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Analysis of changes in land use land cover and seasonal land surface temperature using remote sensing data and GIS in PMC Area, Patna, Bihar

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Abstract- Land use land cover (LULC) has significantly affected land surface temperature (LST) due to rapid regional and global urbanisation. Due to the urban heat effect, the dynamic changes in land surface temperature. This research examines the analysis of modification in land use land cover and LST conditions in the PMC, Patna, Bihar. We have employed the Remote Sensing (RS) approach and GIS methods on satellite-driven data of the study area. Further ground truthing has been done to authenticate the changes concerning LST and LULC from 2007-2017. It examines its association with changes in LULC. Land use land cover map of PMC, Patna was developed by using Indian Remote Sensing (IRS) LISS IV Satellite images of the year 2007-2018 with 5.8-meter spatial resolution. For LULC, the maximum likelihood equation and the supervised classification techniques were implemented to classified two multi-date or multi-temporal satellite images. Then temporal changes were identified by comparing two LULC maps formed independently between 2007 and 2017. The seasonal variations of land surface temperature (LST) maps were developed applying Moderate Resolution Spectroradiometer (MODIS) LST data of 2007 and 2017 acquired from NASA LPDAC to address the variability of land surface temperature. In the recent past, due to imprudent land management, rapid population expansion and their activities related to urban/ economic development caused significant natural landscape changes. Thus, PMC Patna has become environmentally sensitive to ecological and environmental deterioration risks. This study aims to analyse changes in LULC and LST in Patna Municipal Corporation, Patna. It is decisive for updating significant modification of LULC and variation in LST over time 2007-2017 in the study area. The research analysis reveals the substantial changes in land use, land cover, and LST developed in the PMC area, Patna. The result shows significant changes designed in the built-up area by increasing (+) 21.86 %, and cropland and vegetation area declined by (-) 8.95 % and (-) 5.8 %, respectively, between 2007-2017. The LST results indicated land surface temperatures varied from 1.02°C to 3.08°C from 2007 to 2017. These results acknowledged that the changes in LULC have significantly influenced the LST in the PMC area, Patna. It could result from cropland and vegetation cover changes between 2007 and 2017, as acknowledged in the LULC change. The enlargement or extension of built-up area and decrease in the vegetal landscape is human-induced, resulting in temperature changes since 2007. The study shows that changes in different types of LULC due to an increase in anthropogenic activities with the expansion of urban landscape, along with changes in cropping patterns, can degrade the spatial pattern of urban land surface temperature (LST). This study will benefit future land use and urban development action plans. The study will provide helpful guidelines for environmental engineers and planners to consider expanding urban built-up area enlargement and spatial configurations without proper LULC planning and conserve natural ecological sustainability.

Key words: False Color Composite, Geographical Information System, Image processing, Land use Land cover, Land Surface Temperature, Remote sensing, Resourcesat, Satellite Imagery.

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INTRODUCTION

LULC and LST change analysis are essential to land development and management activities. LULC and LST will provide helpful guidelines for environmental engineers and planners to consider expanding urban built-up area enlargement and spatial configurations without proper LULC planning and conserve natural ecological sustainability. The importance of PMC, Patna, the capital of Bihar, is placed on the southern bank of the river Ganges. The PMC, Patna, is a fast-developing city and an imminent place for trade and business in the recent past. The movement of people from different locations of Bihar to search for jobs, education facilities and work caused the rapid population inflation of PMC, Patna.

