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Impacts of Land Use Land Cover Change on Surface Temperature and Groundwater Fluctuation in Raipur District

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ABSTRACT

This study is aimed to analyse the impacts of Land Use / Land Cover (LULC) to Land Surface Temperature (LST) and water level fluctuation in Raipur city, for which pre- & post-monsoon data for four years 2000, 2008, 2014 and 2018 have been analysed. By this study, it has been observed that changing LULC has its direct impact on surface temperature as it is increasing with rapid urbanization. Also due to the modern agricultural practices and increasing urbanization as the major factor responsible for changing LULC, and the declining water level.

INTRODUCTION

As the process of urbanization has its major contribution in changing land use which which is causing disturbance to the ecosystem specially to water resource and changing climate (Battista & Vollaro, 2017; Yan, Wang, Xia, & Feng, 2016).

Therefore in the present study, an effort is made to identify the land surface temperature change in the study area with the help of remote sensing(RS) and geographical information system (GIS) based approach.

Objectives

The objective of the present study is to investigate the impacts of LULC changes on LST values and ground water level.

STUDY AREA

Raipur is the capital of Chhattisgarh state and is geographically situated in central part of India with extends from 21.74 to 20.76E & 81.23 to 82.94N. It covers the total area of about 2912.75 sq. km. In the year 1998 the district was divided into 3 parts Raipur, Mahasamund and Dhamtari districts thereafter in year 2011 it was again divided into 4 sub-districts which are: Raipur, Arang, Abhanpur & Tilda. Mahanadi and Kharun are the major rivers of Raipur district. It has a maximum recorded temperature of 48.36° C while lowest recorded was 12.5° C with an average rainfall of about 1370mm.

MATERIALS AND METHODS

Overall study which have been adopted for this research in order to reach the main objectives which includes the following methodology (Fig.2)

Analysis of Surface Temperature

The study utilized multi-temporal satellite data acquired for the Pre & Post-Monsoon season from Landsat TM (Thematic Mapper) (2000 & 2008) and Landsat ETM+ (Enhanced Thematic Mapper) (2014 & 2018). The images were downloaded from *https://earthexplorer.usgs.gov/* after which geometric and radiometric corrections were done to the required image for removing the errors.

After pre-processing of data, split-window (SW) algorithm which uses Brightness temperature of two (Thermal Infrared) TIR bands, land surface emissivity (mean and difference) for estimating LST (Rajeshwari and Mani, 2014) which is done using the equations given below.

DN (Digital Number) to TOA (Top of Atmospheric) Spectral Radiance

The value of TOA spectral radiance (Lλ) was calculated using the multiplicative rescaling factor with corresponding TIR bands and adding additive rescaling factor with it.

$$L\lambda = ML*Qcal + AL \quad (1)$$

where, Lλ - Top of atmospheric spectral radiance in watts/ (m^2* srad*μm). ML - band specific multiplicative rescaling factor (radiance_mult_band_10/11). Qcal – Dn value for band 10 & 11. AL - band specific additive rescaling factor (radiance_add_band_10/11)

Calculating NDVI

Normalized difference vegetation index (NDVI) is an essential factor to identify vegetation over different land cover types by

