# ANALYZING LAND SURFACE TEMPERATURE DISTRIBUTION FROM LAND USE LAND COVER CHANGES IN SUNDARBANS, INDIA

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## Abstract:

The paper utilizes Landsat 5 TM and Landsat 8 OLI (Operational Land Imager) for analyzing land use/land cover change (LULC) and its impact on land surface temperature in Sundarban Biosphere Reserve, India. Split window algorithm and spectral radiance model were used for determining land surface temperature from Landsat 8 OLI and Landsat 5 TM, respectively. The LULC change analysis has revealed a substantial increase in the waterlogged areas followed by settlement and agricultural area and a decrease in mangrove forests followed by mudflats and mangrove swamps. The distribution of average change in land surface temperature (LST) shows that water recorded highest increase in temperature followed by deposition, open forest and settlement. Overlay of the transect profiles drawn on land use/land cover change map over land surface temperature map revealed that the land surface temperature has increased in those areas which were transformed from open forest to paddy, open forest to settlement, paddy to settlement and deposition to settlement. The study demonstrated that increase in non-evaporating surfaces and decrease in vegetation has increased the land surface temperature of the study area. The albedo of the study area was also estimated and varying degree of changes has been identified. The study demarcates that the increase in the LST and Albedo in the study area is definite and this increase has brought about stress on the sundarban delta.

## ***Key words***

Land surface temperature, Land use land cover, Sundarbans biosphere reserve, landsat, Ecosystem

## Introduction

Sundarbans, one of the largest tidal halophytic mangrove forests in the situated on the vast delta at the head of Bay of Bengal (Maiti and Chowdhuri, 2013) is a world heritage site. The mangrove plants which make up most of the vegetations in the forests is of great ecological significance. Despite its great socio economic and environmental importance, over the last several decades, the Sundarbans mangrove ecosystem has been adversely affected by anthropogenic activities such as deforestation and dumping activities (Campbell et al., 2005). The entire landscape of the Indian Sundarbans has altered owing to these increased anthropogenic pressures. This rate has not slowed down but in fact is on the rise and is anticipated to keep on accelerating (Bandyopadhyay & Mondal, 2014).

Land use land cover (LULC) is perhaps the most relevant form of global environmental change phenomenon occurring at varying spatial and temporal scales. LULC clearly reflects the dimensions of anthropogenic activities on the environment (Lopez et al., 2001; Evrendilek and Wali, 2004). The gradual decline in the vegetative cover and rise in urban agglomerations globally has led to an increase in the $CO_2$ concentration in the atmosphere affecting the surface energy budget of the earth and its climate too (Islam and Islam. 2013). This in return has led to rise in global temperature and subsequently in the sea surface temperature. This change has modified the environment considerably, such as changes in rates of evapotranspiration rates (Owen et al., 1998; Bandyopadhyay et al., 2014) and increased surface temperature per decade of 0.5 ° C which is higher than the global average (Mitra et al. 2009). Over the course of time, LST has emerged as a key parameter for estimating surface energy budget associated with land cover changes (Srivastava et al. 2010). Various authors have verified the effect of land use land cover changes on LST distribution (Ahmed et al. 2013; Buyadi et al. 2013; Julien et al. 2011) using different methods and different datasets (Kumar et al. 2012; McMillin 1975).

The present study was undertaken in mangrove forest of sundarbans using landsat datasets of 2000 and 2017 with an aim to i) assess the extent and patterns of changes of LULC, ii) to highlight the variations of NDVI, iii) to estimate the changes in LST due to changes in LULC, and iv) to find correlation between LULC and LST

## Study area:

The study area is the Indian part of the Sundarbans delta comprising parts of south 24 parganas and north 24 paraganas districts of West Bengal state (Fig.1). It is a network of estuaries, tidal rivers, and creeks intersected by channels, enclosing flat, marshy islands covered with dense mangrove forests. On the east is the Bangladesh part of the Sundarbans, on south is the Head of the Bay of Bengal, while towards its north west is the Kolkata city.

