temperature than the surrounding environment[9]. Land Surface Temperature (LST) pattern offer valuable insights into climatic conditions and can therefore assist in comprehending the urban climate[10,11]. These patterns are influenced by various factors such as vegetation cover, roads, buildings or any other impervious surface[12,13]. LST is crucial in facilitating the heat exchange between land surface and the atmosphere. However, increasing temperature have adverse effect on environment including ecosystem services, energy balance, urban infrastructure, hydrology and human habitat[14].

Satellite based remote sensing techniques are widely employed to identify the land surface change detection using visible to near infrared (VNIR) and shortwave infrared (SWIR) bands. Thermal infrared (TIR) band of satellite has been commonly used for the extraction of LST across different spatial and temporal dimensions[15]. LST varies among different surfaces owing to the diverse surface reflectance and roughness associated with the Land Use / Land Cover (LULC)[16]. Recently, a range of sophisticated satellite sensors such as TM, ETM+, TIRS, MODIS and NOAA have been employed for monitoring LST.Top of Form Various spectral indices used in different LST studies, such as normalized difference vegetation index (NDVI) for vegetation cover analysis[2,17]. Normalised difference water index (NDWI) for water bodies estimation[18]. Similarly, normalised difference built-up index (NDBI) for the identification of built-up areas[19] and normalised difference bareness index (NDBaI) for bare land identification[20–22].

Although, Various studies have been carried out to understand the changes in Land surface Temperature (LST) across different cities of India[2,23–27]. In recent times, Asian high mountains have undergone notable warming particularly in the Alpine Kashmir Himalaya, which has witnessed substantial warming in the past few decades. This warming trend is anticipated to persist and intensify across the entire Himalayan region[28]. Hence, this study focused on the formation of urban heat island (UHI) which is based on the relationship between Land surface temperature and land use land cover changes in the Himalayan city of Srinagar to highlight the temperature differences over the decade in four different seasons of the year i.e. Pre-monsoon (summer), monsoon, post monsoon and winter season.

2 Aims of the Study

The present study aims to:

- Analyze the spatio-temporal changes in land use/land cover (LULC) of Srinagar city between 2010 and 2022.
- Assess the impact of LULC changes on Land Surface Temperature (LST) dynamics over the study period.
- Examine the evolution and spatial extent of the Urban Heat Island (UHI) phenomenon within the city.
- Evaluate the thermal ecological conditions and associated environmental stress in the study area by utilizing the Urban Thermal Field Variance Index (UTFVI).

3 Study Area

The study has been conducted for Srinagar city which is the largest city of union territory of Jammu and Kashmir located between 74°47'24" to 74°79' E longitude and 34°5'23" to 34°89'72" N latitude at an elevation of 1580 m above mean sea level Figure 1. The city is situated in the Kashmir valley on the western part of the Jammu and Kashmir, surrounded by the Himalayas. It is bisected by the Jhelum River which divides it into two sections and eventually joins the well-known Dal Lake located on the city's eastern side. Srinagar boasts a diverse landscape featuring rolling hillocks, enchanting gardens, orchards, wetlands and lakes. Srinagar experiences a sub-Mediterranean climate, characterized by winter temperature ranging from approximately 5-10 °C and summer temperature around 27-32 °C[29]. The population of city has tremendously increased from 0.1 million in 1901 to 1.2 million in 2011[30]. Growing population of city has changed the land use land cover and damaged the wetlands, ponds, forests and agricultural land by haphazard unplanned construction[31].

4 Data

In this study satellite imagery Landsat 5 (TM/MSS) and Landsat 8(OLI/TIRS) Collection 2 level 1 were used for LULC classification and Land surface temperature analysis for the year 2010 and 2022 respectively. These imageries were retrieved from the USGS earth explorer website (http://earthexplorer.usgs.gov/). Detail of data set used is given in Tables 1 and 2, while the detail of resolution of bands used is given in Tables 3 and 4.

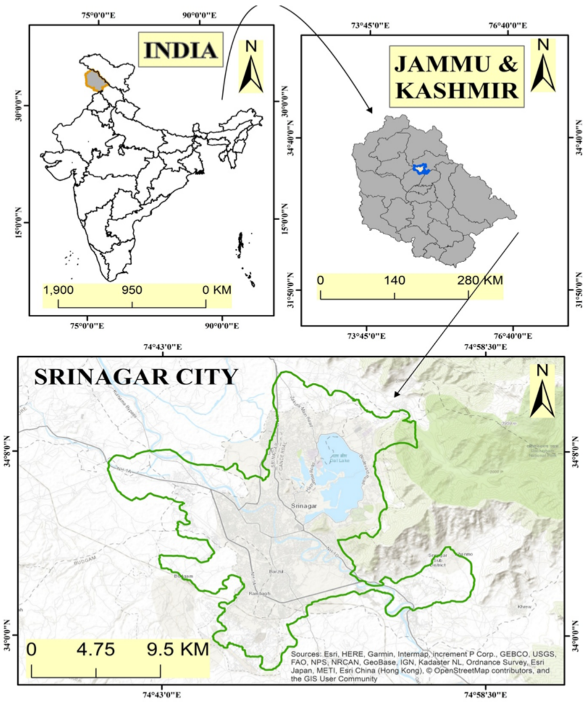

Fig. 1. Map of study area

Table 1. Informative label of Landsat 8 OLI/TIRS

Date of Acquisition	Season	Path/Row	Cloud Cover (%)
17/04/2022	APRIL (Pre-Monsoon)	149/36	3.98
28/06/2022	JULY (Monsoon)	149/36	11.84
26/10/2022	OCTOBER (Post-Monsoon)	149/36	7.84
21/12/2022	DECEMBER (Winter)	149/36	2.32

Table 2. Informative label of Landsat 5 (TM/MSS)

