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IMPACT OF LAND USE LAND COVER CHANGES ON LAND SURFACE TEMPERATURE: ANALYSIS and SIMULATION- *A Case Study of Udaipur UIT Area*

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ABSTRACT

Despite research undertaken elsewhere, the effects of shifting land use and land cover on land surface temperature (LST) are less known in emerging countries' fast-growing cities. For the investigation, Landsat satellite pictures of the Udaipur UIT area from 1991, 2000, 2013, and 2018 were employed. This study first discovered patterns of land cover changes between periods and analysed their effects on LST; then it used an artificial neural network to simulate land cover changes for 2031; and finally, it calculated their implications on LST in the corresponding periods. Due to the increase of built-up and bare soil regions, more Udaipur UIT areas are gradually migrating towards the maximum temperature zone, and if the current trend continues, nearly the whole Udaipur UIT area will be a UHI in 2031. The findings present a major challenge for urban planners working in similar contexts. However, the technique presented in this paper would help them to quantify the impacts of different scenarios (e.g., vegetation loss to accommodate urban growth) on LST and consequently devise appropriate policy measures.

Keywords: land cover change; land surface temperature; urban heat island effect; NDVI; artificial neural network; Markov chain; Udaipur UIT area.

Introduction

Urban Heat Island (UHI) is a natural phenomenon in which the temperature of the air and ground in a city is higher than in the surrounding areas. Urban Heat Island is thought to be the cause of microclimate warming in cities (UHI). UHI is linked to a number of other local issues, including Heat stress, air pollution, and public health issues are all linked. As a result, it is critical currently to incorporate the UHI challenge into urban development planning techniques to minimise it, in order to reduce urban microclimate warming and improve local livability, public health, and well-being.

The current research focuses on the LST component of the UHI effect and calculates LST in a computer simulation. Because the spatial distribution of LST is a major contribution to the UHI effect, it is necessary to get LST as a first step in the UHI analysis and then to simulate future LST so that UHI mitigation techniques can be implemented.

The majority of the studies have concentrated on past land cover changes and their effects on LST. Though the results of these research are important, they lack the ability to simulate the influence of policy changes on future LST. Even though numerous simulation approaches are available to predict future land cover changes in an area, it is also possible to model future LST in that location, research on the simulation of LST has been restricted to date.

LST simulations can also be used to run theoretical numerical simulations to quantify the effects of proposed policies and plans.

Literature Review

For more than 60 years, urban temperature rises, and the construction of urban heat islands (UHI) have been a source of concern. Nieuwolt (1966) conducted one of the initial UHI experiments in 1964 in the metropolitan southern Singapore. Following that, a slew of researchers (Zhong, 1996; Deosthali, 2000; Kim and Baik, 2002; Giridharan et al., 2004; Weng, 2009; Neteler, 2010; Ogashawara and Brum Bastos, 2012; Grover and Singh, 2015) focused on the topic, focusing on various cognitive difficulties. The intensity of UHI is linked to patterns of land use/cover changes (LUCC), such as the composition of vegetation, water, and built-up, as well as changes in these variables (Chen et al., 2006; Grover and Singh, 2015). Temperature concentration is influenced by both horizontal and vertical urban expansion, building spacing, building materials, position of public places, bus stops, railway stations, large and small industrial hubs, and so on.

Scholars in India have only done a few research, mostly for metropolitan cities such as Mumbai (Grover and Singh, 2015), Chennai (Lilly Rose and Devadas, 2009), Jaipur (Jalan and Sharma, 2014), and Delhi (Jalan and Sharma, 2014). (Mallick et al., 2008; Grover and Singh, 2015). However, no similar work has been done for the tiny towns that have begun to experience heating problems. Monitoring them can help create an early warning system for implementing measures that will either solve or mitigate the difficulties. With this in mind, the current research is focused on the rapidly expanding Udaipur UIT sectors of Rajasthan's Udaipur district. Furthermore, the average density of meteorological stations in Rajasthan, India, is 1/520 square kilometres. It is difficult to do any high-resolution studies linked to air or land surface temperature change with this data since it is too scarce.

High resolution, constant and repeating coverage, and the capacity to evaluate earth surface conditions are all advantages of satellite image-based analysis (Owen et al., 1998). For urban climate studies and other decision support, remote sensing and geographic information systems are regarded as the most responsive and effective tools (Abdel Rahman et al., 2016; Deep and Saklani, 2014). The main goal of this research is to simulate future land surface warming based on changes in land use and land cover.

Study Area

Geographically the area of Udaipur UIT is situated between 240 24’ 58” N and 240 42’ 01” north latitude and 730 34’ 30” E to 730 57’ 15” east longitude. The total area of Udaipur UIT is 57,486 hectares (574.86 sq. km) with a north-south extension of about 32 sq. km and about 37.9 sq. km in the east-west direction. The Municipal Corporation Limit of Udaipur city covers an area of 64. 28 sq. km. with an extension of 24^0 31’ 46” to 24^0 37’ 53” N latitude and 73^0 38’ 57” to 73^0 45’ 55” E longitude.

Udaipur city is situated in the Girwa Tehsil of Udaipur district. Udaipur UIT comprises the UIT area and the UIT area consists of Udaipur City and its nearby 62 villages. In this research, the investigator used “Udaipur City” and “Udaipur UIT area” word as synonyms for each other.

Udaipur City has a unique geomorphological setting and is known as the city of Lakes, Venice of the East. It is in a bowl-shaped basin located on the eastern flank of the Aravalli Mountain ranges in southern Rajasthan at 576 m above the mean sea level. Its geographically bowl-shaped position and rugged terrain created favourable site conditions for the settlements in terms of natural defence and microclimate. Lakes are the distinctive feature of the city that form important infrastructure and give visual/psychological relief in its hot dry environment.