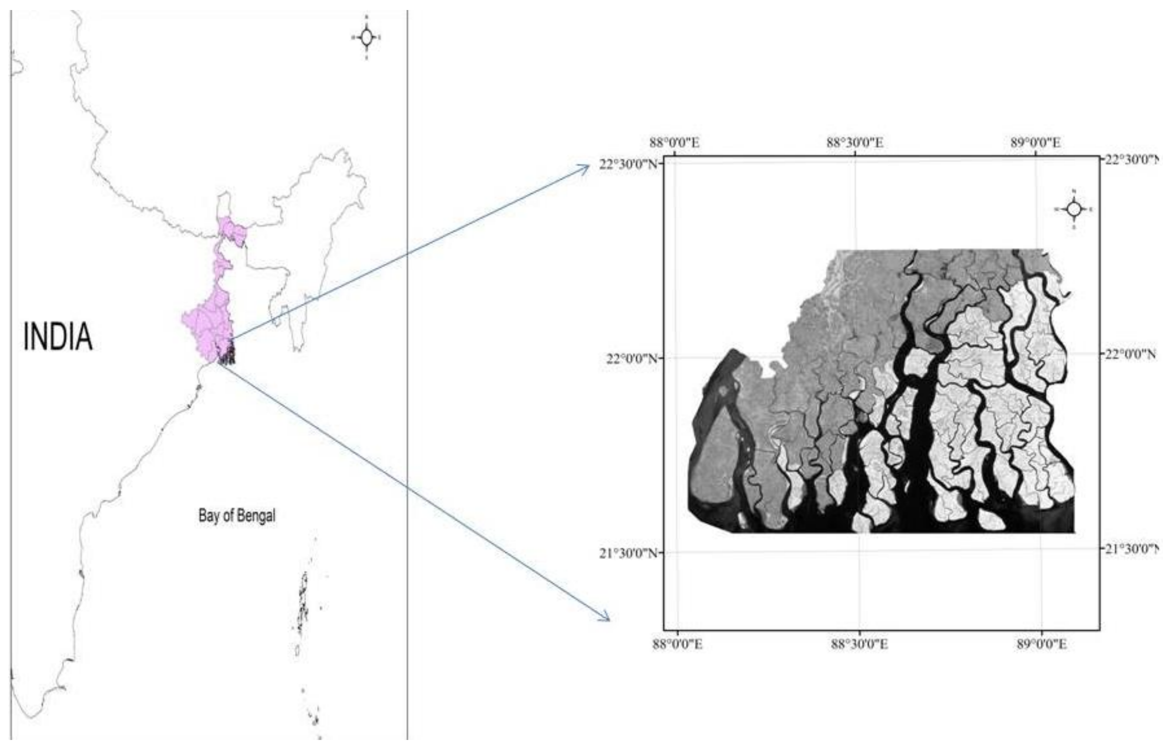


**Figure 1 Study area**

## Methodology

## Database and methodology

Satellite image (LANDSAT 5 TM, 2000) and (LANDSAT 8 OLI, 2017) of were used for assessing LULC changes and their impact on LST. LULC maps of the study area for 2000 and 2017 were generated by supervised classification. The pixel sample ware selected from various spectral classes and run the data using maximum likelihood method. Final groping of similar pixels was done on the basis of sampled pixels for various land use/land cover, classes. The generalized images were reclassified to reduce classification error and improve the accuracy of the classification. Land use/land cover change map was prepared using overlay function in ERDAS Imagine. Surface temperature was derived from geometrically corrected LANDSAT 5 TM (band 6) and LANDSAT 8 TIRS (band 10 and 11). Spectral radiance model was used to retrieve surface temperature from LANDSAT 5 TM and split window method was used to retrieve surface temperature from LANDSAT 8 TIRS. A three step process was followed to derive surface temperature from LANDSAT TM 5 Image. Spectral radiance was calculated using following equation:

$$L = LMIN + (LMAX - LMIN) * DN/255$$

*where L = Spectral Radiance, LMIN = 1.238, LMAX =15.600, DN = Digital Number*.

Spectral Radiance (L) to Temperature in Kelvin may be expressed as:

$$TB = K2/\ln(K1/L+1)$$

*where K1 = Calibration Constant 1 (607.76), K2 = Calibration Constant 1 (1260.56), TB = Brightness temperature*.