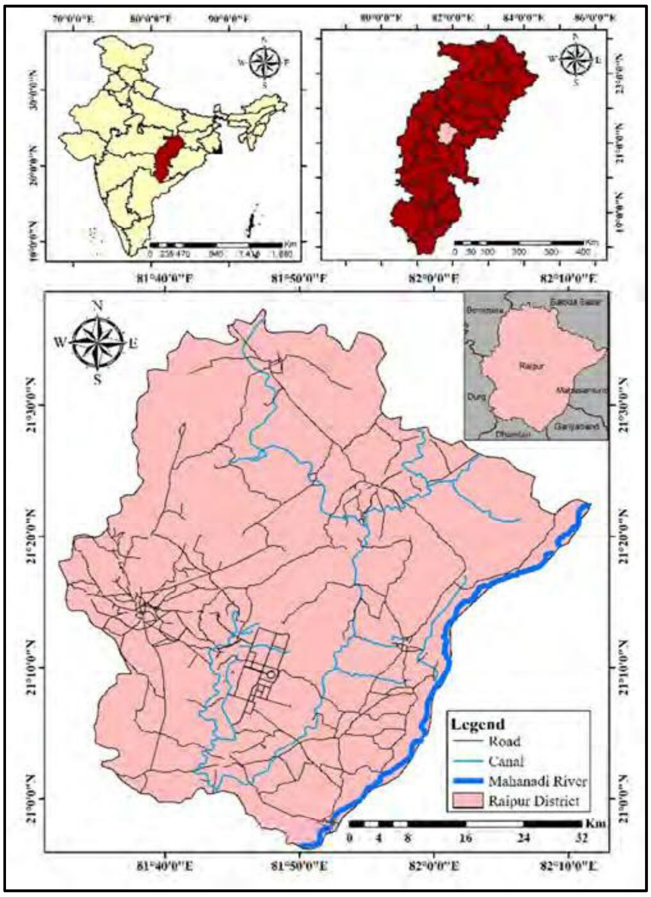

Fig.1. Location Map of Study Area

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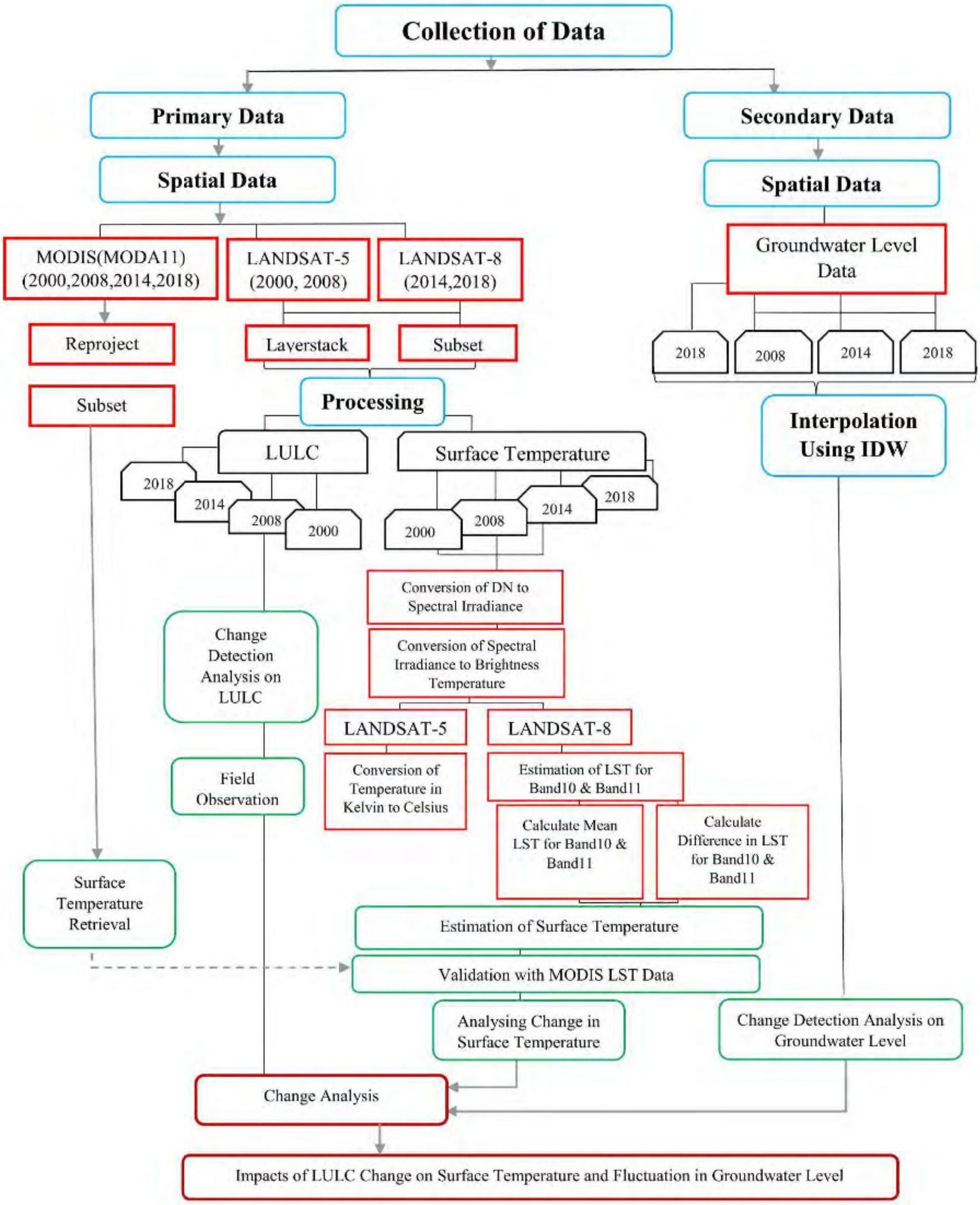

Fig.2. Methodology Flowchart for Analyses

measuring difference between near-infrared. Values for NDVI ranges from -1.0 to +1.0. It is important to calculate the NDVI as it is further used for calculating proportional vegetation (Pv) and later for emissivity (ε).

$$NDVI = \frac{NIR - Red}{NIR + Red} \quad (2)$$

where NIR – near infrared band value of a pixel and RED – Band value of the Red band.

Calculating Proportional Vegetation Index (P_v)

Proportional vegetation (P_v) also known as fractional vegetation is calculated using NDVI values. Which estimates the fraction of area covered under vegetation (Nandi. D., et. al.). The vegetation and bare soil proportions are acquired from the reclassified NDVI image.

$$P_v = \frac{NDVI - NDVI_s}{NDVI_v - NDVI_s}^2 \quad (3)$$

where, Pv – Proportional vegetation. NDVI - normalized difference vegetation index (Calculated using above equation). $NDVI_v$ and $NDVI_s$ – NDVI value for vegetation and soil.

Land Surface Emissivity (LSE) has been estimated for Pre and Post monsoon data of different years using the fractional vegetation.

Estimating Land Surface Emissivity (LSE)

The emissivity can be defined as the relative ability of the surface

Table 1. Data Used and their source

S. No	Data Used	Data Description	Source
1	Landsat-TM	LE07_L1TP_142045_20000505_20170212_01_T1 LE07_L1TP_142045_20001215_20170208_01_T1 LE07_L1TP_142045_20081103_20161224_01_T1 LE07_L1TP_142045_20080511_20161229_01_T1	*https://earthexplorer.usgs.gov/*
2	Landsat-ETM	LC08_L1TP_142045_20140520_20170422_01_T1 LC08_L1TP_142045_20141112_20180524_01_T1 LC08_L1TP_142045_20180515_20180604_01_T1 LC08_L1TP_142045_20181006_20181010_01_T1	*https://earthexplorer.usgs.gov/*
3	MODIS	MOD11A1.A2000126.h25v06.006.2015060094601 MOD11A1.A2000350.h25v06.006.2015111020008 MOD11A1.A2008132.h25v06.006.2015349142925 MOD11A1.A2008004.h25v06.006.2015337153107 MOD11A1.A2014317.h25v06.006.2016210093748 MOD11A1.A2014141.h25v06.006.2016203152354 MOD11A1.A2018132.h25v06.006.2018133090650 MOD11A1.A2018024.h25v06.006.2018025085347	*https://earthexplorer.usgs.gov/*
4	Groundwater Level	Well Observation data for year 2000,2008, 2014 & 2018(May & November)	India-WRIS & CGWB

of any material to emit energy in the form of radiation. Since, LSE is a proportionality factor which scales the black body radiance (Plank's law) to measure emitted radiance and it is the ability of transmitting thermal energy across the surface into the atmosphere. It largely dependent on the surface roughness, nature of vegetation cover etc. Formula to calculate LSE (Rajeshwari and Mani, 2014) is:

$$LSE = \varepsilon_s\ (1\text{-}FVC) + \varepsilon_v \qquad (4)$$

where, LSE - Land Surface Emissivity. P_v - fractional vegetation cover. ε_s – Emissivity value for soil. ε_v - emissivity value for soil