Udaipur is the fifth largest urban centre in Rajasthan. The city has shown a non-uniform pattern of urbanization in the last 130 years. The population of Udaipur city increases annually by about 3 per cent. In 2011, the population in the Municipal Corporation Limit already counts 4,51,735 people. Besides, 1,19,833 people were living outside the Municipal Limit. It is estimated that the population will increase up to 8.30 lakhs in 2022 with a 38.56 per cent growth rate and needs more area for spatial expansion. Moreover, in 1971 the UIT area was only 17.40 sq. km., which increased drastically approximate up to 574 sq. km. shows significant spatial expansion. Thus, monitoring the impacts of spatial and temporal patterns of urban expansion on the environment is critical for sustainable urban planning for a fast-developing cities like Udaipur.

Data Collection

The methodology integrated with this study comprises remote sensing tools as well as spatial and temporal analysis techniques using Land Change Modeler (LCM). The GIS and remote sensing tools were used to classify the satellite data, detect urban changes in the different time frames and simulate future land cover change and LST

Landsat TM, ETM+, and Landsat-8 satellite imageries (1991, 2000, 2013, and 2018) were downloaded from the official website of the United States Geological Survey (USGS) and used to achieve the study's goals. The research region is in Landsat route 143 and row 043. The satellite images were projected using the Universal Transverse Mercator (UTM) projection (within Zone 43 North) and the World Geodetic System (WGS)-1984 datum. The images have a resolution of 30 × 30 m pixels. The downloaded imageries, on the other hand, were converted to a level-one (L1T) terrain-corrected output. Ground control points (GCPs) are used in L1T processing to obtain geometric and radiometric accuracy, while a Digital Elevation Model (DEM) is used for topographic accuracy. In fact, the accuracy of the products is determined by the resolution of the DEM employed and the precision of the ground control points.

Additional data, such as various high-resolution imageries, carto-DEM (10m resolution), topographic maps, socioeconomic and environmental data, and physiographic data, were used to substantiate the findings and predict future scenarios. Google Earth images, existing landcover maps of the area, climate data, and population data were used as auxiliary data in this study. Other supporting data, such as demographic datasets from the 1971, 1981, 1991, 2001, and 2011 censuses, as well as meteorological data, were used to simulate future LST. Secondary data was gathered from the Census, UIT, the study area's Master Plan, the Municipal Corporation, Town Planning, and Meteorological agencies, as well as previous research.

The researchers used GPS to collect almost 2,000 locations in the study area for reliable image classification and data validation.

Methods

The current study's primary goal is to simulate or model future land surface temperatures.

This was accomplished by modelling future land cover changes.

LST and land cover indices have a strong link, according to empirical evidence. Based on the pattern of land cover changes from 1991 to 2000, 2000 to 2013, and 2013 to 2018, land cover maps of the research area were projected for the year 2031. The simulated land cover for each time was used to create four land cover indices: NDVI, NDWI, NDBI, and NDBaI.

Land Surface Temperature Retrieval

Geometrically adjusted TM, ETM+, and Landsat-8 thermal infrared (TIR) channels (band 6 in TM and ETM+, and Band 10 and 11 in Landsat-8 OLI TIRS) are used to calculate surface radiant temperature. The TIR band records radiation from the earth's surface with a spectral range of 10.4-12.5 µm.

The LST was measured from the individual thermal images and was compared between different periods. Based on the literature, different retrieval methods of brightness temperature from the TM, ETM+ and OLI_TIRS images were applied. The obtained temperature values above are Refrenced to a black body. Therefore, corrections for spectral emissivity (e) become necessary. These can be done according to the nature of land cover (Snyder et al., 1998) or by deriving corresponding emissivity values from the Normalized Differences Vegetation Index (NDVI) values for each pixel. The emissivity corrected land surface temperatures (St) have been computed using the equations.

Zones of Heat

The temperature values in this study varied from 26.2 °C to 56.78 °C, which were then divided into six categories (<30 °C, 30 °C to <35 °C, 35 °C to <40 °C, 40 °C to <45 °C, 45 ° C to <50 °C, and ≥50 °C).

Derivation of NDVI, NDWI, NDBI, and NDBaI from the Landsat Imagery

As indicated earlier, four land cover indices were derived in this research including NDVI, NDWI, NDBI, and NDBaI. The following formulas, from the literature, were used to derive their scores (Chen *et al.,* 2002). The NDVI map is prepared using the formula given below.

$NDVI = \frac{Re\,d - NearInfraRed}{NearInfraRed + Red}$
$NDWI = \frac{NearInfraRed - MiddleInfraRed}{NearInfraRed + MiddleInfraRed}$
$NDBI = \frac{MiddleInfraRed - NearInfraRed}{MiddleInfraRed + NearInfraRed}$
$NDBaI = \frac{MiddleInfraRed - ThermalInfraRed}{MiddleInfraRed + ThermalInfraRed}$

Modelling of Urban Land Use

SA number of LULC models have been developed; however, determining which one provides the most accurate depiction is difficult (Wu and Webster 2000; Chang, 2006). Among the number of land use modelling tools and techniques, the commonly used models are the modelling techniques embedded in Terrset.

Land Change Modeler (LCM), Cellular Automata (CA), Markov Chain, CA Markov, GEOMOD, and STCHOICE (Stochastic Choice) are some of the programmes available (Eastman, 2006). The LCM in TERRSET programme was employed in this investigation.

Prediction of Land Cover Change in the UIT Area of Udaipur

The modelling methodology presented above was created to estimate the LULC of Udaipur UIT area in 2018, based on LULC transitions that happened between 2013 and 2018. The modelling assumption, as previously indicated, was that the sort of development that occurred between 2013 and 2018 would be comparable. It's also worth noting that the model variables-distance from current built-up areas and distance from main roadways have been made dynamic. As a result, the modelling technique takes into account the built-ups' dynamism, as new built-ups are more likely to arise near existing built-ups.