Surface Temperature from LANDSAT 8 TIRS was derived using band 10 and 11 following the split-window method first proposed by Mc Millin in 1975. The algorithm is:

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

*where LST = Land surface temperature, $C_0$–$C_6$ = Split window coefficient values (Table 5), TB10 and $TB_{11}$ = Brightness temperature of band 10 and band 11, e = M band 10 and band 11, e = Mean LSE of TIR bands, W = Atmospheric water vapor content,* $\square$ *= Difference in LSE*

$\Delta$

**Table 1: Split window co efficient values for Landsat 8**

| -Constant | Value |
|---|---|
| C0 | 0.268 |
| C1 | 1.378 |
| C2 | 0.183 |
| C3 | 54.3 |
| C4 | 2.238 |
| C5 | 129.2 |
| C6 | 16.4 |

**Table 2 Thermal constant values**

| Thermal constant | Band 10 | Band 11 |
|---|---|---|
| K1 | 1321.08 | 1201.14 |
| K2 | 777.89 | 480.89 |
| Radiance multiplier (ML) | 0.0003342 | 0.0003342 |
| Radiance add (AL) | 0.01 | 0.01 |

The value of Top Atmospheric Spectral Radiance (TOAr) was determined by converting original DNs and TIRS into atmospheric radiance. The original Digital Numbers (DN) of Landsat 8 TIR is converted into radiance based on the methods provided by Chander and Markham (2003):

$$TOAr = ML * DN + AL$$

*where AL = Radiance add, ML = Radiance multiplier, DN = Digital number.*

The Brightness temperature (TB) for both TIR bands was calculated by adapting the following formula:

$$TB = K2/ (\ln K1/TOAr) + 1$$

*where K1 and K2 = Thermal constant for TIR bands, TB = Brightness temperature, TOAr = Atmospheric spectral radiance.*

NDVI is a most widely used vegetation index for monitoring the earth's vegetation cover using satellite imagery. Here NDVI is calculated from the visible and near-infrared light reflected by vegetation cover. Leaf cells scatter (i.e., reflect and transmit) solar radiation in nearinfrared spectral region strong absorption would overheat the plant possibly damaging the tissues. Live green plants appear relatively dark in the PAR and relatively bright in the near-infrared. Clouds and snow tend to be rather bright in the red (as well as other visible wavelengths) and quite dark in the near-infrared. NDVI is calculated from these individual measurements as follows:

**NDVI = NIR –Red/NIR + Red.**

Red and NIR stand for the spectral reflectance measurements acquired in the red and near-infrared regions, respectively. NDVI itself thus varies between -1.0 and 1.0. A land surface transit profile was drawn to generalize the relationship between land use/land cover change and surface temperature distribution. Three transit profiles were generated in east to west direction in land surface temperature map. Land use and land cover maps were then overlaid on surface temperature transit profile. Land use/-land cover relationship with surface temperature was established by overlaying land use/land cover change map on land surface temperature transit profile of current date.

## Software used:

ERDAS Imagine 14, ARC GIS 10.2.2. and Microsoft office suite

## Results and Discussions

## Patterns of land use land cover changes

LULC maps of Sundarban Biosphere Reserve for 2000 and 2017 were generated. The total area of every land use category and percentage of each class between 2000 and 2017 were calculated and are presented in Table 3. Over the last 17 years there has been significant and rapid increase in settlement and waterlogged area and a decrease in deposition and open forest area. One of the most conspicuous changes was noticed in waterlogged of upper part of the biosphere reserve which has gone up from 8.39 to 14.36% at the rate of 71.2% over the period. This change is attributed to river erosion particularly in the northern part of the study area. The study further indicates that settlement area has decreased from 8.38% in 2000 to 5.21% in 2017 registering a decrease of 37.7% indicating the land conversion and pressure on natural recourses of the area. This change is remarkable in the transition and buffer zones and can be attributed to reckless cutting of open forest as a consequence of growth of population. The area under agricultural cultivation has a slight decrease at the rate of 3.1%. This is mainly due to spread of salinity. Deposition area significantly increased from 4.62% to 6.41% followed by mangrove forest from 23.43% in 2000 to 18.42% in 2017 (Table 3).74, 956 ha agricultural land has been reduced to 42,400 ha land in between 2000 to 2017.17,57,02 ha mangrove existed in 2000 but in between the 17 years (from 2000 to 2017), 74.6 ha mangrove area occupied by human settlements, and 3,390.5 ha mangrove converted into agricultural land.