Land Surface Temperature Retrieval

Finally LST was calculated using the brightness temperature (T_B) values of TIR bands 10 & 11 and LSE derived from P_v and NDVI values obtained from OLI bands. Mentioned below are the steps used for the estimation of the LST:

$$LST = TB_{10} + C_1\ (TB_{10} - TB_{11}) + C_2\ (TB_{10} - TB_{11})2 + C_0 + (C_3 + C_4W)\ (1 - \varepsilon) + (C_5 + C_6W)\ \Delta\varepsilon \qquad (5)$$

where, LST - land surface temperature (K). TB_{10} and TB_{11} – brightness from B_{10} & B_{11} (K). C_0 to C_6 - split-window coefficient values (refer Table 3). ε – mean LSE of TIR bands. W – atmospheric water vapour content. Δ ε – Difference in LSE

While LST for Landsat-TM was calculated using the equation:

$$TB = K2/\ln[(K1/L\lambda) + 1] \qquad (6)$$

Where, T_B- At-Satellite Temperature Brightness. K_1 & K_2- thermal conversion constant (refer Table 2 & 4). Lλ – Top of atmosphere spectral radiance.

Classification of Land Use Land Cover

The spatio-temporal data of Landsat-5,7 & 8 was downloaded for 2000, 2008, 2013 & 2018. After the pre-processing of the data land use classification was performed. The study technique use for the above study was visual interpretation. On the basis of which the total area of Raipur district was divided into five classes which are: cultivation, vegetation, open land, waterbody & settlement.

Analysis of Groundwater Level

Groundwater depletion is one of the serious problem to the environment. In order to analyse the combined effects of LULC change on availability of groundwater level, Pre and Post monsoon data for the groundwater from 2000-2018 has been used which was taken from Central Ground Water Board (CGWB), Raipur. Inverse distance weightage (IDW) technique was used for the interpolation of groundwater level data for corresponding year.

RESULTS AND DISCUSSION

Changes in Land Use/Land Cover

LULC map for the year 2000,2008,2014,2018 is given in Fig.3. By the above study it has been observed that area of different LULC class changed over years. This change in Land use shows expansion in urban area while decrease in waterbodies, vegetation and cultivation. Graph showing the changes in different classes is given in Fig.4.

Table 2. Thermal constant Values for LANDSAT 8-ETM

Thermal conversion constant	Band 10	Band 11
K_1	74.8853	480.8883
K_2	1321.0789	1201.1442

Table 3. Split-Window Coefficient values

Thermal conversion constant	Value
K_1	607.76
K_2	1260.56

Table 4. Thermal constant Values for LANDSAT-TM

S.No	Constant	Value
1	C_0	-0.268
2	C_1	1.378
3	C_2	0.183
4	C_3	54.300
5	C_4	-2.238
6	C_5	-129.20
7	C_6	16.400

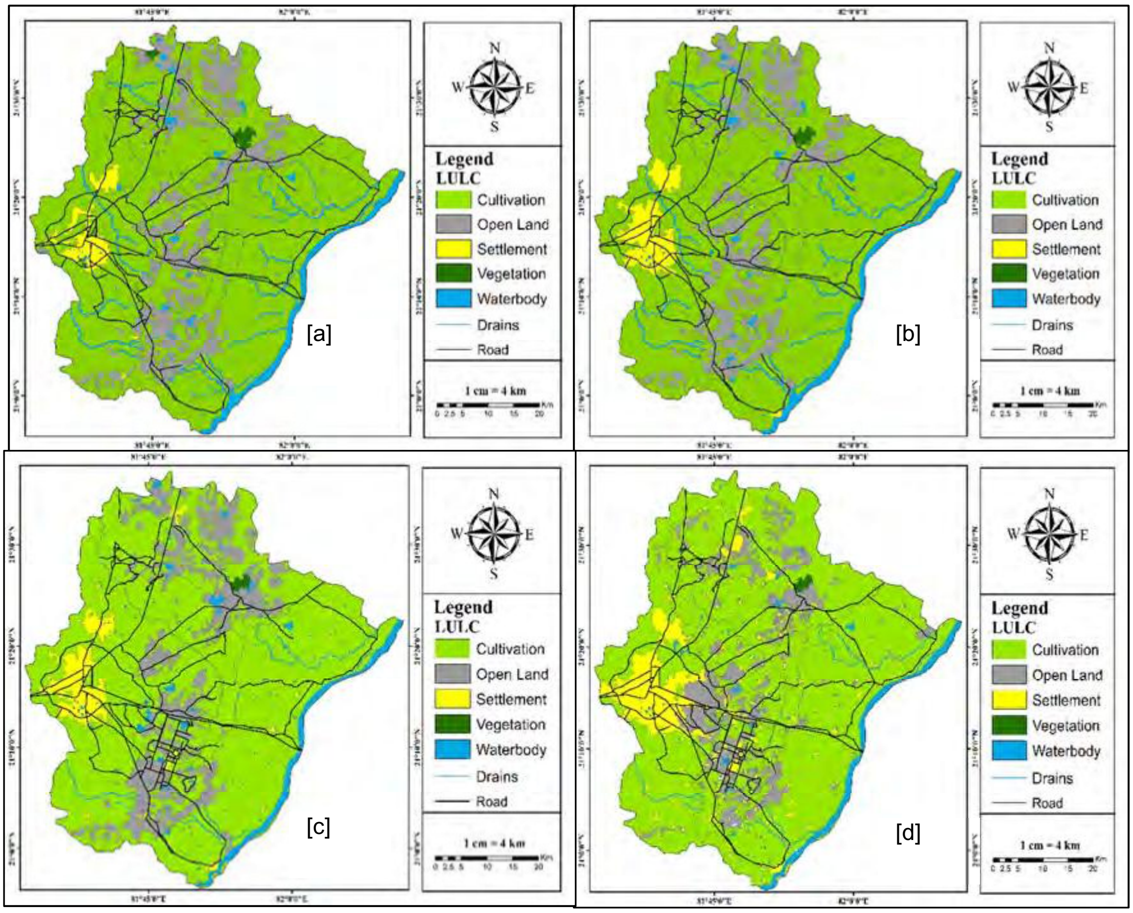

Fig.3. Land Use/Cover (a) 2000, (b) 2008, (c) 2014 and (d) 2018

Changes in Land Use Temperature

Land Surface Temperature were retrieved for Raipur District (Fig.5) from the downloaded Landsat TM & ETM data for year 2000, 2008, 2014 &2018 for pre- & post-monsoon season using the split-window algorithm in QGIS.