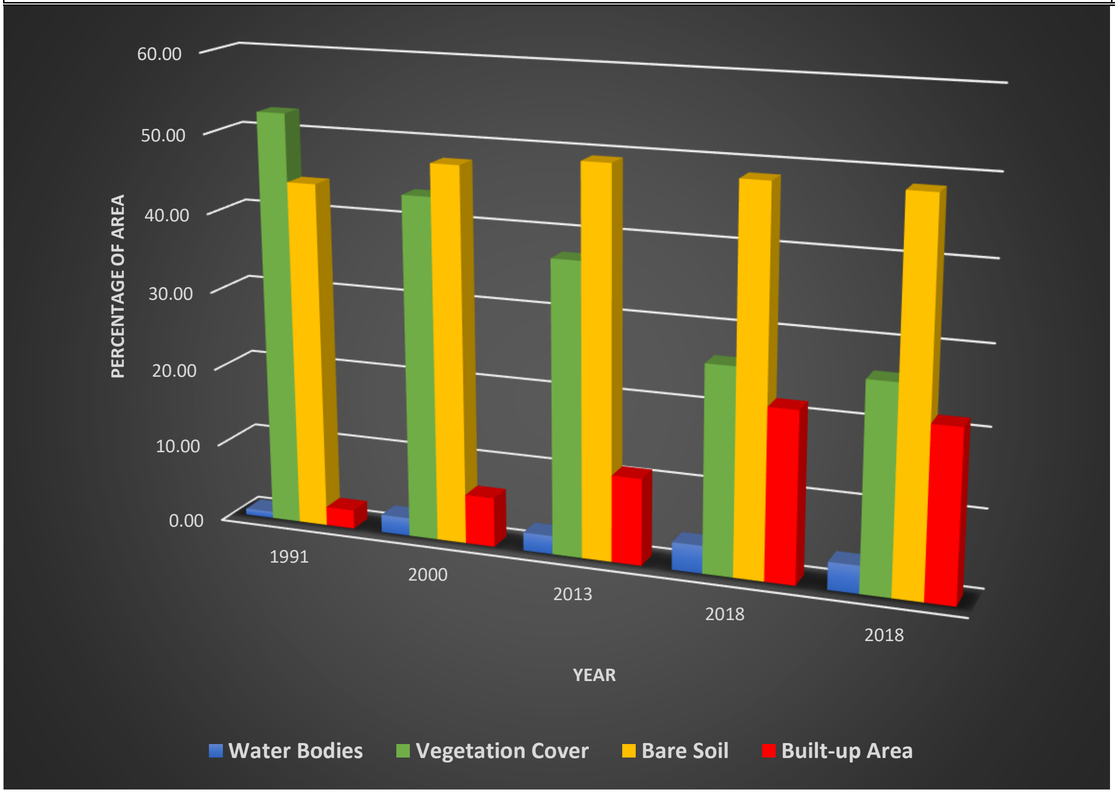
The anticipated roadways for 2022 and 2031 were also incorporated to the model as new infrastructure. As previously said, the investigator additionally employed an incentive and restrictions map to forecast the Udaipur UIT area's scenario for 2031. The Cramer's Value for distance from roadways variables was also high enough to positively affect modelling to consider dynamism rather than only the history from 1991 to 2018. According to Eastman (2006), proximity to roadways is often a very substantial determinant in landcover change. It was interesting to analyse the pattern and tendency of the change in long-term forecasting after calibrating the model and analysing its validity. As a result, a 2031 projection for the Udaipur UIT area has been made. (Map-2). Though the model's prediction power is valid, ecological and human systems' behaviour is very unpredictable due to their intrinsic complexity. Modeling complex systems is fraught with risk, especially in the most rapidly rising cities. The treatment of uncertainty, on the other hand, is outside the scope of this research. Another aspect the researcher wants to emphasise is that this model is not an aim in itself, but rather a tool that gives people a new perspective on the effects of the built-up area sprawling in the Udaipur UIT area.

Results and Discussion

LAND COVER CHANGE PATTERNS

Figure 1 depicts the distribution of land cover in the Udaipur UIT area across the three time periods studied in this study (1991-2000, 2000-2013, and 2013-2018). The figure shows two distinct trends: (a) built-up area and bare soil rose gradually over time; and (b) vegetation cover decreased gradually. More specifically, between 1991 and 2018, the built-up area rose by 9 times. Two facts, however, are not explained by **Figure-1.**