**Table 3 Land Use Land Cover Changes from 2000 to 2017**

| Land use land cover class | 2000 | | 2017 | | 2000-2017 | |
|---|---|---|---|---|---|---|
| | Area (ha) | % of total Area | Area (ha) | % of total Area | change (area) | % change |
| **Mangrove forest** | 175704 | 23.4 | 138279 | 18.42 | -37425 | -21.3 |
| **Mangrove swamp** | 14976.2 | 2.0 | 7598.88 | 1.01 | -7377.32 | -49.3 |
| **Mudflats** | 20416.3 | 4.62 | 48141 | 6.41 | 13437.9 | 38.7 |
| **River** | 222124 | 27.72 | 251720 | 33.53 | 43883 | 21.1 |
| **Sand beach** | 1251.9 | 0.01 | 5164.54 | 0.68 | 5039.44 | 4028.3 |
| **Open scrubs** | 21799.8 | 2.90 | 19136.6 | 2.54 | -2663.2 | -12.2 |
| **Settlements** | 38348.5 | 8.38 | 39172.3 | 5.21 | -23721.4 | -37.7 |
| **Plantations** | 68420 | 8.89 | 31156.9 | 4.15 | -35563.2 | -53.3 |
| **Aquaculture** | 49867.3 | 6.65 | 51912.5 | 6.91 | 2045.2 | 4.1 |
| **Waterlogged area** | 62965.4 | 8.39 | 107826 | 14.36 | 44860.6 | 71.2 |
| **Agricultural land** | 74993 | 6.95 | 50508 | 6.72 | -1640 | -3.1 |
| **Total** | 74973.7 | | 750615.72 | | 876.02 | |

Mangrove forest has decreased from about 175702.8 ha in 2000 to about 138279.8 ha in 2017 , within which , 24773.0 ha forest has been occupied by water logged area, 764.8 ha occupied by aquaculture ponds, 74.6 ha occupied by human settlements and 3390.5 ha occupied by agricultural lands during the period in between 2000 to 2017 . Similarly, mangrove swamps also decreased tremendously, which was about 14970.1 ha in 2000 and reduced to 7598.5 ha in 2017, of which, agricultural land occupied 2321 ha, aquaculture land occupied 1775.9 ha and settlements occupied 1053 ha. On the other hand, Sandy beach increased from 1251 ha in 2000 to 5164.2 ha in 2017. It occupied almost 59 ha of lands from mangrove forests, 2.6 ha from swamps, 221 ha from mudflats, 41.7 ha from agricultural lands, 34 ha from aquaculture ponds. Plantations of the study area also decreased from 68380 ha to about 31156.6 ha during the period of 2000 to 2017, out of which, 7239.7 ha plantation land occupied by agricultural lands , 23,756 land turned into water logged areas, 4622.8 ha land has been transformed into aquaculture firms and 2041 ha land occupied for human settlements . Total area of mudflats was near 20,416.3 ha in 2000 which increased to 48141 ha in 2017 with a rate of 38.7% i.e. 13,437 ha lands added to mudflats. It occupied 1435 ha mangrove forests and 24.2 ha mangrove swamps area. Besides, mudflat also occupied 11318 ha riverine area, 368 ha sandy beach, 130 ha open scrubs , 310.4 ha settlements and 153 .7 ha plantations as well as 208.8 ha agricultural land and 1613.5 ha aquaculture firm. River in 2000 was 221973.3 ha but increased to about 251885.8 ha in 2017, indicating about 43883 ha increase of the river which is almost equal to the certain rate of 21.1%. It takes about 666.4 ha lands from mangrove forests, 4.1 ha from swamps, 2721.9 ha from mudflats.

Moreover , 261.3 ha from sandy beach and 14.9 from the open scrubs , 20.4 from the settlement area , 76.1 ha lands from the plantation area, 44.9 ha from the agricultural lands and also about 560.8 ha from that of the aquaculture lands have been taken up by the rivers . Agricultural land was ~ 74,956.2 ha in 2000 but in 2017 it reduced to ~ 42,000 ha with a decreasing rate of 3.1%. It implies that near 1640 ha agricultural land has decreased in between 2000 to 2017. 6889.7 ha agricultural land has been taken up by mangrove forests and 152.3 ha by mangrove swamps. Not only these but also, 3733.2 ha lands occupied by river and ~ 305 ha land occupied by mudflats. 12,344.2 ha agricultural land became waterlogged and 11,832.4 ha land has been transformed to aquaculture firms, 2485 ha occupied by vegetations and 14798.5 ha has been captured by human settlements. In 2000, open scrub land was nearly, 21,799.8 ha but it significantly reduced to ~19,136 ha in 2017, which implies that it reduced at an amount of 2663.2 ha with a rate of 12.2% in between 2000 to 2017. Out of 2663.2 ha, 2806.8 ha occupied by mangroves, swamps 78.5 ha occupied by swamps, 1170.9 ha by mudflats, 230 ha by rivers, 734 ha by sandy beaches, 5827 ha by human settlement, 4917.6 ha by agricultural lands, 500.2 ha by vegetations, 2318.5 ha by aquaculture firms and even 2115.5 ha open scrubs transformed to waterlogged area.