The hypothesis of applying RS digital data in change analysis gives the result of the differences in the landscape due to modification in the digital or pixel values and the LST variation/distributions in a particular area.[1] The RS and GIS techniques contribute to distinguishing the outcome of changes in LULC and LST after analysing satellite images.[1] The analysis of LULC and LST mapping using RS and GIS approach due to its favour of time-consuming and cost benefits rather than the traditional field methods. Ground information can be captured instantly, directly, and repetitively, and image analysis is done more quickly and cost-effectively than traditional field methods.[2]

The rapid modification of LULC caused a significant impact on the local environment to the regional and global climate due to human intervention in the terrestrial environment[3]. The annual temperatures have continuously increased worldwide for the last 150 years.[3] Some study reveals that alteration of land and changes in temperature caused a negative impact on climatic condition on a global scale.[4] The environmental deterioration is due to rapid urbanisation and city expansion, which depletes the vegetation, agricultural land, and water bodies[3]. Recent studies show climate change is happening because of modifications/changes in LULC.[3] Anthropogenic activities significantly contribute to urban expansion, adversely affecting the natural environment.[3] The analysis of this research has notable changes in LULC and LST that developed in the study area between 2007-2017, associated with the enlargement of built-up land and economic growth.[5] These modifications rate will advance in the forthcoming as expected.[1] These rapid modifications in the landscape will influence nature and human sustainability.[1]

The specific and comprehensive data on LULC and LST is essential for many developing activities.[6] This study aims to determine the changes in LULC and LST between 2007 to 2017. We applied RS and GIS methods to correlate two disparate years of satellite imagery of the same sensor.[7] LISS IV satellite imagery of 2007 and 2018 with 5.8 m spatial resolution were used to examine the temporal changes in LULC.[8] For analysis of changes in Land Surface Temperature (LST/E) of the study area, Moderate Resolution Spectroradiometer (MODIS) LST satellite data for 2007 to 2017 was procured from the NASA LPDAC online to addressed the variability of land surface temperature.[9,10] The supervised maximum classification method was adopted to analyze two multi-date satellite imageries and develop LULC maps. Then temporal changes were identified by contrasting two LULC maps of 2007 and 2017. The LULC maps were composed separately.[11] MODIS LST satellite data were applied to determine Land Surface Temperature (LST) changes. To generate LST variations of the study area during the study period, bands 31 and 32 were for daytime observation of Land Surface Temperature. The main aimed to analyse the LST variations to show the relationship between the changes in LULC and LST. The outcome of the analysis indicated that the changes in LULC features are influencing the LST over time in Patna Municipal Corporation (PMC), Patna, between 2007-2017/18.[10,11] This study will benefit future land use and urban development action plans. The study will provide helpful guidelines for environmental engineers and planners to consider expanding urban built-up area enlargement and spatial configurations without proper LULC planning and conserve natural ecological sustainability.

METHODOLOGY

Location of the Study Area

PMC, Patna is the most populous growing city in India, and it is the headquarters of Patna district and the capital of Bihar state. The area is located on the southern bank of the river Ganga at a Latitude between 25° 33’22’’N to 25°39’20’’N and a Longitude between 85°04’50’’E to 85°16’03.55’’E. The study area exists in SOI toposheet nos. 72G/2 & 72G/6. Physiographically the topography of the study area is flat, and a part of the alluvial floodplain

deposits part of the Ganga basin at the height of 53 m/ 173 feet above MSL: Figure 1 and Figure 2 show the location of the study area. The total area of PMC, Patna, is 109.218 sq. km.[12] The total population of PMC, Patna is 16, 87,828 as per the 2011 census with its seventy-two wards, as per 2011 census.[12,13]

Satellite data obtained from NRSC/NDC data centre/ User Order Processing System [UOPS]. IRS-P6 LISS-IV data of 2007 and IRS R2A LISS-IV data of 2018 (Figure.1 and Figure.2) with spatial resolution 5.8 m was used to examine the temporal changes in LULC types. The images were geo-rectified WGS 84 Datum and UTM Projection.