Date of Acquisition	**Season**	**Path/Row**	**Cloud Cover (%)**
18/04/2010	APRIL (Pre-Monsoon)	149/36	2.00
27/06/2010	JULY (Monsoon)	149/36	11.00
17/10/2010	OCTOBER (Post-Monsoon)	149/36	1.00
20/12/2010	DECEMBER (Winter)	149/36	5.00

Table 3. Specification of bands of Landsat 8 for LST retrieval

BANDS	**WAVELENGTH (μm)**	**RESOLUTION (m)**
B4 – Red	0.636 – 0.673	30
B5 – Near infrared (NIR)	0.851 – 0.879	30
B10 – TIRS 1	10.60 – 11.19	100

Table 4. Specification of bands of Landsat 5 for LST retrieval

BANDS	**WAVELENGTH (μm)**	**RESOLUTION (m)**
B6 - Thermal	10.40 - 12.50	120

5 Methodology

5.1 Method for land use land cover classification:

Various methods were used in the recent past for LULC classification which includes Maximum likelihood classifier, Indices overlay method, Neural networks, K-means clustering, etc.[(32–34)]. In this study we applied maximum likelihood classification method for LULC classification. Four LULC classes has been identified i.e. built-up area, agricultural land, water bodies and vegetation cover.

To validate the classified maps kappa coefficient was applied using 350 randomly distributed points. These points then converted to kml to export them on google earth imagery for accuracy assessment. The overall accuracy was more than 89% of each map, literature suggests that accuracy above 80% is acceptable[(35)]. The overall methodology that has been applied for LULC classification is provided in Figure 2.

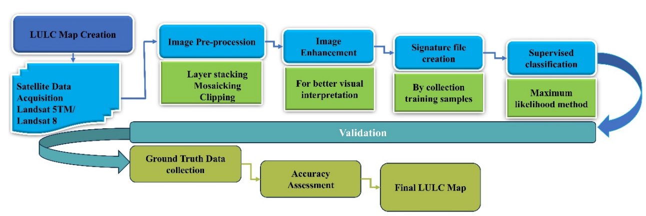

Fig. 2. Flowchart for the creation of LULC from Landsat 5 and Landsat 8

5.2 Method for land surface temperature (LST) extraction:

For the extraction of LST, mono window algorithm has been applied. LST retrieval using mono window algorithm involves five steps[(36)]. Details of methodology used for LST retrieval from Landsat data set is provided in Figure 3.

Step first involves conversion of digital number (DN) to spectral radiance (L_λ) using Equations (1) and (2) respectively.

Spectral radiance calculation for Landsat 5 TM:

$$L\lambda = \left(\frac{(Lmax\lambda - Lmin\lambda)}{QCALMAX - QCALMIN}\right) \times (QCAL - QCALMIN) + LMIN\lambda \tag{1}$$

Where, L_λ = Spectral radiance

$QCAL$ = Quantized calibrated pixel value.

$Lmax\lambda$= Spectral radiance scaled to QCALMAX, which is taken from meta data.

$Lmin\lambda$= Spectral radiance scaled to QCALMIN, taken from the metadata

$QCALMAX$ = Maximum Quantized calibrated pixel value

$QCALMIN$ = Minimum Quantized calibrated pixel value

Spectral radiance calculation for Landsat 8 (OLI):

$$L_\lambda = M_L \times Q_{cal} + A_L \tag{2}$$

Where:

M_L = multiplicative rescaling aspect of thermal band.

Q_{cal}. quantized pixel value.

A_L. additive rescaling factor of thermal band.

Second step involves conversion of spectral radiance to at satellite brightness temperature using Equation (3).

$$T = \frac{K2}{ln(\frac{k1}{L\,\lambda} + 1)} \tag{3}$$

Where,

T= effective satellite Temperature in Kelvin.

k_1, and K_2 are Thermal Constants and value is given in Table 5 (from metadata).

Ln = Logarithmic function.

Third step involves the calculation of proportion of vegetation (p_v) by using Equation (4).

$$Pn = \left[\frac{NDVI - NDVImin}{NDVImax - NDVImin}\right]^2 \tag{4}$$

Fourth step involves emissivity correction by using Equation (5).

$$E = 0.004 * P_v + 0.986 \tag{5}$$

In the last step LST was calculated following Artis & Carnahan (1982) [37] using Equation (6).

$$T = \left[\frac{BT}{1 + (\lambda \times \frac{BT}{P} ln\,(\varepsilon)}\right] \tag{6}$$

Where,

T= LST in kelvin

B_T= brightness temperature

λ = wavelength of radiance

$P = h \times c\ l\ s$ (h is plank's constant whose value is 6.624×10^{-34} Js, and c is velocity of light, s is Boltzmann constant (1.38×10^{-23} J/K)

ε = emissivity corrected

Table 5. Thermal Constant values for Landsat 5 & Landsat 8

Thermal Constant	Landsat 5	Landsat 8
K1	607.76	774.8853
K2	1260.56	1321.0789

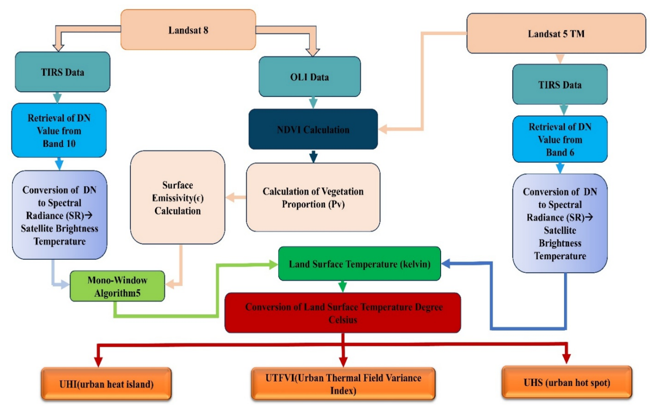

Fig. 3. Flowchart of methodology used for retrieval of LST from Landsat 5 & Landsat 8