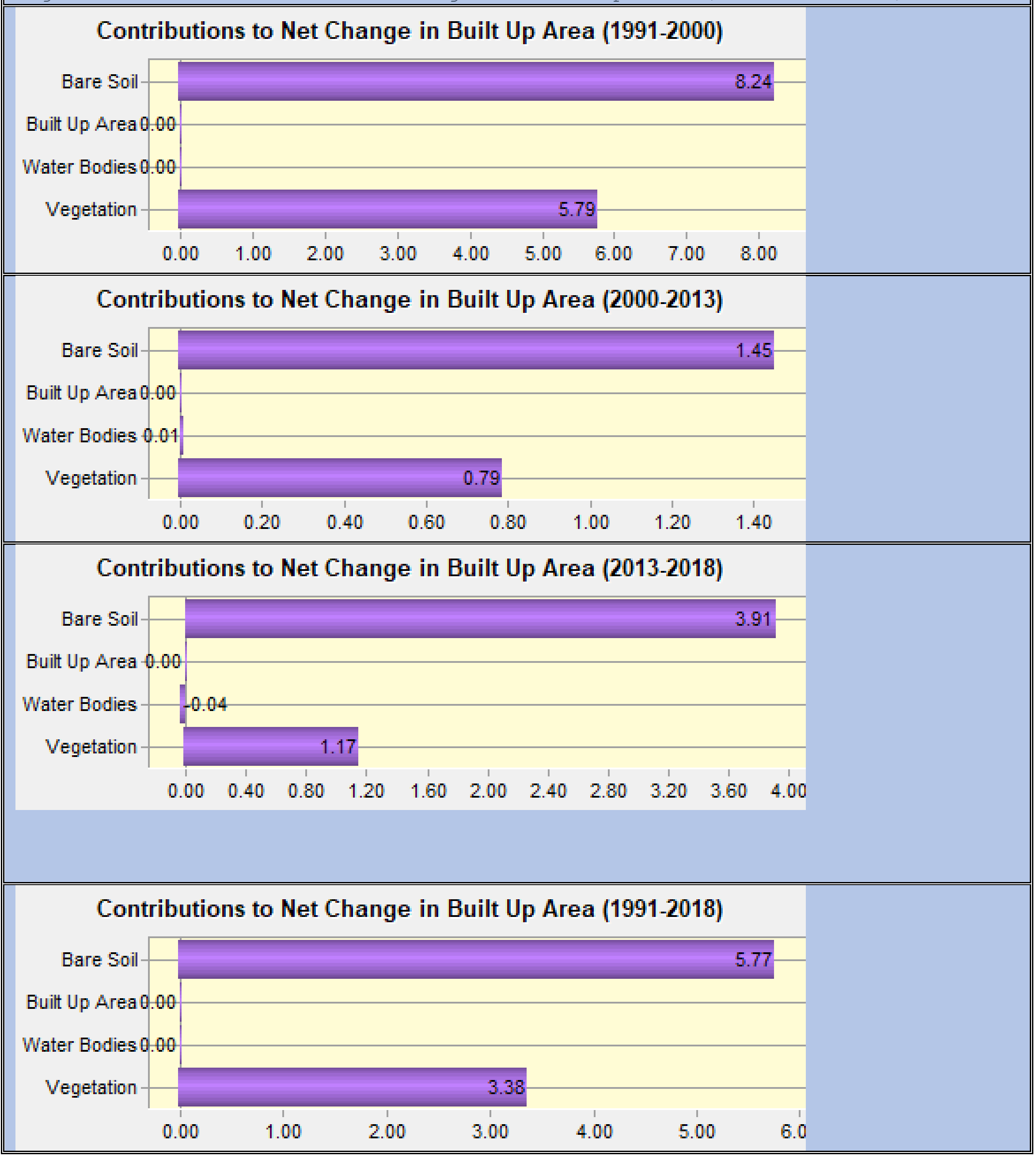
Figure-1 Percentage of Land Cover Types in Udaipur UIT Area



First, it is unclear whether the built-up areas were only the receiver of lands from other types or donors as well to other types (e.g., converted from built- up to water body). Second, the patterns of conversions like the extent of conversion from one category to the others). To understand these relationships, further analyses were conducted (**Figures-2**).

In each of the three time periods, there was a large increase in the built- up area category (e.g., 1991-2000; 2000-2013 and 2013-2018). This signifies that portions of the other land cover classes have been changed to built-up land cover. However, a substantial change occurred in the bare soil category in all the three periods.

Figure-2 Contributions to net change in Built-up Area (Unit % of Area)



This land cover category both gained and lost lands in substantial amount in each period. The findings also exhibit a noteworthy loss in vegetation cover in all the three periods. **Figure-2** reveals the conversion patterns between the categories. It shows that bare soil was the main contributor to forming the built-up areas followed by vegetation coverThe analysis of the predicted map of Udaipur City- 2031 indicate that the growth trend of Built ups in the coming eighteen years are likely to keep the pace of expanding at an alarming situation.

The analysis of the predicted map of Udaipur City- 2031 indicates that the growth trend of Built ups in the coming eighteen years is likely to keep the pace of expansion at an alarming situation.

Table 1 Comparison of the Existing and Expected LULC of Udaipur City-2031				
Land Use Class	Area (ha) 2018	Area (ha) 2031	Expected Change in 2031	
			in hectare	In %
Water Bodies	2029.68	2029.68	0.00	0.00
Vegetation Cover	15090.48	11367.63	3722.85	-24.67
Bare Soil Area	27880.83	18546.30	9334.53	-33.48
Built-up Area	**12485.70**	**25543.08**	**-13057.38**	**+104.58**

The built-up area would grow by two times its current size. The bare soil land would shrink by approximately 33.48 percent of its current area. The model also showed a 24.67 percent drop in the area of Vegetation Cover. The spatiotemporal dynamics of the built-up area can be clearly deduced from table (Table 1), which shows that while the percentage of built-up area was only 14.49 percent in 2018, it is expected to increase to 37.04 percent by 2031.

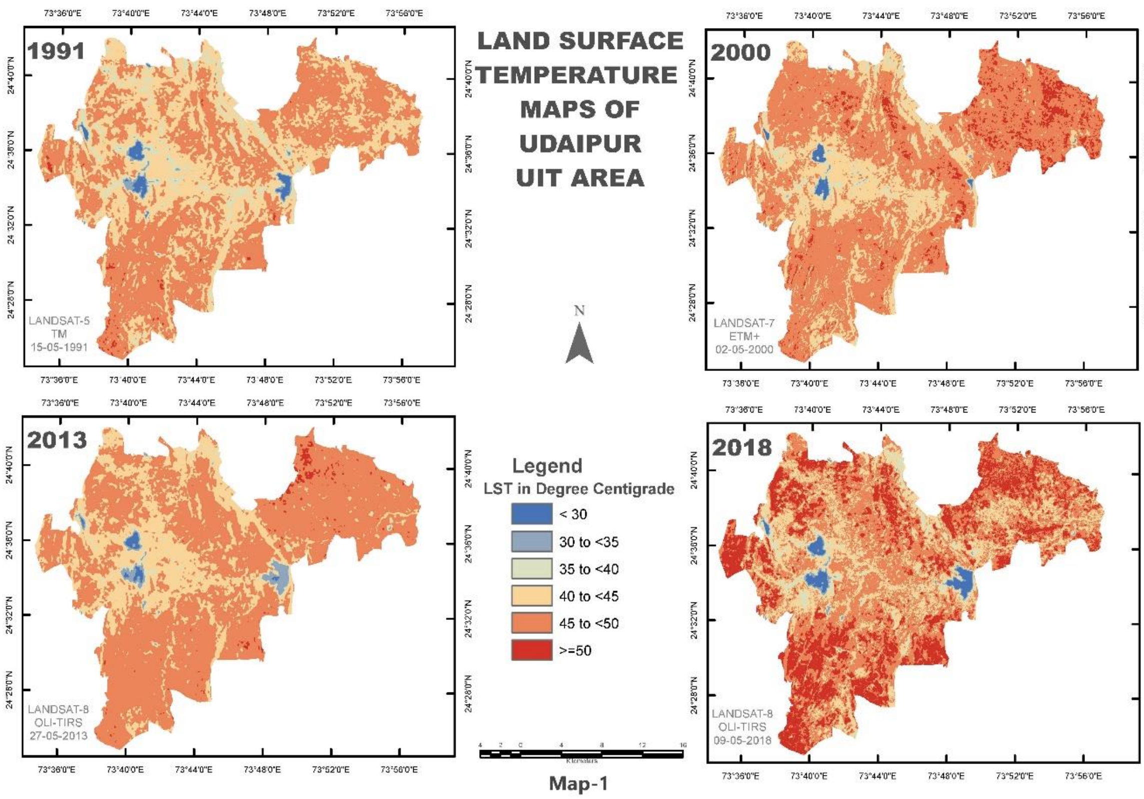
Table 2 Spatio-temporal Dynamism of the Built-up Area