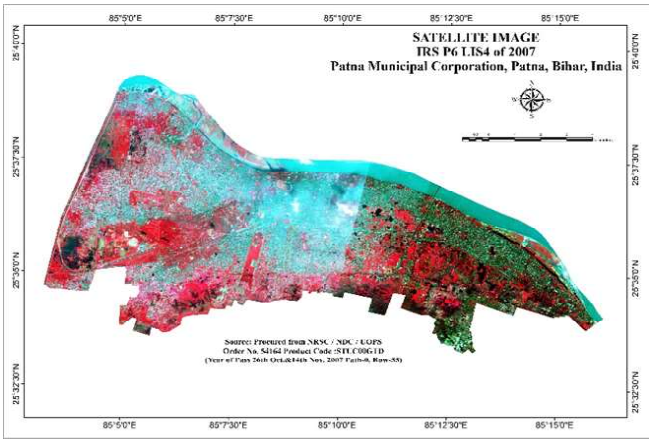

Fig.1- Study Area Map (LISS-1V Image/2007)

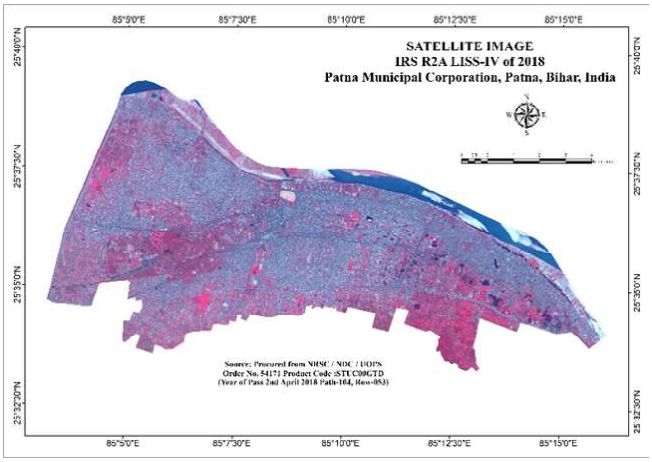

Fig.2- Study Area Map (LISS-1V Image/2018)
Source: Procured from NRSC/NDC/UOPS

IMAGE PRE-PROCESSING

Image Classification

The Image Classification method was used to analyse multi-pixel satellite images. The classification procedure can arrange or categorise the DN values in an image into separate classes.[11,12]

Supervised Classification

We applied a supervised classification method for ground inspection at particular locations in the study area. In the supervised process, first established the training set and derived a pixel value of the spectral image. The classified pixels developed into different LULC types.[12]

Maximum Likelihood Classifier

The supervised maximum classification procedure was used to generate five different LULC maps. This Likelihood Classifier method is worked on a probability function. This activity determines the variance and covariance of each class.[11,12] The maximum classifier is described as follows.[12,14]

$$L_k(X) = \frac{1}{(2\pi)^{\frac{n}{2}}|\Sigma_k|^{\frac{1}{2}}} \exp\left[-\frac{1}{2}(X-\mu_k)\Sigma_k^{-1}(X-\mu_k)^t\right]$$

Where n: represents the number of bands
X: n bands of image data
Lk(X): class k likelihood of X
μk: class k mean vector
Σk: matrix of class k variance-covariance
|Σk| : determinant of Σk

LST Method

We applied GIS Spatial Analyst mathematical tool and calculated the surface emissivity for each image. MODIS LST satellite data (bands 31 and 32) were used for daytime observation to address the variability of land surface temperature.[9,10] This study uses the 250m resolution datasets to estimate Land Surface Temperature (LST).[10] The temporal distributions of LST were evaluated at the season and month scales to understand the better relationship in the study area. The procured MODIS data were reprojected UTM projection and datum WGS 84. The coordinates system of the satellite data was converted

Table 1- Technical Specification of Satellite Data

Satellite	Sensor	Acquisition Date	Spectral Band	Resolution (m)	Path/Row
(IRS P6)	LISS IV	26.10.2007 14.11.2007	B2- 0.52-0.59 B3- 0.62-0.68 B4- 0.77-0.86	5.8	102/56 102/55
(IRS R2A)	LISS IV	02.04.2018	B2- 0.52-0.59 B3- 0.62-0.68 B4- 0.77-0.86	5.8	104/53

into degrees Celsius (°C). We extracted pixels' surface emissivity from satellite-derived surface emissivity. Then the measured temperature is transformed into a standardised temperature by dividing them with satellite-derived surface emissivity at each pixel. The standardised temperatures were used to interpolate LST using the Kriging method. Finally, we converted interpolated temperature map to a surface temperature map by multiplying it with the satellite-derived surface emissivity.