**NDVI Patterns in the study area**

The NDVI values vary between -1 and +1. In the study, the values of more than 0.3 indicate the richest or healthy vegetation. NDVI value below 0 indicates the water body and from 0.01 to 0.02 is non vegetated area followed by 0.02 to 0.03 as unhealthy vegetation. According to Fig: 5 the healthy vegetation have declined in Sundarban Biosphere Reserve but the non vegetated cover have increase gradually over the time period. And a slight increase in unhealthy vegetation cover is shown by Fig: 5 to paddy cultivation in these seasons. In 2000 the NDVI range between -0.75 to +0.72, which reduced to between -0.16 to + 0.40 in 2017. Therefore, it can be said that the NDVI is decreasing in Sundarban Biosphere Reserve over the time.

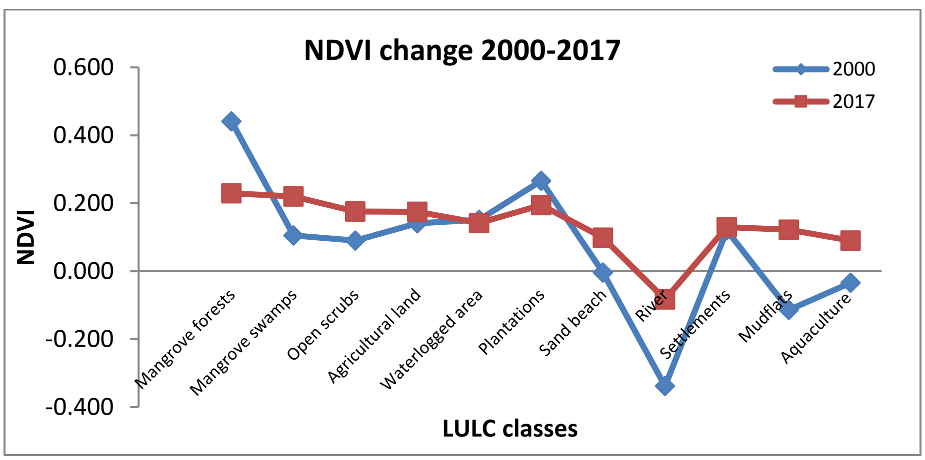


**Figure 2 NDVI change 2000-2017**

**Changes in land surface temperature**

The average surface temperature of the study area has increased at the rate of 0.041˚c per decade. Fig.6 shows that all the LULC classes identified recorded increase in the surface temperature over the study period. Spatio-temporal distribution of surface temperature shows that settlements recorded the highest average temperature 28 ºC in 2000 and 29.2 ºC in 2017 followed by waterlogged 23.4̊C in2000 and river deposition 20.4̊ C 2017. This implies that growth of settlement does bring up surface temperature by replacing vegetation with non-evaporating surface. The lowest average temperature was recorded in River is 19.7̊ C 2000 and 20.4̊ C in 2017 followed by Sandy beach 27 ºC in 2000 –29 ºC in 2017 and Mangrove forest 27 ºC in 2000 –22.7̊ C in 2017 (Figure 6). Vegetation showed a considerably lower and almost similar radiant temperature in both years because vegetation can reduce amount of heat stored in the soil and surface through transpiration.

Vegetation has low temperature because the amount of heat stored is reduced through transpiration (Omran 2012). Surface temperature of water was low compared to other classes but the increase rate was high because the date of the data acquisition was November and the radiant reflected from the water body was lower than other objects in winter seasons. Rate of increase of surface temperature was highest over Setttlements (1.52 ºC) followed by Sand beaches (1.24 ºC) Mudfltas and Aquaculture firms and Mangrove Forest (~0.047˚C), River (0.0411˚C), Plantations and settlement (~0.029˚ C). Waterlogged areas and agricultural field experienced rate of temperature decrease being respectively 0.041˚C and 0.011˚C (Table 10).