5.3 Method for urban heat island (UHI) detection:

Urban heat island is formed when the temperature of city is higher than its surroundings. UHI is calculated using the Equation (7). [37].

$$UHI = \frac{LST - LST\ mean}{STD} \tag{7}$$

5.4 Method for quantifying Urban Thermal Field Variance Index (UTFVI):

Urban thermal field variance index (UTFVI) is used to evaluate the impact of urban heat island [38]. It is determined by using Equation (8).

$$UTFVI = \frac{LST - LST\ mean}{LST} \tag{8}$$

5.5 Method for identification of urban hot spot (UHS):

Urban hotspot in the present study has been calculated using following equation.

$$UHS = LST > \mu + 2 \times \delta \tag{9}$$

Here, μ is the mean LST and δ is the standard deviation of LST.

Results and Discussion

6.1 Land use land cover change assessment:

Land use land cover classification of Srinagar city was carried out using supervised maximum likelihood classification in four categories i.e. water body, agricultural land, settlement and vegetation cover Figure 4. The areal change in different LULC classes is given in Figures 5 and 6, which reveals that the area covered by water bodies in 2010 was 16.6 sq.km (6.49%) which reduced to 14.75 sq. km (6%) in 2022 i.e. slightly decreased by 1.85 sq. km (0.49%), whereas the built-up area in 2010 was 48.35 sq. km (18.86%) which increased to 127.89 sq. km (50%) in 2022, shows massive increase in the built -up area by 79.54 sq. km (31.02%) which is expanded into the agricultural and natural vegetation land that led to the reduction of both over the decade. The area under agricultural land in 2010 was 91.45 sq. km (35.66%) which reduced in 2022 to 39.68 sq. km (15%) has seen substantial reduction by 51.77 sq. km (20.18%) which is due to the encroachment by urban expansion in the area. On the other hand, the area under natural vegetation in 2010 was 99.95 sq. (38.99%) km which is also reduced to 74.1 sq. km (29%) in 2022 i.e. decreased by 25.85 sq. km (10.11%) which is attributed to expansion of built-up area and conversion of area under vegetation cover to urbanisation. This transformation is not merely a spatial pattern but is rooted in broader regional and socio-political dynamics. Srinagar, being the summer capital of Jammu and Kashmir, has undergone rapid urban expansion especially post-2010 due major infrastructural development, population pressure and growing influx of tourist. Smart City initiatives, and tourism-driven construction have significantly reshaped the city's land use, led to the steady conversion of vegetative and agricultural lands into impervious built-up surfaces. Additionally, the valley's constrained geography and limited availability of plain land further intensify land competition, accelerating this change.

A study conducted by Ahmad et al., (2024)[39] recorded similar observation of Srinagar city which shows substantial decrease in water bodies, vegetation cover and increase in built-up area from the year 2000 to 2020. It reflects that urbanisation is growing at a rapid rate which is possibly due to population growth, economic development of city which led to demand of housing and infrastructural development. At the same time this steady increase in the built-up area is at the cost of natural vegetation and agricultural land which shows substantial decrease in area over a decade. This reduction in the natural vegetation and water bodies reflects potential environmental concern including increase runoff, reduction in biodiversity and natural resources.