By the estimation of LST, it has been observed that there is constant rise in the temperature since 2000 due to changing land use, and the major difference in the temperature is in the urban area (Fig.6), and the area surrounding it while the area covered with waterbodies or dense vegetation has relatively lower temperature (Fig.7).

It has also been observed that during summer season, urban area has relatively low temperature than that of barren & cultivated land, this may be because of vegetation and waterbodies present in the urban areas. Also due to the lack of vegetation cover in summer after crops are harvested in rural areas may be the cause for relatively higher temperature of the area *(Suggested from the Study by IIT-Gandhinagar team).*

Validation with (Moderate Resolution Imaging Spectroradiometer) MODIS Data

For the accuracy assessment, derived output has been compared with the LST retrieved from MODIS (MOD11A1) data (Fig.8). For the validation of the estimated temperature total of 20 random points were taken and land surface temperature of those points from the retrieved data were matched with the MODIS data and it was found that the average difference of about ±1°C was observed between them (Fig.9) and (Table 5).

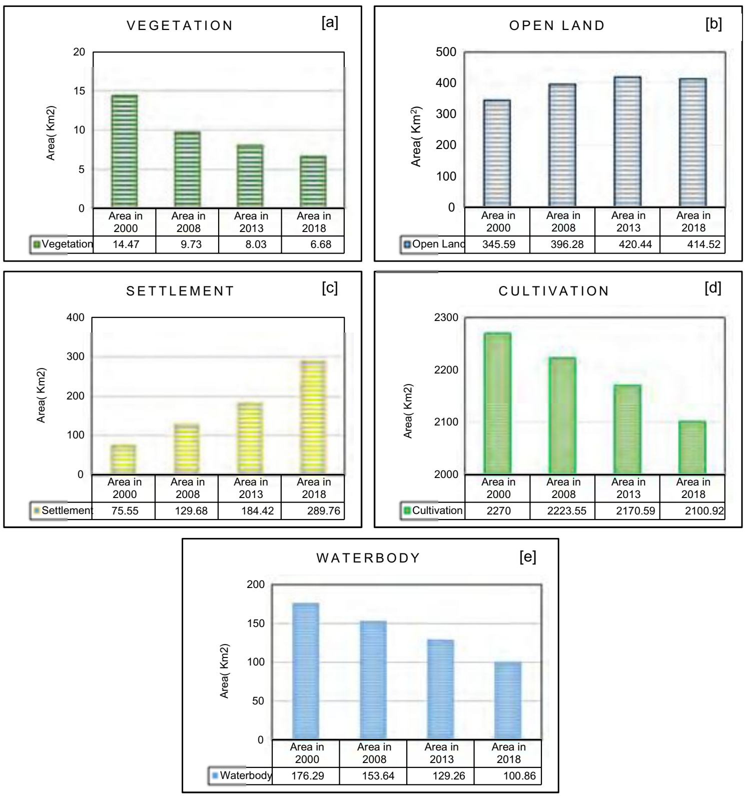

Fig.4. Changes in different classes for LULC from 2000-2018 **(a)** Vegetation, **(b)** Open Land, **(c)** Settlement, **(d)** Cultivation, **(e)** Water body