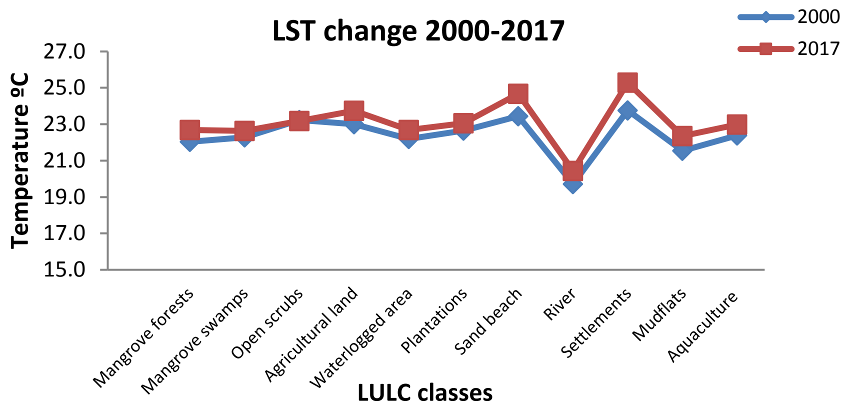


**Figure 6 LST change 2000-2017**

## Land use/land cover change and land surface temperature relations

Land use/land cover change map revealed that the surface temperature has increased at high rate in those areas where land use/land cover classes were converted to settlement. Highest increase of temperature was observed where Mangrove Forests were converted into settlement followed by paddy to settlement (1.80 ºC) and deposition to settlement (1.66 ºC) while a decrease of land surface temperature is observed where settlements were transformed into waterlogged (0.19 ºC). It was seen from the profiles that surface temperature has increased due to transformation of land use/land cover classes into non-evaporating surfaces. Land surface temperature has increased due to transformation of deposition and open forest into settlement, conversion of paddy into settlement while it has decreased due to transformation of settlement into waterlogged areas and conversion of open forest into paddy. It is inferred from the analysis that surface temperature has increased in response to different land use/land cover changes in different zones of the study area. For example, in core area the temperature increased due to increase in deposition. Buffer zone recorded high surface temperature due to transformation of open forest to settlement while in transition zone surface temperature has decreased only in those areas which are characterized with waterlogged areas.

## To evaluate the relation between NDVI and LST of the Land use land cover classes

The relationship between the LST and NDVI of the same landuse classes were plotted. It has been observed that those LULC classes having higher LST have an inverse relationship with the NDVI of the same class except in water logged areas or rivers where both NDVI and LST are lesser. Another exception is seen in case of plantations. This may be due to the presence of settlements in an around plantations which influence the LST of the class. It can be inferred that with increasing LST the NDVI can be seen decreasing for most class.

## Conclusions

The study demonstrates significant changes in land use land cover in the study area. Surface energy budget of the study experienced alteration considerably in response to large scale land use/land cover changes. One of the distinct changes was observed in the northern part of the reserve where unprecedented increase in seasonal waterlogged area was recorded due to high tidal water. Another important change was observed as the expansion of settlement due to exponential growth of population. The area under paddy has increased to feed the million mouths. While open forest, deposition and water body experienced decrease in their respective areas. The changes in land use/land cover modified the radiant surface temperature and consequently surface energy budget. These changes in land surface temperature were validated by transect profiles and land use change map drawn in three parts of the study area. These profiles revealed that the land surface temperature has increased in those areas which are transformed from open forest to paddy, open forest to settlement, paddy to settlement and deposition to settlement. Thus, increase in non-evaporating surfaces and decrease in vegetation has increased the land surface temperature of the study area. Hence land surface temperature acts an important function of land use/land cover and modifies the temperature of surrounding areas.

As the direct driving force in the exchange of long-wave radiation and turbulent heat fluxes at the surface–atmosphere interface, land surface temperature (LST) is one of the most important parameters in the physical processes of surface energy and water balance at local through global scales Due to the strong heterogeneity of land surface characteristics such as vegetation, topography, and soil, LST changes rapidly in space as well as in time and an adequate characterization of LST distribution and its temporal evolution, therefore, requires measurements with detailed spatial and temporal sampling.

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