Monitoring the Land Surface and water bodies temperature and its impact on surface water turbidity in Raipur, Chhattisgarh, India

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Abstract. Land use land cover change is the process taking place in different parts of the country throughout the world and is adversely affecting the environment and will continue to affect both directly and indirectly. It has an impact on the water resource in a negative way. Rapid urban growth as a major cause of land-use change is one of the biggest reasons for the rise in surface temperature, and LULC change is one of the major causes of concern throughout the world. In developing countries like India, rapid urbanization is greatly influencing surface temperature and water resources. Surface water bodies are greatly affected by the rapid urban growth, which is taking place in almost all parts throughout the country, especially in the central part of India which is having plain areas. Many studies have been conducted by using the thermal data in integration with the Remote Sensing (RS) and Geographic Information System (GIS) techniques for estimation of Land Surface Temperature (LST), and based on those studies, it can be concluded that changing land use has its direct impact on surface temperature as with increasing urbanization rise in LST has been observed. Therefore, the present study has been done to estimate the impacts of changing LULC on surface temperature and turbidity in surface water using the satellite-derived thermal data, and based on results obtained it can be concluded that areas covered with the settlement, open or barren land have a relatively higher temperature than those of the areas which have plants, and vegetation on and nearby it, also waterbodies with turbid areas are showing relatively higher temperature than that of clear surface water.

Keywords: RS, GIS, Urbanization, Land Use Land Cover Change, Land Surface Temperature.

1. Introduction
Changing LULC due to different human activities is causing changes at local, regional, and global level, such land-use change practices like modern agriculture practices, urban expansion and deforestation etc. are majorly responsible for the degradation of the natural resources [14]. As a major land cover change, urbanization has a great influence on climate change, which has been observed globally. With the increasing urbanization, there is an increase in Land Surface temperature throughout the world [7], [9] It also has its great influence on surface water quality in terms of turbidity as with the rapid urbanization. Hence, it is important to understand the distribution of LST and its relation to Land Use change [8]; also, its temporal variation should be studied in order to understand the mechanism and come to the
possible solution for overcoming the adverse impacts of it [10] It has also been observed that due to rapid urbanization surface water quality is also being adversely affected, and will also be one of the key factors in poor water quality, [13] [20] [25] [2].

The present study was conducted on the major city area of Raipur district, which was formerly recognized as the part of Madhya Pradesh but later in the year 2000, it was recognized as the capital of Chhattisgarh after the formation of Chhattisgarh state. It is also the largest and one of the fast-growing cities of the state which is taking part in rapid urbanization, industrialization, and deforestation which is adversely affecting the land surface temperature and the surface water quality of the whole city. Atal Nagar, formally named as Naya Raipur region is the part of Raipur District which has been recognized as the main area of the city which is going under rapid transformation from natural land cover to into collective form urban materials, like blacktop, concrete, and metal structures which absorbs more heat than that of the natural covers resulting in increased surface body temperature which have its notable ecological effects on the environment and water resources [19] [24].

Landsat series data, which is the longest series of satellite data available freely, has been downloaded from the United States Geological Survey (USGS) and has been used for thermal and land use classification. In order to analyze the land use land cover pattern, a visual interpretation technique has been used. Normalized Difference Vegetation Index (NDVI), Emissivity values from the thermal data in order to estimate the difference in surface temperature, also for analyzing the changes in surface water quality and quantity for monitoring the turbidity of water bodies [15], Normalized Difference Water Index (NDWI) and Automated Water Extraction Index for Study Area (AWEI) [6] has been and on the basis of those changes in the water quality as turbidity is one of the major water quality parameter [17] therefore, for some major waterbodies turbidity on the basis of temperature variation has been analyzed. The above study reveals that these kinds of techniques can suggest better solutions for sustainable development and management.

2. The objective of the Study

The objective of current research is to assess the impact of changing LULC on LST and surface water turbidity using the thermal data. The primary purposes of conducting the study include:

- Determining the change in LST for different Land use cover of the Study area.
- To identify the variation in LST due to LULC for 2000, 2009 and 2019
- Identifying the variation in the surface temperature that occurred due to increasing pollution and turbidity in the study area’s surface water bodies.

3. Study Area

The study area (Figure 1) covers a total area of 485.34 Sq.Km. The major city area of Raipur and Naya Raipur is coming under the Raipur District of Chhattisgarh, with extends from 21.32N to 21.06N latitude and 81.49E to 81.92E longitude. The study area covers fall under 64G/11, 64G/12, and 64G/16 topographical maps of Survey of India on a 1:50,000 scale.
4 Materials and Methodology

4.1 Materials
For conducting this study, Landsat dataset have been used for both detections of LULC change and Surface temperature Estimation as it is one of the longest series data which is freely available to download. After retrieval of LST data from Landsat, (Moderate Resolution Imaging Spectroradiometer) MODIS surface temperature data has been used for validation [23] of results derived from Landsat Data details of the data has been given in Table 1.