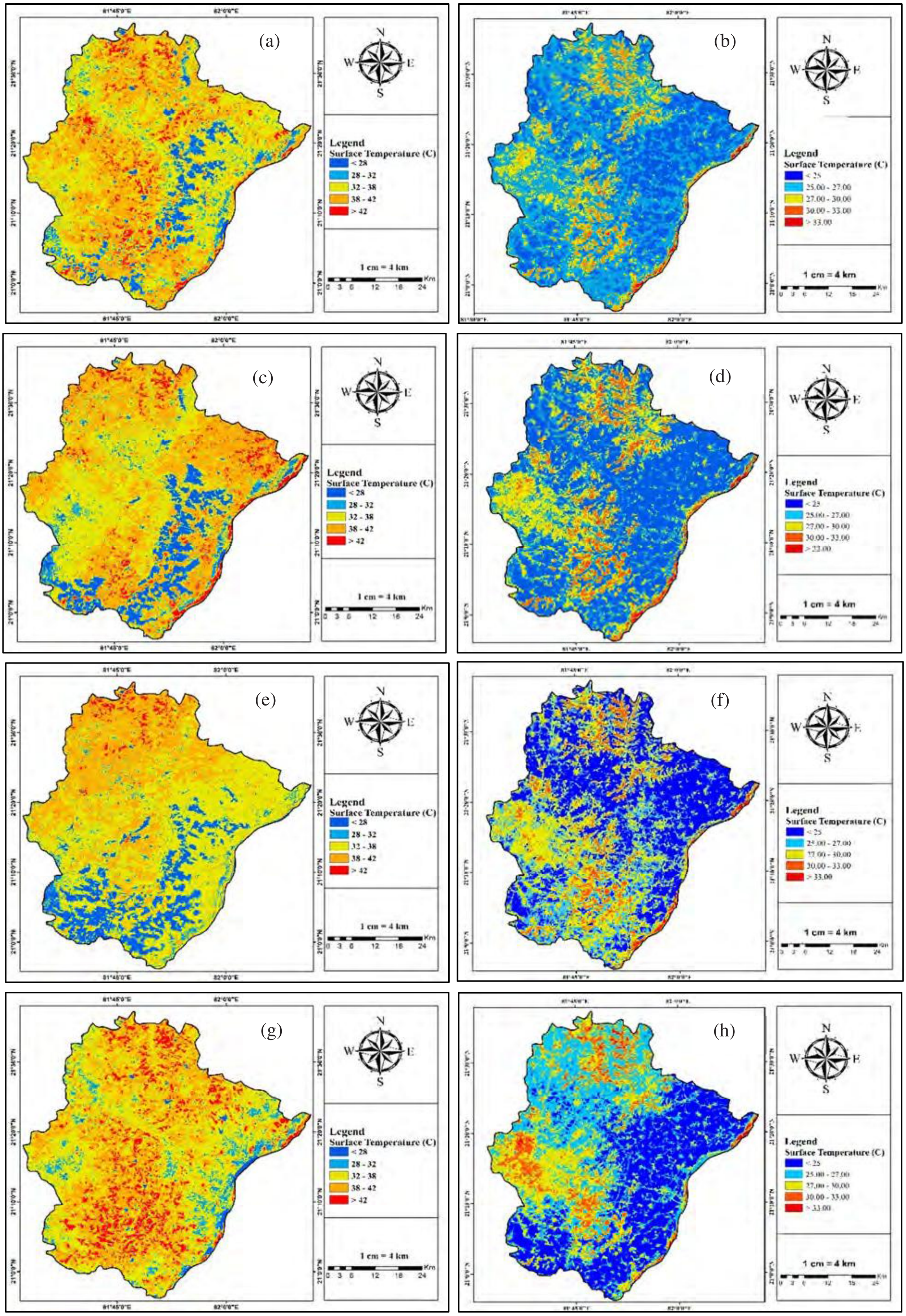

Fig.5. Estimated Land Surface Temperature for Raipur District for Pre-Monsoon (a, c, e, g) and Post-Monsoon (b, d, f, h) in 2000, 2008, 2014 and 2018)

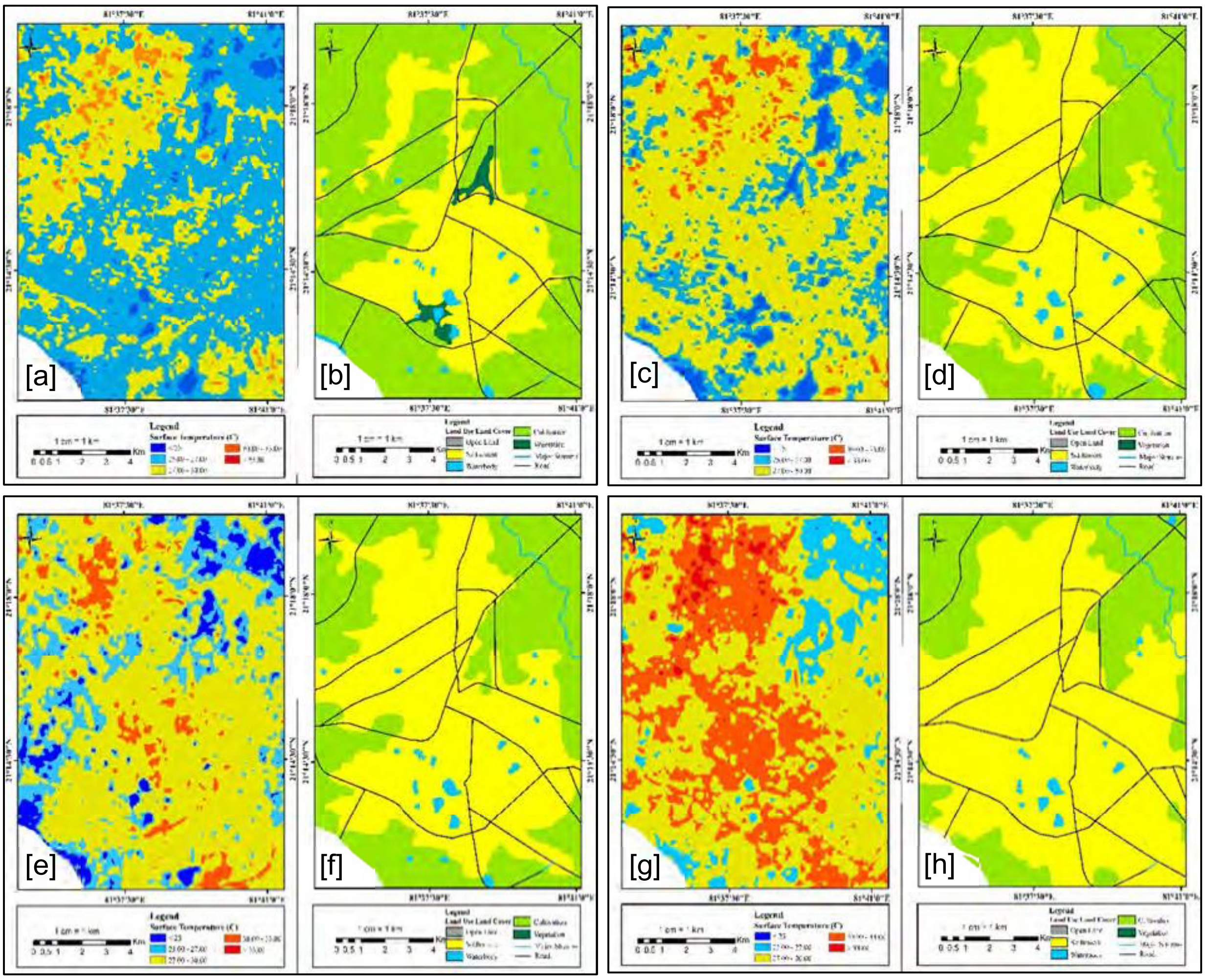

Fig.6. Changes in LST & LULC for Urban area for Raipur District from year 2000-2018 (a, c, e, g LST in 2000, 2008, 2014 and 2018) and (b, d, f, h LULC in 2000, 2008, 2014 and 2018).