CHANGE ANALYSIS OF LULC

Classification/Post-Classification Change Analysis

The pre and post-classified LULC images were used to examine the changes and the most crucial technique of getting the changes of LULC. The significance of this technique which reduces the impacts of LULC between multi-temporal data and develops a better matrix of land use land cover changes.

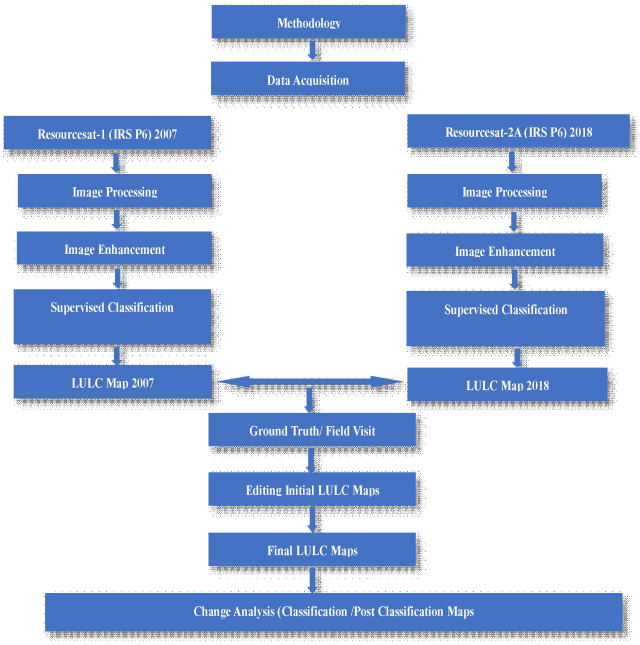

Fig.3- Flow Chart of LULC Method

LST Estimation and Change Analysis

The seasonal variations of land surface temperature (LST) were developed using Moderate Resolution Spectroradiometer (MODIS) LST satellite data from 2007 and 2017. To address the variability of the land surface temperature detected by comparing two LST-derived images, which were produced independently. Validation was done through punctual and spatially distributed for accuracy assessment procedures and through the interpolation Inverse Distance Weighting (IDW) method.

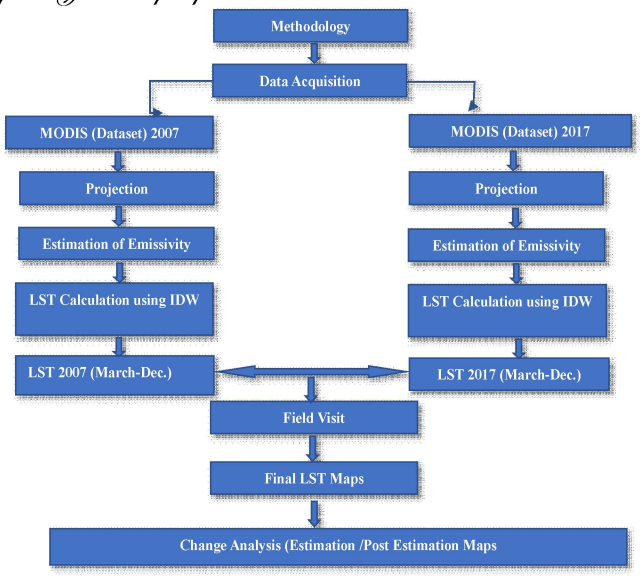

Fig.4- Flow Chart (Methodology)

RESULTS & DISCUSSIONS

Land use Land Cover (LULC)

The outcome of the analysis indicates that the LULC features of the study area have been modified between 2007-2017. The Built-up land has increased by 21.86 %, whereas decreased Agriculture included Fallow Land by 8.95 % and vegetation by 5.8 %. Water bodies and wasteland is also dropping between 2007-2017. These changes are significantly contributed by human concern such as social and economic activities due to improper LULC management. The relative changes are shown below in (Table-2).