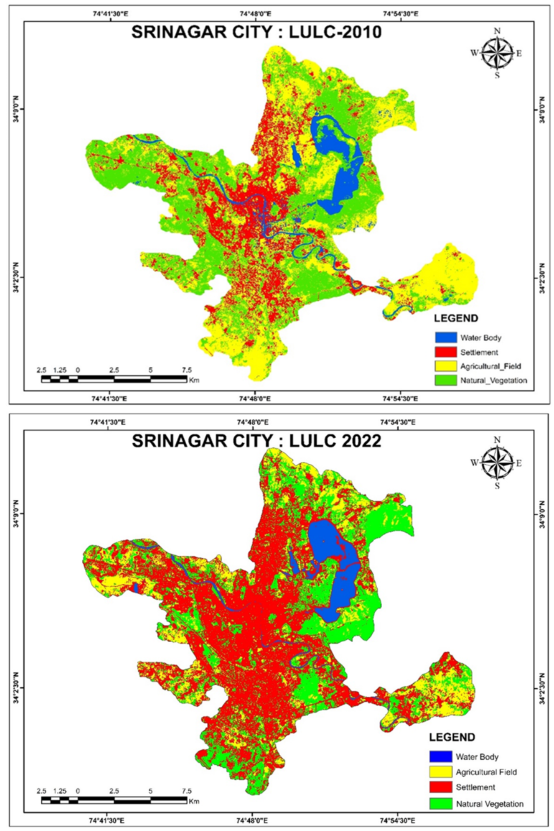

Fig. 4. LULC of Srinagar city, 2010 & 2022

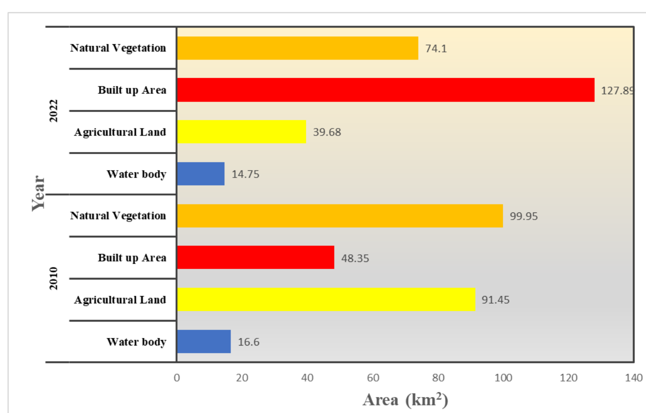

Fig. 5. Area in sq.km under different LULC category of Srinagar city

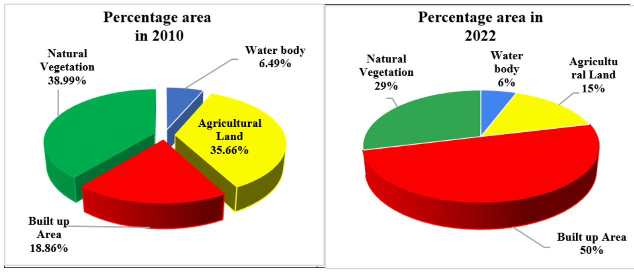

Fig. 6. Percentage of area under different LULC category of Srinagar city

6.2 Seasonal variation of land surface temperature (LST):

LST of Srinagar city was calculated for four different seasons i.e. pre-monsoon (April), Monsoon (July), post-monsoon (October) and winter (December) of the year 2010 and 2022 respectively. Figure 7 reveals significant changes in LST across different seasons.

Tables 6 and 7 reveal that in the year 2010, minimum as well as maximum temperature was observed over built-up area i.e. -2.93°C and 34.6°C in the month of December and July respectively. built-up area exhibits higher mean LST than other LULC categories across all the seasons of the year except for the month of December, followed by agricultural land, vegetation and water bodies. Whereas, in the month of December highest temperature observed over agricultural land followed by natural vegetation, built-up area and water bodies.

However, In the year 2022, minimum temperature was -7.78°C over agricultural land in the month of December whereas, maximum temperature 37.19°C observed over built-up area in the month of June, which was 2.59 °C higher than temperature reported in 2010. In the year 2022 also, Built-up area showed higher LST across all the months except for the month of December which is followed by agricultural land, natural vegetation and water bodies. While, in the month of December highest temperature observed over natural vegetation followed by built up, water bodies and agricultural land. The overall observation reveals that in both the year 2010 and 2022 built-up area & water bodies showed highest and lowest LST respectively than other LULC category and other LULC categories such as natural vegetation, water bodies and agricultural land also showed consistent increase in LST over a decade. Many researches from different cities have reported similar observation where the average LST of different LULC categories have increased significantly over the years[4,40].

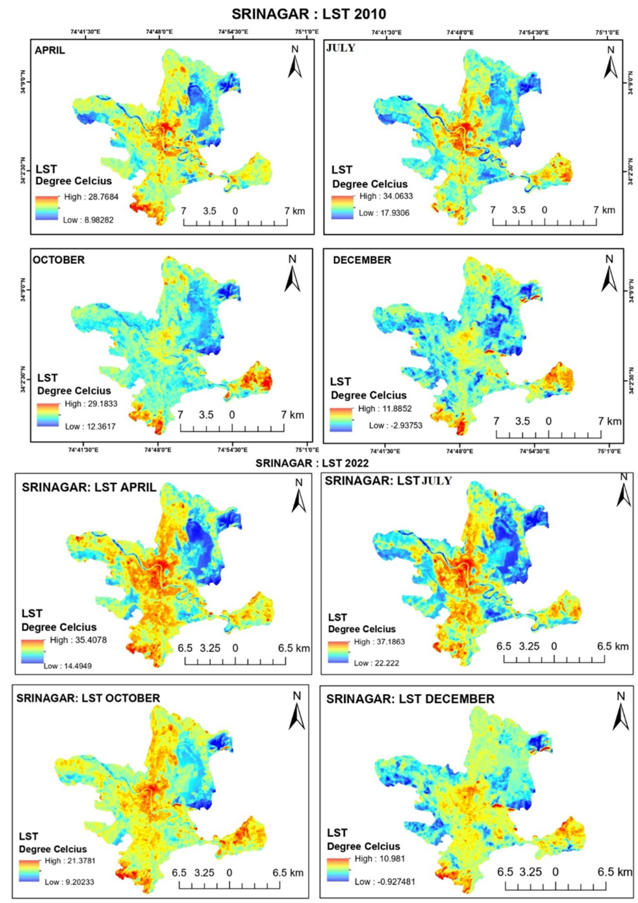

Fig. 7. LST of Srinagar city for the year 2010 and 2022

6.3 Urban Hotspot identification:

As shown in the Figure 8, in the year 2010 during pre-monsoon and monsoon season small patches of UHS observed in the middle portion however, during post monsoon and winter season UHS are also confined in the eastern part of the city. In the year 2022, during pre-monsoon the UHS concentrated in central and southern part, during the monsoon period they are expanded to eastern direction, while, during post monsoon and winter season growing trend towards eastern and southern side can be seen. The mean area under UHI in 2010 was 247.22 sq.km which increased to 253.14 sq. km in 2022. These observations of UHI suggest changes in the distribution and intensity of UHIs over time, likely influenced by urbanisation, land use changes and seasonal variations. The shift towards eastern and southern sides is indicative of urban sprawl and reduction in vegetation cover, both of which can affect local temperature and create UHIs.