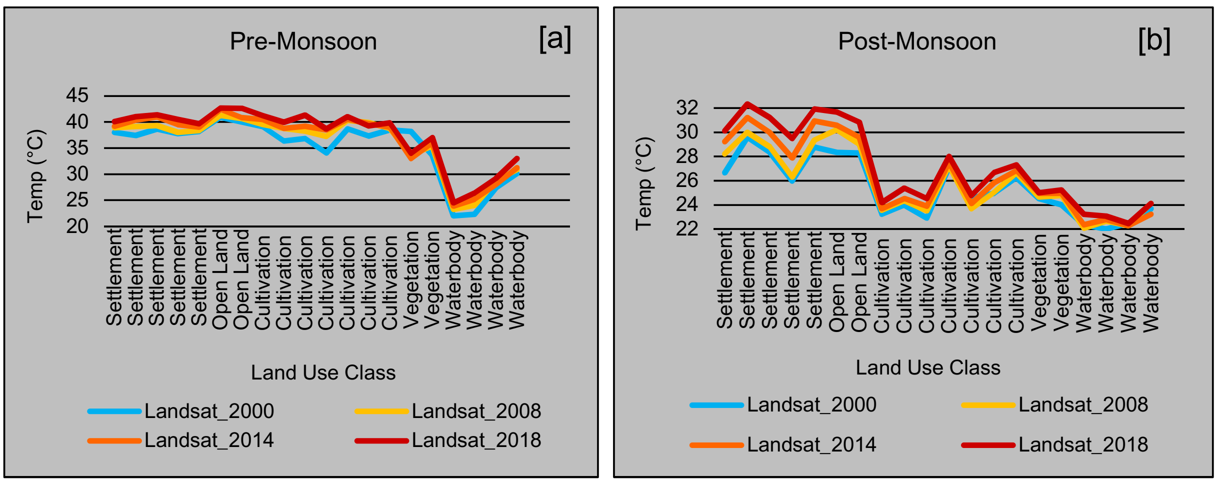

Fig.7. Graph showing LST for **(a)** Pre-Monsoon data **(b)** Post Monsoon Data for 2000, 2008, 2014, 2018.

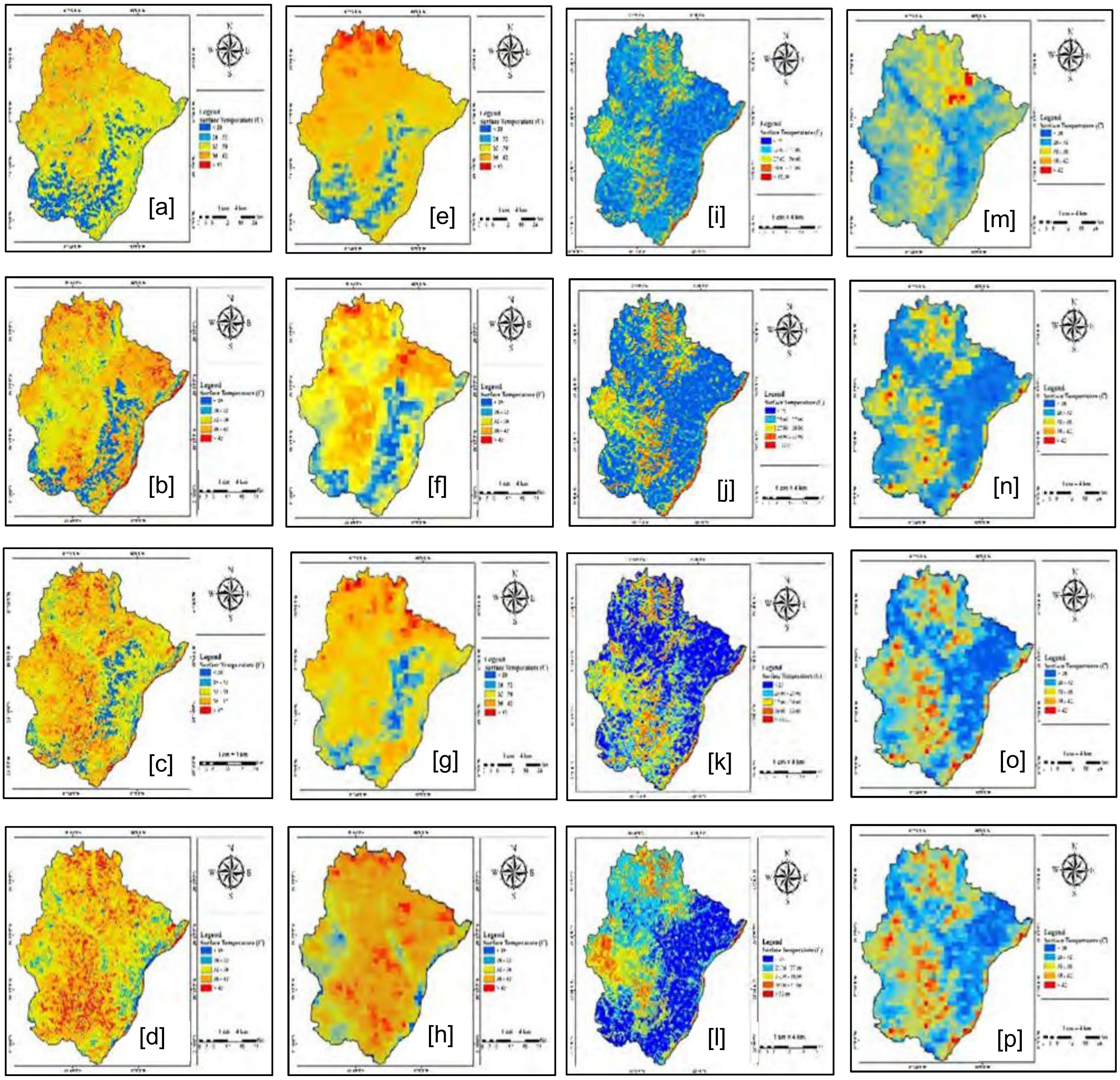

Fig.8. Estimated Land Surface Temperature for Raipur District from year 2000-2018 (a, b, c, d showing Landsat e, f, g, h showing MODIS data for Pre-Monsoon and i, j, k, l showing Landsat and m, n, o, p showing MODIS data for Post-Monsoon in 2000, 2008, 2014 & 2018)

Changes in Groundwater Level

Changing land use/land cover and growing population in greatly influencing the availability to groundwater resources for various purposes. Increasing population and urbanization lead to declination of water level (Patra et al.,2018), the study was to made to analyse these changes.

It has been observed that the groundwater depth, both minimum and maximum level, has become deeper since last 19 years i.e. from 2000 to 2018 (Fig.10). The differences in minimum and maximum depth of groundwater have gone down by about ~2.5 and ~4.6 mbgl during for Pre-monsoon while it has declined to ~3.0 and ~5.8 mbgl during post-monsoon from 2000 to 2018 (Fig.11).