LULC Type	1991		2000		2013		2018		2031	
	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
Non-built-up	56104.74	97.60	53861.13	93.69	51124.5	88.93	45000.99	78.28	31943.61	55.57
Built-up	1381.95	2.40	3625.56	6.31	6362.19	11.07	12485.7	21.72	25543.08	44.43
Total	**57492.79**	**100.0**	**57492.29**	**100.0**	**57492.14**	**100.0**	**57492.44**	**100.0**	**57492.4**	**100.00**

The transition between land classes over the last 37 years, as well as the shift that would occur if the situation remained unchanged, clearly shows that built-up area has increased while vegetation cover and bare soil areas have decreased.

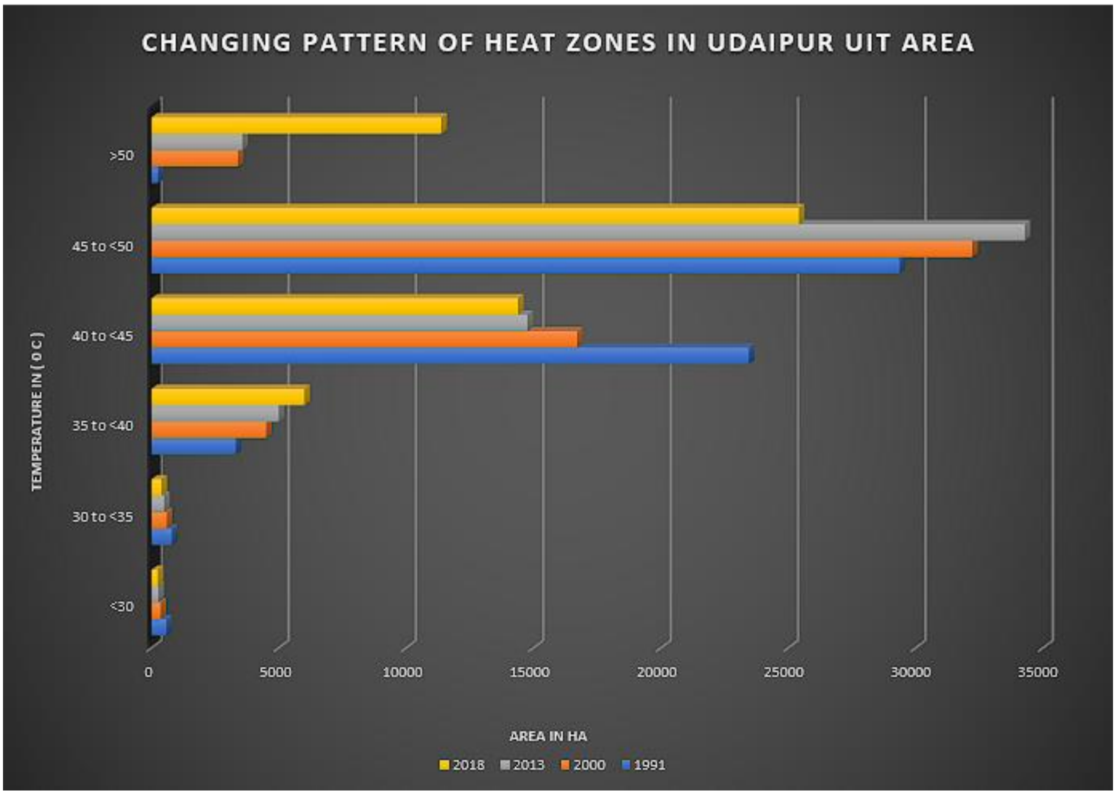
CHANGE IN LAND SURFACE TEMPERATURE

Map 1 shows the patterns of LST changes in the four periods (1991, 2000, 2013 and 2018). The results show that the LSTs ranged from 26.2° C to 53.8° C, 26.3° C to 54.4° C, 29.1° C to 52.1° C and 27.3° C to 56.7° C. **Figure- 3** depicts that the area of study area fell within the lower temperature zones (< 30^0 C to < 35^0 C) and constantly decreased in the four periods of the present study. Whereas, the area



under the temperature zone of 35^0 to 40^0 C constantly increased during the same periods. Around 0.44 per cent of areas of Udaipur UIT experienced a temperature greater than 50^0C