Table 6. LST across different seasons for the year 2010

LULC Classes	Land surface temperature (° C)											
	April			July			October			December		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
Built-up	12.83	28.77	20.8	18.38	34.6	26.49	13.3	27.51	20.4	-2.93	7	2.03
Agricultural land	10.44	28.35	19.4	17.93	34.5	26.27	12.36	28.18	20.27	-1.84	11.89	5.02
Water bodies	10.44	21.5	15.97	16.93	27.93	22.93	12.36	22.38	17.37	-1.3	3.96	1.33
Natural vegetation	8.98	28.76	18.88	17.5	33.6	26.26	13.77	27.9	20.2	-1.3	10.92	4.08

Table 7. LST across different seasons for the year 2022

LULC Classes	Land surface temperature (° C)											
	April			July			October			December		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
Built-up	16.52	35.16	25.9	22.6	37.19	29.89	11.77	20.4	16.8	-0.43	8.28	3.9
Agricultural land	15.98	34.2	25.8	22.85	35.52	29.18	10.09	19.89	15.29	-7.78	3.24	-2.27
Water bodies	17.6	25.5	21.55	23.79	29.31	26.55	12.63	16.69	14.66	0.44	4.95	2.69
Natural vegetation	14.49	30.41	22.45	22.48	36.14	28	9.2	20	15	0.93	10.98	6

6.4 Urban Thermal Field Variance Index (UTFVI) for ecological condition assessment:

Urban thermal field variance index (UTFVI) is commonly utilized to assess the UHI effect and quality of life in urban environment[41,42]. To classify the UTFVI this study followed six tier classification proposed by Zhang 2006 (Excellent, good, normal, bad, worse & worst) as shown in Table 8 & Figure 9.

In 2010 majority of the area falls in the "excellent" condition of ecological evaluation index (EEI) with area percentage ranging from 47.27 in April to 57.91 in December. However, in 2022 there is slight decrease in excellent EEI with percentage ranges from 44.83 in April to 47.24 in December. Area under "Good" to "Normal" EEI is negligible with percentage 9.16 in April 2010 which reduced 1.34 in April 2022 thus experiencing weak to moderate UHI phenomenon. However, percentage of area under "Worst" EEI in 2010 was 43.57, 36.49,33.52 & 41.93 for the month of April, July, October & December respectively, which significantly increased in 2022 to 49.8 in April, 44.08 in July, 42.69 in October & 50.06 in December. This indicates gradual deterioration in urban ecological condition from 2010 to 2022 as area under "excellent" and "normal" category reduced from 2010 to 2022 but there is increase in area under "worst" category which reflects an increase in UHI intensity and a corresponding decrease in urban environmental quality.

6.5 Analysis of association between LULC & LST:

Built up area shows higher mean LST in all the months of 2010 & 2022 which represents the formation of heat spots due to heat absorption and retention over the regions. This is consistent with other studies which shows positive correlation between LST and built up[21,23,43]. Agricultural land also exhibits increase in mean LST in April and June, similar results observed by[9,44] where agricultural land exhibits higher LST compared to natural vegetations due to increase in soil exposure over the regions. Water bodies also show consistent increase in LST. However, waterbodies generally exhibit lower temperature which creates cooling effect in the surrounding, but this cooling effect reduced due to rising temperature of water bodies[45]. Natural vegetation shows similar trend to agricultural land with increase in mean LST in April and June but a decrease in October and December.

7 Implications of the Study

The study reveals that the rapid urban expansion of Srinagar city over the past decade has come at a significant environmental and societal cost. The conversion of agricultural and vegetative land into built-up areas is not just a physical transformation but also reflects the changing human-environment relationship. These kind of unchecked LULC alteration in an ecologically fragile region are intensifying the land surface temperature and worsening the urban heat island effect. These are not merely environmental changes as they directly impact everyday life. Hotter summers, especially in densely populated areas, pose health risks, increase energy demands, and strain basic infrastructure. Simultaneously, the shrinking of agricultural land threatens local food production and the livelihoods of farmers on the city's outskirts.

Table 8. UTFVI across the seasons for the year 2010 and 2022

UTFVI	Urban heat island (UHI)	Ecological Evaluation Index (EEI)	(Area in %)							
			2010				2022			
			April	July	October	December	April	July	October	December
<0.00	None	Excellent	47.27	51.72	56.63	57.91	44.83	49.98	48.23	47.24
0.000-0.005	Weak	Good	0	6.24	0	0.17	1.31	1.44	2.36	0.71
0.0005-0.010	Moderate	Normal	9.16	0	0	0	1.34	1.52	2.28	0.63
0.010-0.015	Strong	Bad	0	0	9.86	0	1.36	1.56	2.23	0.64
0.015-0.020	Stronger	Worse	0	5.54	0	0	1.38	1.42	2.3	0.73
>0.020	Strongest	Worst	43.57	36.49	33.52	41.93	49.8	44.08	42.69	50.06