CONCLUSION

In present study, an integrated use of remote sensing and GIS was used to analyse the changing land use/ land cover in form of urban expansion and its impact on land surface temperature as increasing surface temperature is related to decreasing biomass and fluctuation in groundwater depth. The results obtained revealed that urbanization

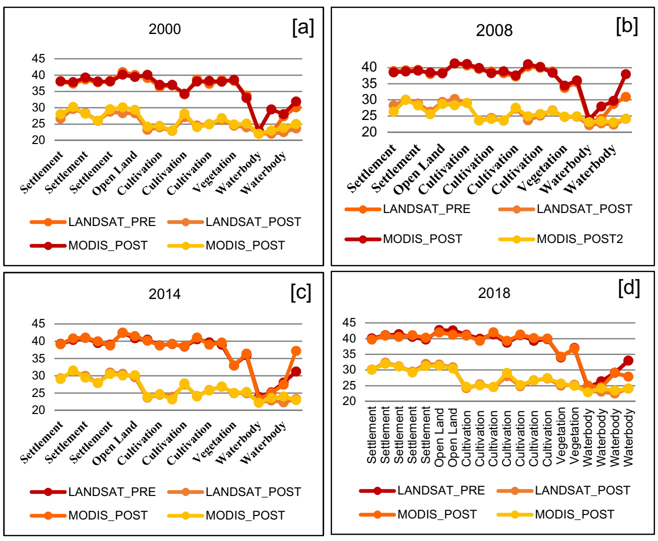

Fig.9. Validation of Retrieved LST from MODIS Data

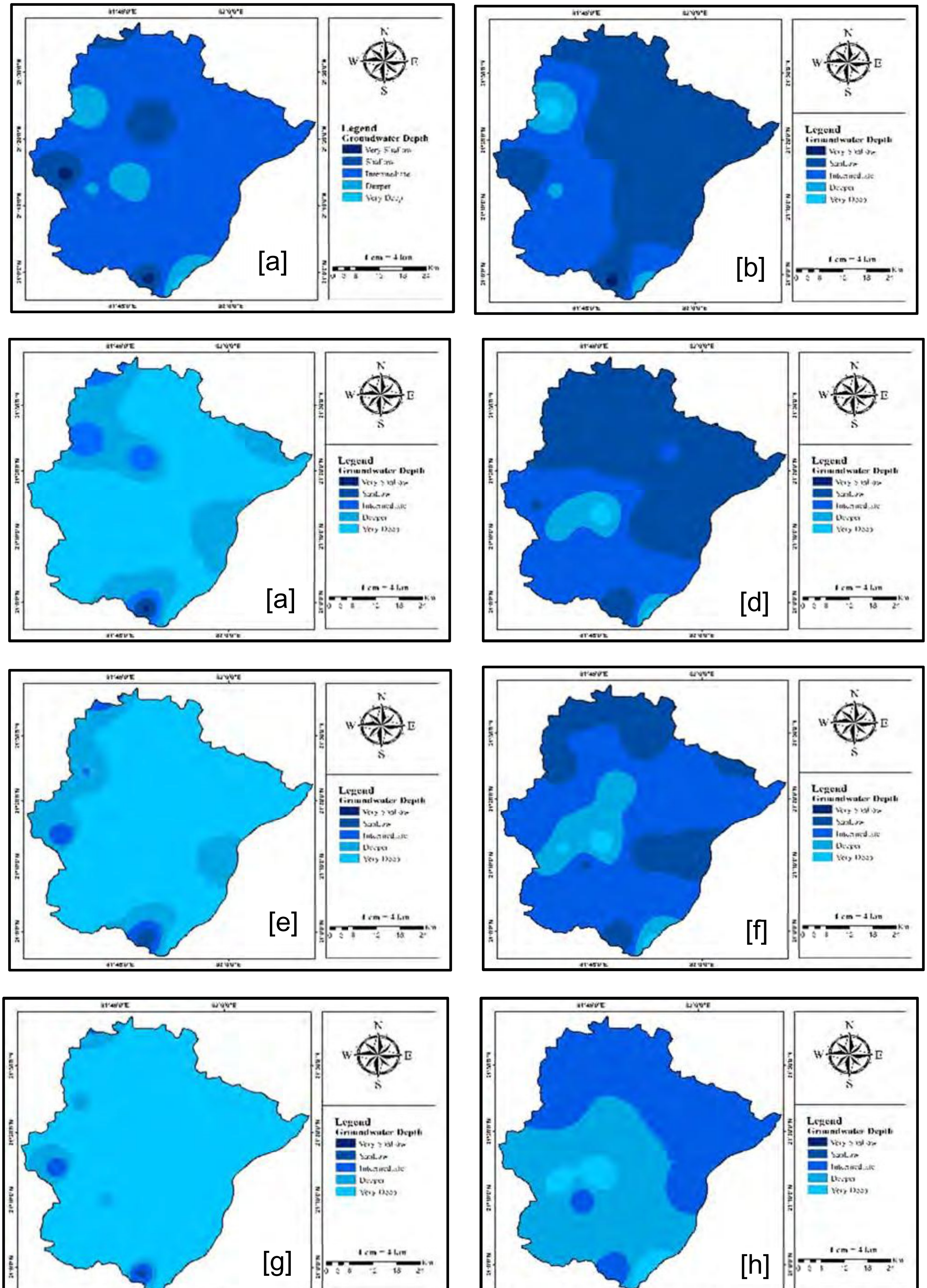

Fig.10. Groundwater Depth for Raipur District from year 2000-2018 (a, c, e, g Pre-Monsoon in 2000, 2008, 2014 & 2018 and b, d, f, h Post-Monsoon in 2000, 2008, 2014 & 2018)

Table 5. Comparison between Temperature of MODIS & Landsat Data for different Location