The supervised maximum classification techniques were applied to classified two multi-temporal imageries. We categorised different LULC classes such as built-up area waterbodies, agriculture included fallow land, wasteland, and vegetation. Then temporal changes were identified by the contrast between two LULC maps of 2007 (Figure.5) and 2018 (Figure.6). The LULC maps were prepared independently. The accuracy of the LULC map (Pre classified/post-classified) was done through field verification and satellite Image (Google).

Land Surface Temperature (LST)

In this study area, the seasonal (March & December) LST estimation reflected a significant change from 2007 to 2017. The maximum LST was 24.07 °C, whereas the minimum LST was 23.09 °C in March 2007. In March 2017, the maximum LST showed 27.15 °C, whereas the minimum LST was observed at 25.92 °C. The results

Table 2- The comparative study of LULC between 2007-2018

Class Name	LULC Area (2007) (Sq.Km.)	% of LULC Area (2007)	LULC Area (2018) (Sq.Km.)	% of LULC Area (2018)	% Change Between 2007 & 2018
Water Bodies	8.9	7.43	5.18	4.33	(-) 3.1
Agriculture/Fallow Land	31.92	26.66	21.18	17.71	(-) 8.95
Waste Land	16.56	13.83	11.86	9.92	(-) 3.91
Built-up Land	44.67	37.36	70.80	59.22	(+) 21.86
Vegetations	17.49	14.60	10.52	8.80	(-) 5.8
Total area	**119.54**	**100**	**119.54**	**100**	