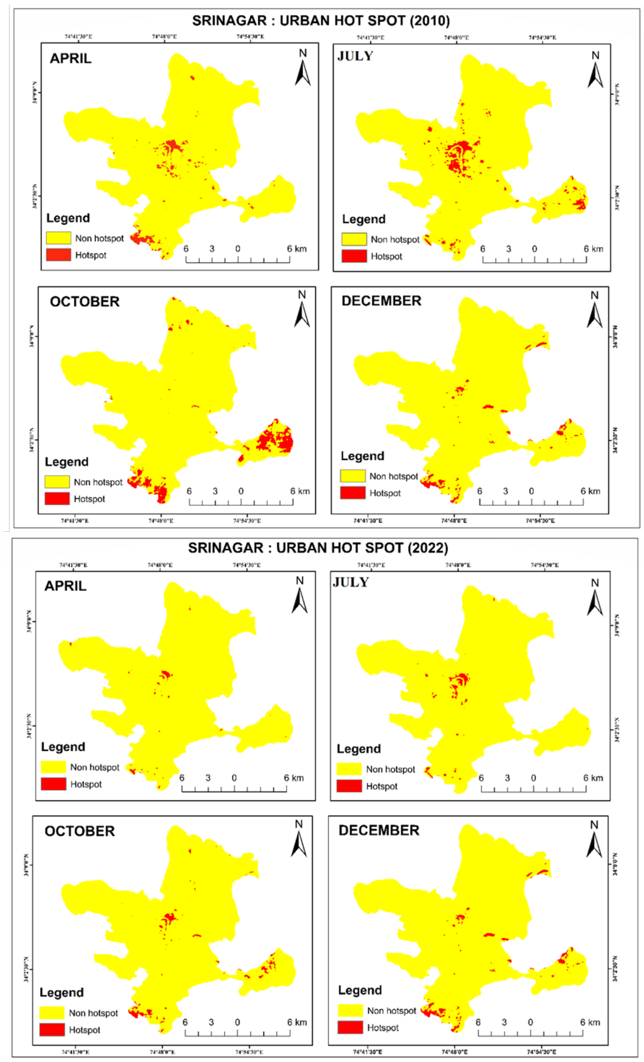

Fig. 8. Shows urban hotspots

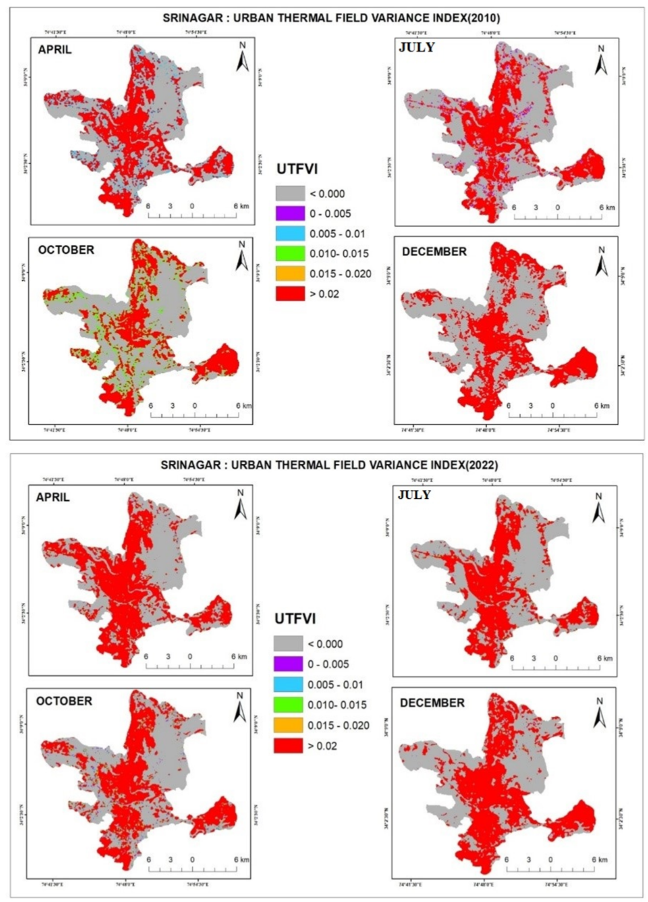

Fig. 9. UTFVI of Srinagar city for the year 2010 and 2022

Even more concerning is the gradual loss of water bodies, particularly the drying of natural springs[29] which have long sustained local communities. These changes are putting increasing stress on already vulnerable water resources, with serious implication for both daily life and the region's tourism-driven economy.

These findings highlight the urgent need for more thoughtful and climate-sensitive urban planning. By preserving green spaces, restoring wetlands and springs, and employing scientific tools like the UTFVI to guide decisions, local authorities can help make the city more resilient. Therefore, this particular study not only contributes to academic understanding but offers practical direction for addressing the emerging environmental and societal challenges the city is facing.

8 Conclusion

This study demonstrates the significant impact of urbanization on land surface temperature and the urban heat island phenomenon in Srinagar city over the period from 2010 to 2022. The analysis shows that built-up areas have experienced the most substantial increases in LST, with June temperatures rising from 34.6°C in 2010 to 37.19°C in 2022. This increase is indicative of the intensifying UHI effect, particularly in areas with dense construction and reduced vegetation. The Urban Thermal Field Variance Index (UTFVI) further corroborates these findings, showing a marked decline in areas with "Excellent" ecological conditions and a corresponding rise in areas categorized as "Worst." This trend reflects the deterioration of urban ecological quality due to the expansion of built-up areas at the expense of agricultural land and natural vegetation, which have decreased by 20.18% and 10.11%, respectively, over the decade. The growing prevalence of higher LSTs and poorer ecological conditions underscores the need for immediate and comprehensive urban planning strategies that prioritize the preservation of green spaces, the reduction of impervious surfaces, and the adoption of cooling technologies to mitigate the adverse effects of urbanization on the local climate and public health in Srinagar city.