	Longi-tude	Lati-tude	Feature	2000				2008				2014				2018			
				LANDSAT		MODIS		LANDSAT		MODIS		LANDSAT		MODIS		LANDSAT		MODIS	
				PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST
1	81.65	21.22	Settlement	38.01	26.67	38.08	26.29	38.92	28.21	38.52	28.00	39.22	29.23	39.13	29.03	40.1	30.12	39.65	30.03
2	81.61	21.31	Settlement	37.4	29.59	37.83	30.00	39.16	30	38.76	30.23	40.38	31.2	40.84	31.55	41.05	32.33	40.95	32.00
3	81.57	21.26	Settlement	38.66	28.35	39.25	28.22	39.31	28.8	39.02	28.12	40.97	29.96	41.00	29.45	41.38	31.2	40.52	31.13
4	82.04	21.31	Settlement	37.75	25.97	38.00	25.50	38	26.3	38.45	25.98	39.48	27.88	40.00	27.89	40.5	29.48	41.05	29.20
5	81.79	21.14	Settlement	38.2	28.76	38.00	28.67	38.38	29.35	38.2	29.54	39.00	30.93	38.75	30.51	39.64	31.92	40.29	31.23
6	81.83	21.46	Open Land	40.9	28.35	40.1	28.32	41.25	30.23	41.32	30.09	42.44	30.58	42.49	30.09	42.7	31.68	41.94	31.33
7	81.91	21.41	Open Land	40.01	28.3	39.43	29.00	40.68	29.02	41.08	29.35	40.87	29.59	41.48	30.15	42.6	30.82	41.20	30.46
8	81.65	21.45	Cultivation	39.11	23.24	40.04	23.56	39.54	23.56	39.86	24.17	40.48	23.68	40.13	23.88	41.22	24.21	40.96	24.59
9	81.95	21.3	Cultivation	36.38	24.00	36.99	24.02	38.77	24.36	38.24	24.44	38.8	24.54	38.77	24.69	39.96	25.4	39.27	25.10
10	81.89	21.14	Cultivation	36.84	22.92	37.01	23.56	38.24	23.5	38.87	23.01	39.2	23.89	39.23	23.17	41.32	24.54	41.96	24.57
11	81.66	21.15	Cultivation	34.06	27.09	34.26	27.50	37.22	27.25	37.57	28.18	38.46	27.5	38.56	27.78	38.66	28.02	39.25	29.05
12	81.72	21.21	Cultivation	38.66	24.59	38.00	24.89	40.31	23.68	41.04	24.06	40.58	24.11	41.04	24.00	41.04	24.79	41.23	25.19
13	81.73	21.26	Cultivation	37.29	24.97	38.20	25.60	39.92	25.04	40.2	24.85	39.67	25.83	39.02	25.74	39.28	26.67	40.14	26.71
14	81.6	21.08	Cultivation	38.46	26.25	37.99	26.54	38.77	26.67	38.39	26.80	39.02	26.83	39.59	26.9	39.82	27.3	40.00	27.37
15	81.91	21.44	Vegetation	38.2	24.53	38.56	24.78	33.66	24.66	34.40	24.87	33.00	24.97	32.97	25.00	33.97	25.02	34.2	25.71
16	81.92	21.45	Vegetation	33.66	24.01	33.00	24.89	35.43	24.77	36.02	25.12	36.00	24.97	36.44	25.33	37.01	25.25	36.84	24.95
17	81.86	21.4	Waterbody	22.00	22.38	22.95	23.08	23.24	22.08	23.87	22.00	23.88	22.37	23.29	22.18	24.5	23.24	25.00	22.92
18	81.79	21.26	Waterbody	22.33	22	29.50	23.42	24.01	22.68	27.93	22.99	25.2	22.81	24.99	23.56	26.38	23.07	24.57	24.15
19	81.78	21.47	Waterbody	27.35	22.49	28.02	23.03	28.68	22.29	29.65	23.8	28	22.3	27.45	24.01	29.14	22.48	29.04	23.45
20	81.77	21.15	Waterbody	30.1	23.68	31.93	24.10	30.87	24.11	37.94	25.03	31.22	23.24	37.2	22.96	33	24.11	27.88	24.00

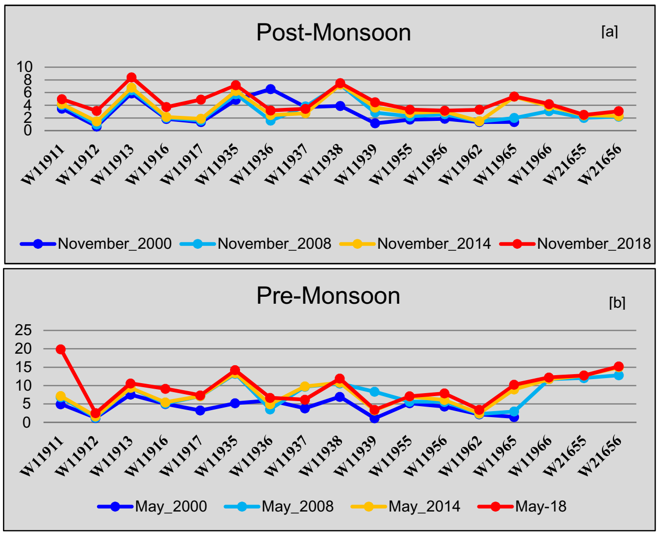

Fig.11. Graph showing Water Level for **(a)** Post-Monsoon data **(b)** Pre-Monsoon Data for 2000, 2008, 2014, 2018.

has increased to almost three times from 2000 to 2018. Also by the use of Remote sensing and GIS techniques it has been concluded that due to the development of urban area surface temperature has raised by ~1-2°C for open land and urban area while ~0.2-0.5°C for cultivation and waterbodies. This study has also demonstrated that changing Land Use/Cover is greatly affecting the land surface temperature as well as it has its negative impacts on other environment related factors like declined groundwater level etc. These changes occurring due the rapid urbanization and deforestation which on one hand has resulted in decreased rate of infiltration while on the other hand due to the increasing need for water supply ground water is over used resulting in declination of water level.

In order to check the accuracy of the output generated from the methodology were validated with the MODIS data by taking 20 random points throughout the district and on the basis of that it has been observed that there is average difference of 1°C between retrieved temperature data from Landsat- ETM & TM and MODIS-MOD11A1.

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