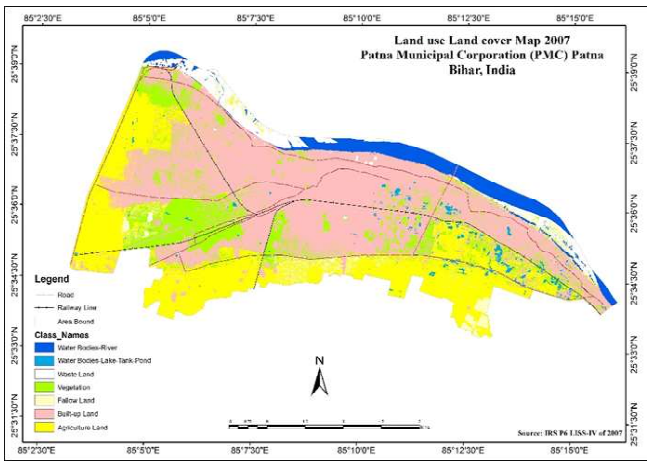

Fig.5- LULC Map (2007) of the Study Area
Source: Resourcesat-1 LISS IV of 2007

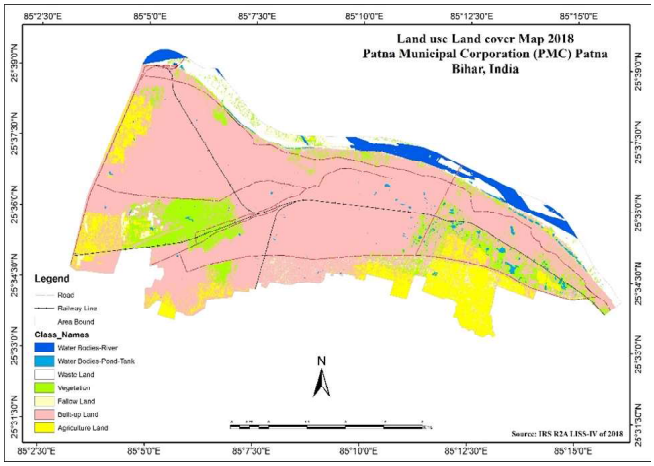

Fig.6- LULC Map-2018 of the Study Area
Source: Resourcesat-2A LISS IV of 2018

Table 3- The comparative seasonal changes of LST between 2007-2017

Land Surface Temp ^{o}C	March 2007 (LST ^{o}C)	March 2017 (LST ^{o}C)	LST Change 2007 to 2017 in March (LST ^{o}C)	December (2007) (LST ^{o}C)	December (2017) (LST ^{o}C)	LST Change 2007 to 2017 in Dec (LST ^{o}C)
Maximum Temp ^{o}C	24.07	27.15	+3.08	17.71	18.73	+1.02
Minimum Temp ^{o}C	23.09	25.92	+2.83	17.17	17.97	+0.8

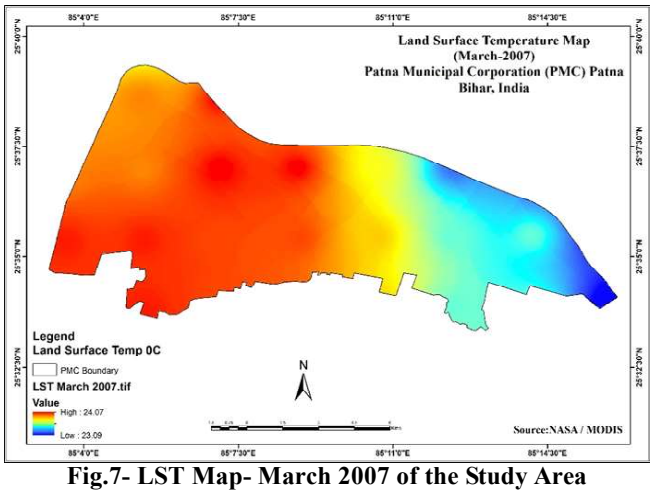

Fig.7- LST Map- March 2007 of the Study Area
Source: Moderate Resolution Spectroradiometer (MODIS) LST satellite data of 2007

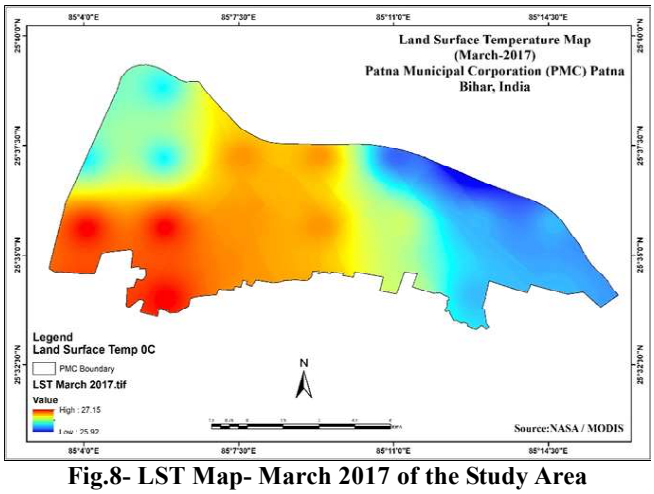

Fig.8- LST Map- March 2017 of the Study Area
Source: Moderate Resolution Spectroradiometer (MODIS) LST satellite data of 2017