Table 1. Data Used and their description

| S.No | Data Used       | Data Description                                                                 | Date & Month | Source                                                                 |
|------|-----------------|----------------------------------------------------------------------------------|--------------|------------------------------------------------------------------------|
| 1.   | LANDSAT-TM      | LT05_L1TP_142045_20090522_20161026_01_T1.tar                                    | 22nd May 2009| https://earthexplorer.usgs.gov/                                        |
| 2.   | LANDSAT-ETM     | LE07_L1TP_142045_20000505_20170212_01_T1.tar                                    | 5th May 2000 | https://earthexplorer.usgs.gov/                                        |
|      |                 | LC08_L1TP_142045_20190518_20190522_01_T1.tar                                    | 18th May 2019|                                                                         |
|      |                 | MOD11A1.A2000126.h25v06.006.201506094601.hdf                                   | 5th May 2000 |                                                                         |
| 3.   | MODIS           | MOD11A1.A2009139.h25v06.006.2016013045513.hdf                                  | 22nd May 2009| https://earthexplorer.usgs.gov/                                        |
|      |                 | MOD11A2.A2019137.h25v06.006.2019150085900.hdf                                  | 18th May 2019|                                                                         |
| 4.   | SOI Toposheet   | 64G/11, 64G/12 and 64G/16                                                      | -            | Survey of India                                                       |

4.2 Methodology
Overall methodology adopted for this research in order to reach the objectives has been represented in the flowchart (Figure 2).
The present study was done for analyzing LULC change and its impacts on the LST and the changes in turbidity of surface water bodies. So, for achieving the desired objectives study was conducted in three parts described below.

**Figure 2. Flow Chart for Adopted Methodology**

4.2.1. *Land Use Land Cover Classification*. Landsat TM & ETM imagery was used for preparing the LULC maps for the year 2000, 2009, and 2019 (Figure 3) using the technique of visual interpretation [22] [1], and then the change detection analysis has been done for each class based on the area changed for all the classified image the results of which have been shown by the method of tabular representation in (Table 2) LULC maps prepared using the satellite imagery have been checked with Survey of India (SOI) toposheets (for feature identification) and with the google imageries for three different years.
Figure 3. Changes in LULC Study area in year 2000, 2009 & 2019

Table 2. Changes in different classes for LULC from 2000-2019

| S.No | Feature    | Area in 2000 (Sq. Km.) | Area in % (2000) | Area in 2009 (Sq. Km.) | Area in % (2009) | Area in 2019 (Sq. Km.) | Area in % (2019) |
|------|------------|------------------------|------------------|------------------------|------------------|------------------------|------------------|
| 1    | Cultivation| 315.98                 | 65.10            | 305.83                 | 63.01            | 222.61                 | 45.86            |
| 2    | Vegetation | 29.25                  | 6.027            | 0                      | 0                | 0                      | 0                |
| 3    | Open Land  | 83.6                   | 17.22            | 95                     | 19.573           | 105.1                  | 21.65            |
| 4    | Waterbody  | 11.32                  | 2.33             | 8.45                   | 1.74             | 7.39                   | 1.52             |
| 5    | Settlement | 45.19                  | 9.31             | 76.06                  | 15.67            | 150.24                 | 30.95            |
|      | Total Area | 485.34                 |                  | 485.34                 |                  | 485.34                 |                  |

4.2.2. Estimation of Surface Temperature. Once the classification of the LULC image from LANDSAT TM & ETM data was done, the land surface temperature was estimated using SWA, [12] [26] [18] using the Thermal Infrared (TIR) and Operational Land Imager (OLI) bands of Landsat imagery by following image processing operations.
4.2.3. Top of Atmosphere (TOA) Radiance. For calculating the radiance value, Digital Number (DN) values of the TIRS band are transformed to TOA radiance using the algorithm by way of conversion using additive and rescaling factors assigned to specific bands defined metadata file.