Figure- 3 Changing Pattern of Heat Zones in Udaipur UIT Area

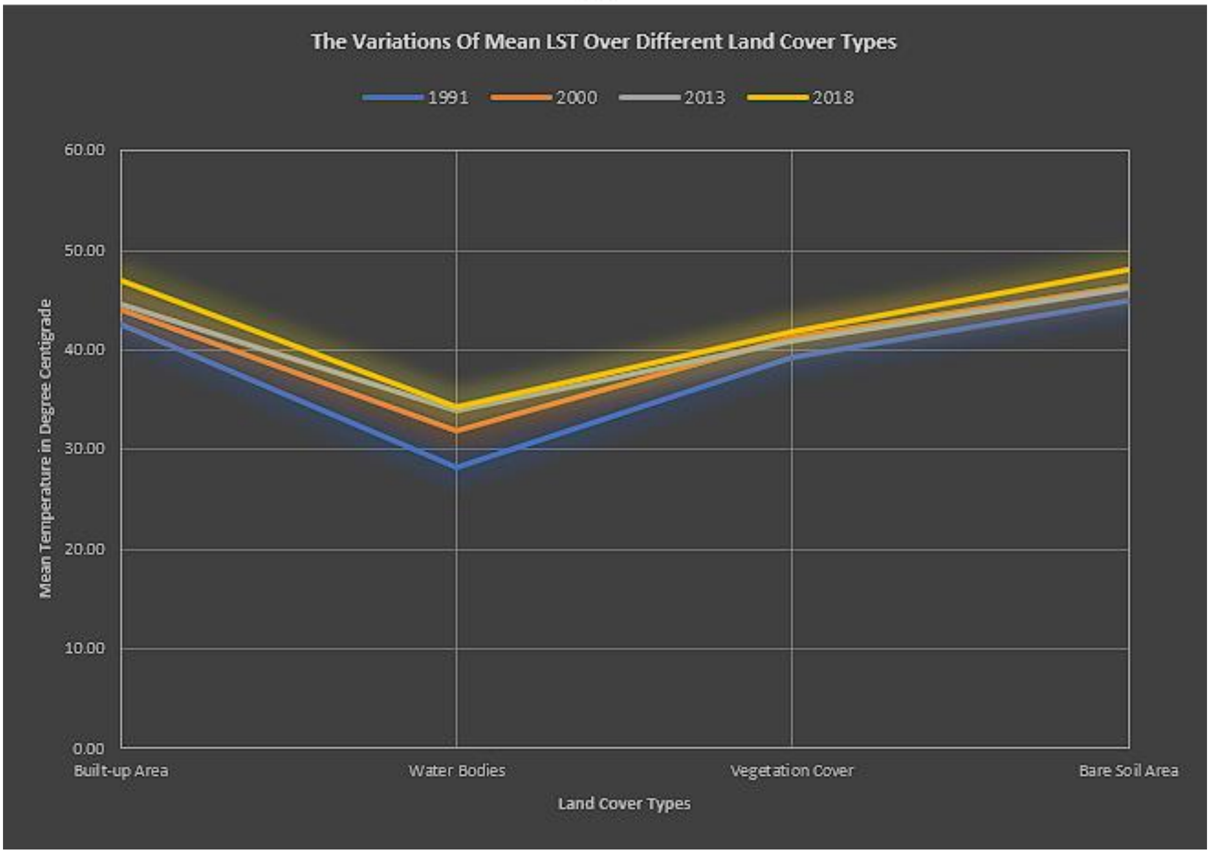


in 1991, which was found to increase to around 19 per cent in 2018. In 1991, almost half part of the study area was under the lower and moderate temperature zones (< 45^0 C) that decreased to one-third and moved into the higher temperature zones (> 45^0 C) in 2018.

VARIATIONS IN TEMPERATURE FOR DIFFERENT LAND COVER TYPES

Investigating the relationships between thermal signatures and land cover types is the best way to assess the impact of land cover changes on LST. In each of the four eras, **Figure-4** summarises the average LST values by land cover type. In all four times, the built-up and bare soil land had the highest LST, followed by vegetation cover and water body. The data suggest that by replacing natural vegetation with non-evaporating, non-transpiring surfaces, built-up areas raise surface temperatures. Furthermore, as shown in **Figure-3,** the LST increased for all land cover categories (including vegetation) during the periods, indicating that the urban warming effect was at work—otherwise, temperature for vegetation would not have increased. The findings in **Figure-3** are sufficient to establish the urban warming phenomenon in the Udaipur UIT area.

Figure-4 The Variations of Mean LST Over Different Land Cover Types



RELATIONSHIP BETWEEN TEMPERATURE AND LAND COVER INDICES

In order to establish quantitative correlations between LST and the indices, four land cover indices (e.g., NDVI, NDWI, NDBI, and NDBaI) were developed. In this study, a higher degree of LST was found to be associated with a lower NDVI, as stated in the literature. In 1991, the NDVI was between -0.25 and +0.88, but by 2018, it had dropped to between -0.48 and +0.71. As a result, the NDVI in the Udaipur UIT area has reduced over time.

This study also discovered that the NDWI and NDBaI values fell over time, implying that both the water content in vegetation and the bareness of the soil decreased. From 1991 to 2018, the LST and other indexes' correlations and linear regression equations were determined. LST has a positive association with NDBI and negative relationships with NDVI, NDWI, and NDBaI, according to numerous correlation and regression analyses.

SIMULATING THE FUTURE LAND COVER DYNAMICS

The primary goal of this study was to model future LST in the Udaipur UIT area. To achieve the goal, the future land covers of the area were first simulated. The MLP Markov Chain model was used to predict land cover for 2031, as previously described. Map 2 depicts the simulated land cover. It's worth noting that in 2018,
21.72 percent of the Udaipur UIT area was classified as built-up. According to the modelling results, in 2031, 44.43 percent of the Udaipur UIT area will be changed to "built-up area" land cover type. (**See Map 2**)