References

1) Hatab AA, Cavinato MER, Lagerkvist CJ. Urbanization, livestock systems and food security in developing countries: A systematic review of the literature. *Food Security*. 2019;11(2):279–299. Available from: https://doi.org/10.1007/s12571-019-00906-1.
2) Gohain KJ, Mohammad P, Goswami A. Assessing the impact of land use land cover changes on land surface temperature over Pune city, India. *Quaternary International*. 2021;575-576:259–269. Available from: https://dx.doi.org/10.1016/j.quaint.2020.04.052.
3) Kumari B, Shahfahad, Tayyab M, Ahmed IA, Baig MRI, Ali MA, et al. Land use/land cover (LU/LC) change dynamics using indices overlay method in Gautam Buddha Nagar District-India. *GeoJournal*. 2022;87(3):2287–2305. Available from: https://doi.org/10.1007/s10708-021-10374-w.
4) Tran DX, Pla F, Latorre-Carmona P, Myint SW, Caetano M, Kieu HV. Characterizing the relationship between land use land cover change and land surface temperature. *ISPRS Journal of Photogrammetry and Remote Sensing*. 2017;124:119–132. Available from: https://dx.doi.org/10.1016/j.isprsjprs.2017.01.001.
5) Chettry V, Surawar M. Urban sprawl assessment in Raipur and Bhubaneswar urban agglomerations from 1991 to 2018 using geoinformatics. *Arabian Journal of Geosciences*. 2020;13(14):667. Available from: https://dx.doi.org/10.1007/s12517-020-05693-0.
6) Bindajam AA, Mallick J. Impact of the Spatial Configuration of Streets Networks on Urban Growth: A Case Study of Abha City, Saudi Arabia. *Sustainability*. 2020;12(5):1856. Available from: https://dx.doi.org/10.3390/su12051856.
7) Lee SH, Baik JJ. Evaluation of the vegetated urban canopy model (VUCM) and its impacts on urban boundary layer simulation. *Asia-Pacific Journal of Atmospheric Sciences*. 2011;47(2):151–165. Available from: https://dx.doi.org/10.1007/s13143-011-0005-z.
8) Liu L, Zhang Y. Urban Heat Island Analysis Using the Landsat TM Data and ASTER Data: A Case Study in Hong Kong. *Remote Sensing*. 2011;3(7):1535–1552. Available from: https://dx.doi.org/10.3390/rs3071535.
9) Guo X, Wang J, Liu X. Impacts of agricultural practices on land surface temperature: A case study in the North China Plain. *Agricultural and Forest Meteorology*. 2019;279:107746.
10) Bendib A, Dridi H, Kalla MI. Contribution of Landsat 8 data for the estimation of land surface temperature in Batna city, Eastern Algeria. *Geocarto International*. 2017;32(5):503–513. Available from: https://dx.doi.org/10.1080/10106049.2016.1156167.
11) Gorgani SA, Panahi M, Rezaie F. The relationship between NDVI and LST in the urban area of Mashhad, Iran. In: International Conference on Civil Engineering Architecture & Urban Sustainable Development. 2013. Available from: https://www.researchgate.net/publication/265601825_The_Relationship_between_NDVI_and_LST_in_the_urban_area_of_Mashhad_Iran.
12) Ramaiah M, Avtar R, Rahman MM. Land Cover Influences on LST in Two Proposed Smart Cities of India: Comparative Analysis Using Spectral Indices. *Land*. 2020;9(9):292. Available from: https://doi.org/10.3390/land9090292.
13) Weng Q. Thermal infrared remote sensing for urban climate and environmental studies: Methods, applications, and trends. *ISPRS Journal of Photogrammetry and Remote Sensing*. 2009;64(4):335–344. Available from: https://doi.org/10.1016/j.isprsjprs.2009.03.007.
14) Pandey A, Mondal A, Guha S, Upadhyay PK, Singh D. A Long-Term Analysis of the Dependency of Land Surface Temperature on Land Surface Indexes. *Papers in Applied Geography*. 2023;9(3):279–294. Available from: https://dx.doi.org/10.1080/23754931.2023.2187314.
15) Wemegah CS, Yamba EI, Aryee JNA, Sam F, Amekudzi LK. Assessment of urban heat island warming in the greater accra region. *Scientific African*. 2020;8:e00426. Available from: https://dx.doi.org/10.1016/j.sciaf.2020.e00426.
16) Dewan AM, Corner RJ. Impact of land use and land cover changes on urban land surface temperature. *Dhaka megacity: Geospatial perspectives on urbanisation, environment and health*. 2014;p. 219–238. Available from: https://doi.org/10.1007/978-94-007-6735-5_12.
17) Goetz SJ. Multi-sensor analysis of NDVI, surface temperature and biophysical variables at a mixed grassland site. *International Journal of Remote Sensing*. 1997;18(1):71–94. Available from: https://doi.org/10.1080/014311697219286.
18) Howard L. The climate of London: deduced from meteorological observations, made at different places in the neighbourhood of the metropolis. W. Phillips, George Yard, Lombard Street. 1818. Available from: https://books.google.co.in/books/about/The_Climate_of_London.html?id=7skTAAAAYAAJ&redir_esc=y.
19) Kayet N, Pathak K, Chakrabarty A, Sahoo S. Spatial impact of land use/land cover change on surface temperature distribution in Saranda Forest, Jharkhand. *Modeling Earth Systems and Environment*. 2016;2(3):1–10. Available from: https://dx.doi.org/10.1007/s40808-016-0159-x.
20) Govind NR, Ramesh H. The impact of spatiotemporal patterns of land use land cover and land surface temperature on an urban cool island: a case study of Bengaluru. *Environmental Monitoring and Assessment*. 2019;191(5):1–20. Available from: https://doi.org/10.1007/s10661-019-7440-1.
21) Oke TR. The energetic basis of the urban heat island. *Quarterly Journal of the Royal Meteorological Society*. 1982;108(455):1–24. Available from: https://doi.org/10.1002/qj.49710845502.