For Landsat 5 & 8

\[ L_\lambda = M L \cdot Q_{\text{cal}} + AL \]  

where,

- \( L_\lambda \) – TOA radiance in watts/ (m²*srad*μm).
- \( M L \) – Multiplicative rescaling factor (specific value for each band taken from Metadata file)
- \( Q_{\text{cal}} \) – Quantized standard pixel values of Digital number (taken from Metadata file)
- \( AL \) – Additive rescaling factor (taken from Metadata file)

While for Landsat 7

\[ L_\lambda = (L_{\lambda_{\text{max}}} - L_{\lambda_{\text{min}}}/ Q_{\text{CAL_{max}}} - Q_{\text{CAL_{min}}}) \cdot (Q_{\text{CAL}} - Q_{\text{CAL_{min}}}) + L_{\lambda_{\text{min}}} \]  

where,

- \( L_\lambda \) – Radiance value
- \( Q_{\text{CAL}} \) - DN value
- \( L_{\lambda_{\text{min}}} \) - spectral radiance scales to QCALMIN
- \( L_{\lambda_{\text{max}}} \) - spectral radiance scales to QCALMAX
- \( Q_{\text{CAL_{min}}} \) = minimum quantized pixel value (typically = 1)
- \( Q_{\text{CAL_{max}}} \) = maximum quantized pixel value (typically = 255)

4.2.4. Calculating NDVI. The NDVI value ranges between -1 to +1; it helps for the qualitative assessment of vegetation. Negative values indicate for clouds, water, and other non-vegetated, non-reflected surfaces, while positive values indicate vegetation & other reflective surfaces. NDVI is calculated from Infrared (IR) and Near-Infrared (NIR) bands using the algorithm:

\[ \text{NDVI} = \frac{(\text{NIR} - \text{Red})}{(\text{NIR} + \text{Red})} \]  

where,

- \( \text{NIR} \) – Pixel value of NIR band
- \( \text{RED} \) – Pixel value of Red band

4.2.5. Fractional Vegetation Cover (ρv). Proportional Vegetation cover is calculated using the NDVI values using the below algorithm [4] [11].

\[ \rho_v = \frac{(\text{NDVI} - \text{NDVI}_{s})}{(\text{NDVI}_{v} - \text{NDVI})} \]  

where,

- \( \rho_v \) – Proportional vegetation.
- \( \text{NDVI}_{v} \) and \( \text{NDVI} \) – NDVI value for vegetation and soil.

4.2.6. Land Surface Emissivity (LSE). The emissivity of any object can be defined as its ability to measure the emitted infrared energy which is required to convert brightness temperature values to surface temperature, which has been calculated using an algorithm:

\[ \text{LSE} = \varepsilon_s (1 - \text{FVC}) + \varepsilon_v \]  

where,

- \( \varepsilon_v \) – Emissivity of Vegetation
- \( \varepsilon_s \) - Emissivity of Soil
- \( \rho_v \) (FVC) – Proportional Vegetation Cover
The average value of $\varepsilon_s$ is 0.978 is defined while 0.978 may be defined as average emissivity for vegetation ($\varepsilon_v$) [21].

4.2.7. Land Surface Temperature. LST for the present study was calculated using the split-window algorithm, which is the most popular algorithm for retrieving the surface temperature. In the final step for estimation of LST was calculated using the value of brightness temperature (TB) from TIR bands, split-window coefficient values, constant thermal values (Table), and other values such as $\rho_v$ and NDVI values derived from the sensors using different algorithms using equations:

For Landsat- 8 data, LST was calculated using the equation:

$$\text{LST} = \text{TB}_{10} + C1(\text{TB}_{10} − \text{TB}_{11}) + C2(\text{TB}_{10} − \text{TB}_{11})2 + C0 + (C3 + C4W)(1− \varepsilon) + (C5 + C6W)\Delta \varepsilon$$

where,

$\text{TB}_{10}$ and $\text{TB}_{11}$ – Brightness value for Band 10 & 11.

$\Delta \varepsilon$ – Difference in LSE derived from two bands.

$C0$ to $C6$ – Constant values for split-window coefficient (Table 3) [21, 18].

$\varepsilon$ – Mean value calculated from two TIR bands

While LST for Landsat- 5 & 7 was calculated using the equation:

$$\text{TB} = \frac{K_2}{\ln[(K_1/\text{Lλ}) +1]}$$

Where,

$\text{TB}$ - At-Satellite Temperature Brightness.

$K_1$ & $K_2$ - Thermal conversion constant (Table 4)

$L\lambda$ – TOA Radiance

| S.No | Constant | Values |
|------|----------|--------|
| 1    | $C0$     | -0.268 |
| 2    | $C1$     | 1.378  |
| 3    | $C2$     | 0.183  |
| 4    | $C3$     | 54.300 |
| 5    | $C4$     | -2.238 |
| 6    | $C5$     | -129.20|
| 7    | $C6$     | 16.400 |

**Table 3. Split-Window Coefficient values**

**Table 4 Thermal constant Values for LANDSAT TM & ETM Data**

| Thermal Conversion Constant | Landsat- 5 | Landsat- 7 | Landsat- 8 |
|-----------------------------|------------|------------|------------|
|                             | Band_6     | B6_VCID_1  | B6_VCID_2  | Band_10     | Band_11     |
| $K_1$                       | 607.76     | 666.09     | 666.09     | 774.8853    | 480.8883    |
| $K_2$                       | 1260.56    | 1282.71    | 1282.71    | 1321.0789   | 1201.1442   |