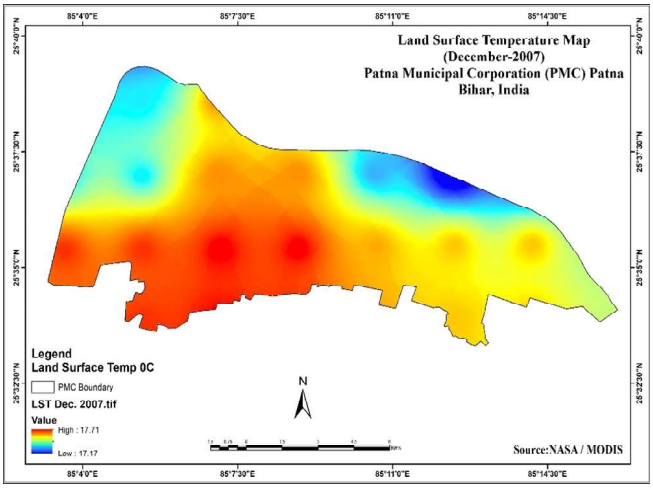

Fig.9- LST Map- December 2007 of the Study Area Source: Moderate Resolution Spectroradiometer (MODIS) LST satellite data of 2007

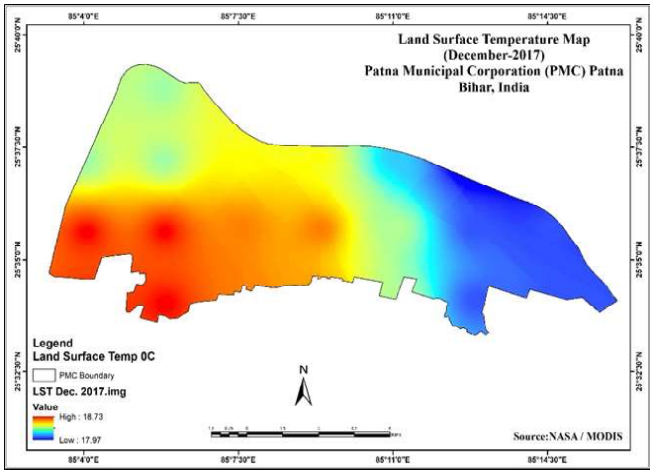

Fig.10- LST Map- December 2017 of the Study Area Source: Moderate Resolution Spectroradiometer (MODIS) LST satellite data of 2017

indicated that LST estimation significantly changed by +3.08°C from March 2007 to 2017. In December 2007, the LST estimation revealed that the maximum and minimum values were 17.71°C and 17.17°C, respectively; in 2017, the maximum and minimum LST was 18.73°C and 17.97°C, respectively. The results estimated that LST estimation significantly changed by +1.02°C in December from 2007 to 2017. The study observed that changes in LULC or landforms, primarily expanding built-up areas and reducing vegetation/ agriculture land related to social and economic concerns, can significantly change LST. The Built-up land has increased by 21.86 %, whereas decreased Agriculture included Fallow Land by 8.95 % and vegetation by 5.8 %. Water bodies and wasteland is also dropping between 2007-2017. It is estimated that significant changes in these classes of LULC are contributing to the rising LST of the study area. Most importantly concluded that replacing natural vegetation and agricultural land with non-evaporating, non-transpiring surfaces like built-up material such as concrete, metal, stone and urban construction can increase LST or surface radiant temperature.[15]

CONCLUSION

PMC, Patna, one of the most vulnerable areas due to rapid changes in LULC due to urban and economic development, will generate or affect Land Surface Temperature. LST increases when the natural LULC is modified or mismanaged without proper planning because LULC is directly proportional to LST. In this study, multi-temporal LISS IV data for LULC classification and MODIS LST/E datasets were used for LST estimation and then detected the changes between 2007-2017, which may be correlated with the findings of the results to understand better LULC influences LST. Change analysis was done by comparing pre-classified/post-classified maps and ground verification. The result showed the main negative changes of LULC that have occurred in the agriculture/ fallow class, vegetation, water bodies and wasteland due to the urbanisation or urban expansion and ultimately influencing the LST. Based on the findings, these negative changes mainly observed rapid enlargement of the built-up area without proper planning and economic concerns. Avoiding LULC changes without appropriate planning, conserving natural ecological sustainability and growing more vegetation would help reduce LST in PMC, Patna.

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