22) Chen X, Zhang Y. Impacts of urban surface characteristics on spatiotemporal pattern of land surface temperature in Kunming of China. *Sustainable Cities and Society*. 2017;32:87–99. Available from: https://dx.doi.org/10.1016/j.scs.2017.03.013.
23) Santamouris M. Cooling the cities – A review of reflective and green roof mitigation technologies to fight heat island and improve comfort in urban environments. *Solar Energy*. 2014;103:682–703. Available from: https://dx.doi.org/10.1016/j.solener.2012.07.003.
24) Murtaza KO, Shafai S, Shahid P, Romshoo SA. Understanding the linkages between spatio-temporal urban land system changes and land surface temperature in Srinagar City, India, using image archives from Google Earth Engine. *Environmental Science and Pollution Research*. 2023;30:107281–107295. Available from: https://dx.doi.org/10.1007/s11356-023-28889-9.
25) Rafiq M, Rashid I, Romshoo SA. Estimation and validation of remotely sensed land surface temperature in Kashmir valley. *Journal of Himalayan Ecology & Sustainable Development*. 2014;9:1–80. Available from: https://envirsc.uok.edu.in/Files/ab1ac1f1-07e3-42a2-85bc-83717ef39155/Journal/0f7e8ec3-3997-4af6-b6f5-9cd55b18fd3b.pdf.
26) Aithal BH, Chandan MC, Nimish G. Assessing land surface temperature and land use change through spatio-temporal analysis: a case study of select major cities of India. *Arabian Journal of Geosciences*. 2019;12(11):1–16. Available from: https://dx.doi.org/10.1007/s12517-019-4547-1.
27) Bera D, Chatterjee ND, Mumtaz F, Dinda S, Ghosh S, Zhao N, et al. Integrated Influencing Mechanism of Potential Drivers on Seasonal Variability of LST in Kolkata Municipal Corporation, India. *Land*. 2022;11(9):1461. Available from: https://dx.doi.org/10.3390/land11091461.
28) Romshoo SA, Abdullah T, Rashid I, Bahuguna IM. Explaining the differential response of glaciers across different mountain ranges in the north-western Himalaya, India. *Cold Regions Science and Technology*. 2022;196:103515. Available from: https://dx.doi.org/10.1016/j.coldregions.2022.103515.
29) Mir DRA. The Drying Springs of Kashmir. Greater Kashmir. February 21, 2025. Available from: https://www.greaterkashmir.com/opinion/the-drying-springs-of-kashmir/.
30) Farooq M, Muslim M. Dynamics and forecasting of population growth and urban expansion in Srinagar City – A Geospatial Approach. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*. 2014;XL-8:709–716. Available from: https://dx.doi.org/10.5194/isprsarchives-xl-8-709-2014.
31) Fazal S, Amin A. Impact of Urban Land Transformation on Water Bodies in Srinagar City, India. *Journal of Environmental Protection*. 2011;02(02):142–153. Available from: https://dx.doi.org/10.4236/jep.2011.22016.
32) Kühn I, Klotz S. Urbanization and homogenization – Comparing the floras of urban and rural areas in Germany. *Biological Conservation*. 2006;127(3):292–300. Available from: https://dx.doi.org/10.1016/j.biocon.2005.06.033.
33) Jothimani M, Gunalan J, Duraisamy R, Abebe A. Study the Relationship Between LULC, LST, NDVI, NDWI and NDBI in Greater Arba Minch Area, Rift Valley, Ethiopia. In: Proceedings of the 3rd International Conference on Integrated Intelligent Computing Communication & Security (ICIIC 2021). Atlantis Press. 2021;p. 183–193. Available from: https://doi.org/10.2991/ahis.k.210913.023.
34) Shahfahad, Kumari B, Tayyab M, Ahmed IA, Baig MRI, Khan MF, et al. Longitudinal study of land surface temperature (LST) using mono- and split-window algorithms and its relationship with NDVI and NDBI over selected metro cities of India. *Arabian Journal of Geosciences*. 2020;13(19):1–19. Available from: https://dx.doi.org/10.1007/s12517-020-06068-1.
35) Zhang Y, Yu T, Gu X, Zhang Y, Chen L, Yu S, et al. Land Surface Temperature Retrieval from CBERS-02 IRMSS Thermal Infrared Data and Its Applications in Quantitative Analysis of Urban Heat Island Effect. *Journal of Remote Sensing*. 2006;10(5):789–797. Available from: https://dx.doi.org/10.11834/jrs.200605117.
36) Meng Y, Yang M, Liu S, Mou Y, Peng C, Zhou X. Quantitative assessment of the importance of bio-physical drivers of land cover change based on a random forest method. *Ecological Informatics*. 2021;61:101204. Available from: https://dx.doi.org/10.1016/j.ecoinf.2020.101204.
37) Artis DA, Carnahan WH. Survey of emissivity variability in thermography of urban areas. *Remote Sensing of Environment*. 1982;12(4):313–329. Available from: https://dx.doi.org/10.1016/0034-4257(82)90043-8.
38) Liu L, Zhang Y. Urban Heat Island Analysis Using the Landsat TM Data and ASTER Data: A Case Study in Hong Kong. *Remote Sensing*. 2011;3(7):1535–1552. Available from: https://doi.org/10.3390/rs3071535.
39) Ahmad WS, Jamal S, Sharma A, Malik IH. Spatiotemporal analysis of urban expansion in Srinagar city, Kashmir. *Discover Cities*. 2024;1(1):1–19. Available from: https://doi.org/10.1007/s44327-024-00009-3.
40) Yan Y, Mao K, Shi J, Piao S, Shen X, Dozier J, et al. Driving forces of land surface temperature anomalous changes in North America in 2002–2018. *Scientific Reports*. 2002;10(1):6931. Available from: https://doi.org/10.1038/s41598-020-63701-5.
41) Degerli BC, Cetin M. Evaluation of UTFVI index effect on climate change in terms of urbanization. Environmental Science and Pollution Research. *Environmental Science and Pollution Research*. 2023;30:75273–75280. Available from: https://doi.org/10.1007/s11356-023-27613-x.
42) Renard F, Alonso L, Fitts Y, Hadjiosif A, Comby J. Evaluation of the Effect of Urban Redevelopment on Surface Urban Heat Islands. *Remote Sensing*. 2019;11(3):299. Available from: https://dx.doi.org/10.3390/rs11030299.
43) Weng Q, Lu D, Schubring J. Estimation of land surface temperature–vegetation abundance relationship for urban heat island studies. *Remote Sensing of Environment*. 2004;89(4):467–483. Available from: https://dx.doi.org/10.1016/j.rse.2003.11.005.
44) Wang W, Zhang Y, Li J. Agricultural intensification and its impact on land surface temperature: Evidence from the North China Plain. *Environmental Research Letters*. 2019;14(5):054005.
45) Ghosh S, Das A. Modelling urban cooling island impact of green space and water bodies on surface urban heat island in a continuously developing urban area. *Modeling Earth Systems and Environment*. 2018;4(2):501–515. Available from: https://dx.doi.org/10.1007/s40808-018-0456-7.