SIMULATING THE LST MAP OF THE FUTURE

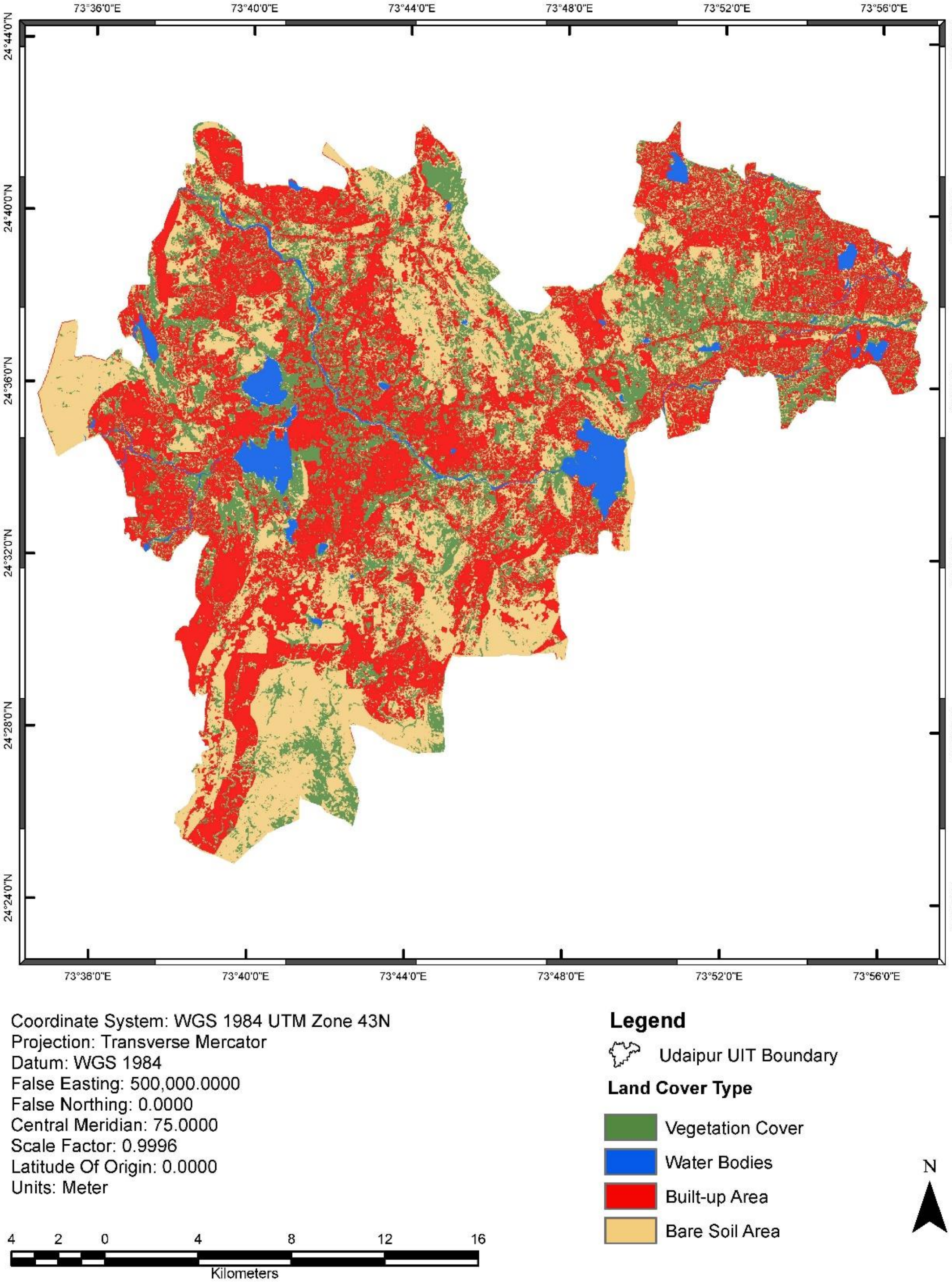
Map 3 depicts the simulated LST for 2031. In 2031, about half of the territory of Udaipur UIT is expected to be in the highest temperature zone (>50 °C). It's worth noting that in 2031, just about 2% of the Udaipur UIT will enjoy lower temperatures (<30^0 C).

DISCUSSION

This study simulates the effects of changing land cover on land surface temperature (LST) in the Udaipur UIT area for the year 2031. Several studies have looked into the impact of changing land cover on LST (Liu, L, 2011). On the other hand, there is only a few research works that models future urban growth (Tewolde, M.G.,2011; Zeug, G.,2010). This study is the first to combine both methodologies and estimate LST based on simulated land cover changes. This study looked at the observed association between land cover changes and LST in four time periods (1991, 2000, 2013, and 2031) for the same area, in addition to the simulated LST. The observed associations were found to be consistent with the literature's well-established results that:

(a) For all four times, the highest temperature was found to be connected with built-up and bare soil areas, while the lowest temperature was found to be associated with water bodies and vegetated areas inside the Udaipur UIT area (Weng, Q., 2001).