4.2.8. Validation with MODIS Data. Derived surface temperature values from Landsat data has been checked and validated with the MODIS (Figure 4) generated surface temperature data based on 20 random points (Figure 5) taken from the study area, which representing a different class for its accuracy and it was observed that an average difference of about ±1°C was between them.
Figure 4. Estimated Land Surface Temperature for Study Area for year 2000, 2009 and 2019 (a, c, e showing Landsat b, d, f MODIS data for Pre-Monsoon
For validating the results obtained for affected surface water bodies due to changed land use cover, which is calculated based on its turbidity, the data was analyzed using thermal data, NDWI and AWEI were calculated.

![Temperature graph for years 2000, 2009, and 2019](image)

**Figure 5.** Validation of Landsat Retrieved Temperature Data with MODIS Data using 20 Random points from the study area.

4.2.9 **NDWI Calculation.** NDWI is an index used to calculate water component in imagery, by using the formula water components present in the area are highlighted, therefore, water bodies present in the study area was calculated using the index derived from NIR and Short Wave Infrared (SWIR) band for the year 2000, 2009 and 2019 (Figure 6) to monitor the changes which occurred during this period. AWEI It is used to differentiate water from dry land, which is suitable for water body mapping. The equation used to derive the NDWI index is:

\[
NDWI = \frac{\text{NIR} - \text{SWIR}}{\text{NIR} + \text{SWIR}} \quad (8)
\]

where,
NIR - Near-Infrared
SWIR – Short-Wave Infrared

![Temperature graph for years 2000, 2009, and 2019](image)
4.2.10. Calculating the AWEI. AWEI is the new technique introduced to extract the surface water with accuracy in the classification of only the particular areas' water bodies, which includes shadow and dark surfaces, which is not done correctly using other methods [6]. Thus, the AWEI values were calculated for the year 2000, 2009 and 2019 (shown in Figure 7) to detect the changes which took place during the period and also to check the accuracy level of the satellite-derived NDWI values for each year and the result was almost accurate from both the techniques. AWEI was derived using the equation:

$$4 \times (\text{Green} + \text{SWIR2}) - (0.25 \times \text{NIR} + 2.75 \times \text{SWIR1})$$

where,
NIR - Near-Infrared
SWIR$_1$ – Short-Wave Infrared
SWIR$_2$ – Short-Wave Infrared or Mid-Wave Infrared (MIR)
5. **Result and Discussion**

The LULC study has been done to interpret the changes which took place since 2000. LULC classification has been done using the remotely sensed data by the technique of visual interpretation so as to increase the accuracy of the classified data, as per the results obtained by it reflects that there is a high increase in the urban area with about 30.95% in the year 2019 which was 9.31% of the total area in the year 2000 while there is a continuous decrease in other natural land use covers such as forest, vegetation, cultivation or other surface water bodies (Figure 8.).

The estimated surface temperature derived from the satellite data reveals that there is an increase in temperature with the increasing urbanization & industrialization. Also by the above study, it has been observed that the area which has been transformed from natural land cover to urban land use has shown an increasing trend of temperature while the area which comes under the same classification type has not much variation in its temperature, from this it can be proved that LULC and LST have their direct relationship with each other. After retrieved surface temperature, turbidity in the major surface water bodies was identified for the study area with the help of temperature variation in turbid and pure water (Figure 9.). It has been observed that water with higher impurities has a relatively higher surface temperature.

**Figure 7.** Automated Water Extraction Index for Study Area (AWEI) in (a) 2000, (b) 2009 and (c) 2019
6. Conclusion
The present study has been conducted to analyze the changes in land use which took place since last two decades, i.e., from 2000 to 2019, as a part of the development and its effect on surface temperature and...
surface water turbidity, the turbidity of the water was analyzed on the basis of thermal data analysis with the integrated use of RS and GIS techniques.

For the estimation of Surface temperature, LANDSAT TM & ETM data has been processed. The derived output were validated with the help of MODIS surface temperature data by comparing the results obtained by both the data for which 20 random points were taken throughout the study area, it was observed that about 1°C of an average temperature difference between both the data. By the results obtained from the conducted study, it has also been observed that changing land use land cover is negatively impacting the environment as with the land-use change majorly in the form of urbanization, which has increased to almost three times from 2000 to 2019 is the main cause of increasing temperature and poor surface water quality. Results also revealed that there is about 1-1.5°C rise in the urban area temperature for the last two decades, while land-use areas like cultivated land, vegetation, etc. have relatively lesser surface temperature variations.

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