MLP MARKOV MODEL SIMULATED LAND COVER MAP OF UDAIPUR UIT AREA-2031



Map-2

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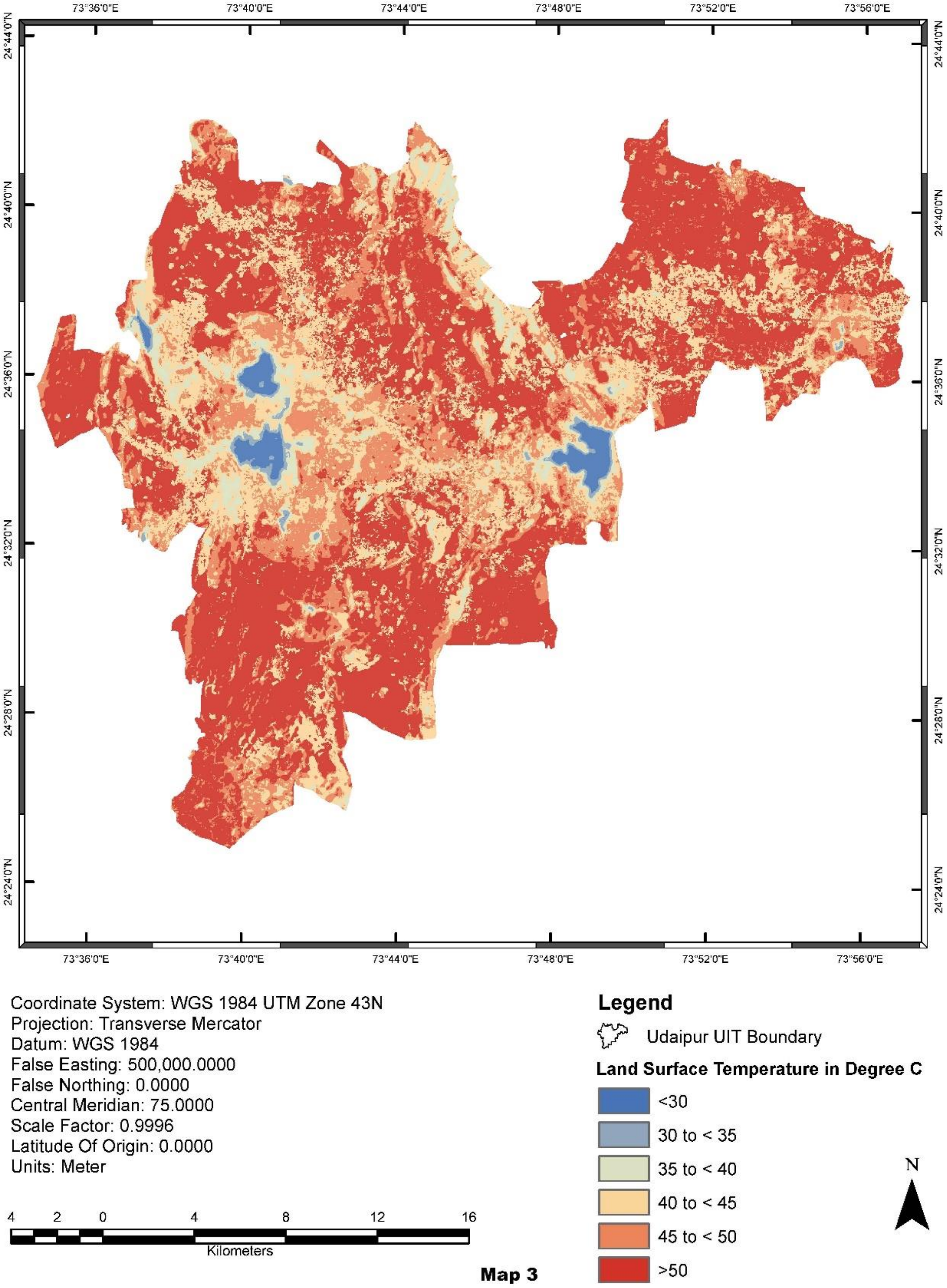
SIMULATED LAND SURFACE TEMPERATURE MAP OF UDAIPUR UIT AREA-2031



Map 3

(b) Over the periods, built-up areas developed dramatically (nine fold) at the expense of natural cover, resulting in more regions falling under the higher temperature zones.

(c) In the Udaipur UIT area, a progressive increase in temperature was observed for all land cover categories, implying an urban microclimate warming impact (Ren, 2008). and

(d) Regression analysis revealed a positive relationship between LST and NDBI, as well as a negative relationship between LST and the other three land cover indices studied in this study (e.g., NDVI, NDWI, and NDBaI) (Weng, Q.,2006).

Given that the observed associations' conclusions are compatible with the literature, the simulated relationships are thought to be defendable because they are based on well-known methodologies in the literature- MLP Markov. The model's simulation results were determined to be a real source of concern for policymakers and urban planners in the Udaipur UIT area. The findings presented in this research show

show that within the research region, there would be no spatially scattered sporadic UHI; rather, the entire Udaipur UIT area would become a UHI. It should be noted that urbanisation is the primary driver of land cover changes and, as a result, LST. However, unless a radical decentralisation policy is implemented, it will be difficult to halt or reverse the urbanisation process in the Udaipur UIT area, which contains all of the key opportunities (e.g., jobs) and services (e.g., hospitals/education) in Rajasthan's southern region. Expansion control measures (e.g., green belts, the creation of artificial water bodies) can be used to assist reduce the UHI effect by containing growth. Furthermore, regulations should not be limited to merely managing horizontal growth. Vertical expansion (e.g., building height) can also produce LST, as previously mentioned. Additional consideration of new urbanism (e.g., green building) concepts during the planning approval (or development assessment) stage of development would also aid in lowering LST in the study region (Kibert, C.J.,2012).

Despite the fact that the results are informative, they should be interpreted with caution because they were obtained from satellite imageries taken in the same month but for separate dates. Using more real datasets, future research should strive to validate the conclusions revealed in this study. Furthermore, while UHI and LST were frequently used interchangeably in this study, they are not the same concepts; rather, LST is regarded to be one contributing factor to UHI. UHI requires data from a comparative geography (e.g., rural vs. urban), which was not taken into account in this study. In order to simulate the UHI effect in this scenario, future research should strive to expand the study region by integrating the rural/ less urbanised surrounds of the Udaipur UIT area.

CONCLUSION

To the best of the lead investigator's knowledge, this is the first study to demonstrate a strategy for predicting future land surface temperatures (LST) in urban areas using simulations based on observed connections between land cover and LST changes in the Udaipur UIT area. The following findings were drawn as a result of this:

(1) Between 1991 and 2018, the quantity of built-up area expanded ninefold, and by 2031, it is predicted to rise double.

(2) There is a substantial negative relationship between NDVI and LST, but a large positive relationship between NDBI and LST, implying that vegetation and water bodies lower the LST while expanding built-up areas causes LST. As a result, future city planning should place a greater emphasis on urban greening.

(3) Due to the increase of built-up and bare soil regions, more Udaipur UIT areas are gradually migrating towards the maximum temperature zone, and if the current trend continues, nearly the whole Udaipur UIT area will be a UHI in 2031. As a result, a compact-town-style decentralisation of metropolitan areas (e.g., satellite-towns) could be a viable option for preventing the establishment of large-scale urban heat islands in the future.

(4) For the derivation of future LST, the study used a single land cover index (e.g., NDVI) and a simple regression equation. It's feasible that the various land cover indices may be employed as independent factors in a multiple regression equation model to calculate the LST in a more robust method, perhaps through factor analysis. The Principal Investigator will take them into account and improve the model offered here.

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