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Temporal Change of Urban Heat Island Scenario in Sreerampur sub-division in West Bengal: a Geospatial Approach

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Abstract
Urbanisation is one of the major indicators of development of the modern world. The whole world has been going under the process of urbanisation at a rapid rate and India is also not an exception in this case. Since last few decades, India has also witnessed a remarkable progress in the process of urban development. This continuous urban development has also accelerated the urban heat island event with the progress of time. An attempt has been made in this paper to analyse the temporal change in urban heat island phenomenon in Sreerampur sub-division owing to rapid urbanisation of the study area. The study has been done by adopting a Geospatial approach where Land Surface Temperature (LST) maps and Landuse and landcover maps of the study area has been prepared from Landsat satellite images. The study revealed that the LST always remained much higher than the average values for the years taken for study and this event clearly signifies the occurrence of urban heat island. Notable land use and land cover change for urban development has been considered to be responsible for the occurrence of urban heat island over the area.
Keywords: *Urbanisation, urban heat island, LST, Landuse and landcover change.*

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I. INTRODUCTION

Urbanisation is one of the major keys of development of the modern world. At present, the world is undergoing the process of urbanisation at a rapid rate. India is also not an exception. Census data of 1901 revealed that about 11.4% of population in India resided in urban areas in 1901 that has increased to become 31.16% in 2011 (Sen and Bhattacharjee, 2021). Continuous process of urbanisation has led to the construction of more and more buildings, cemented pavements and masonry structures to fulfil the needs of this continuously increasing urban population. Often times, urbanisation also takes place at the expense of the surrounding land covers where by it is noticed that vegetated areas are cleared off indiscriminately or waterbodies are filled up for the construction of residential, industrial and business complexes. Hence, it can be seen that concretization and urbanisation are the two sides of the same coin. Unplanned and unscientific urban expansion is having a significant impact upon the physical environment to a large extent (Roy and Basak, 2020). Urban Heat Island is one such event where it is seen that the urbanised areas experience more temperature than its surrounding rural areas because the concrete structures, tall buildings and cemented pavements trap in them a considerable amount of heat energy (Singh, 2005). With increase in urbanisation, the urban heat island phenomenon is also being triggered. Using modern technique of GIS and Remote Sensing, it has become possible to portray the temporal changes in the urban heat island event of any area. An attempt has been made in this paper to analyse the change in urban heat island scenario of Sreerampur sub-division in West Bengal for the years of 1999, 2009 and 2019.

II. MATERIALS AND METHODS

In order to accomplish the task, Landsat 5 TM and Landsat 7 ETM+ satellite images were downloaded from USGS Earth Explorer. Landuse and landcover maps and Land Surface Temperature (LST) maps were prepared from the satellite images using ERDAS Imagine 2014 and ArcGIS 10.3 software by following the specific algorithms (Adhikari and Roy, 2020) in order to understand the temporal change in the phenomenon. Graphs were prepared using MS Excel. Finally, all maps and graphs were analysed to arrive at the necessary results.
Details of satellite data collected for preparing the maps are given below in table 1:

Table 1: Details of Satellite images referred

Aquisition date	Sensor and Satellite	Reference System/path/row
1999/03/28	Landsat 5 TM	UTM -45N/138/44
2009/03/07	Landsat 5 TM	UTM-45N/138/44
2019/03/11	Landsat 7 ETM+	UTM- 45N/138/44

Source: USGS Earth Explorer

III. RESULTS AND DISCUSSIONS

A brief idea about Study Area:

Sreerampur sub-division is one of the most urbanised and densely populated administrative unit of Hooghly district and is located on the left back of the River Hoogly. The sub division comprises of 7 police stations, 4 community development blocks, 6 municipalities and 34 census towns. The total population of the sub-division is 1469.849 according to 2011 census. The sub division has latitudinal extension from 22°38´56´´N to 22°48´20´´ N while the longitudinal extension is from 87°58´51´´E to 88°21´43´´ E. The total area of the sub-division is about 398.50 sq. km.

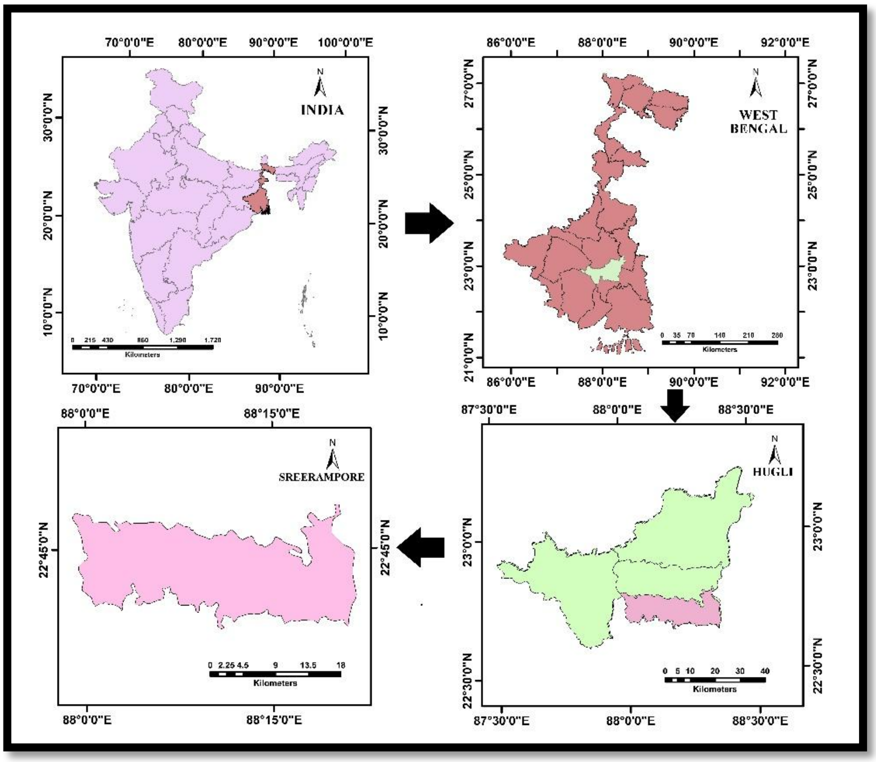

Figure 1: Location Map of the Study Area

Land use and landcover of Sreerampur sub-division:

Since the intensity of urban heat island largely depends upon the area under built up area, a temporal analysis of land use and landcover has been performed for the years of 1999, 2009 and 2019.

Year 1999:

In the year 1999, out of the total area of 39850 hectares, 12360.8 hectares was covered with dense vegetation accounting for about 31% of total area. Out of the total area of 39850 hectares, 3681.5 hectares was covered with scattered vegetation accounting for about 9.24% of total area. Out of the total area of 39850 hectares, 14532.9 hectares was occupied by barren lands accounting for about 36.5% of total area. Built up area accounted for 19.9% of the total area where out of the total area of 39850 hectares, 7913.79 hectares was under built up area. Out of the total area of 39850 hectares, 1361.79 hectares was covered with waterbodies accounting for about 3.41% of total area. Hence, it can be seen that most of the area of Sreerampur sub-division was covered by barren land in 1999.

As it can be seen from the figure 2, dense vegetation is occupying the central part and eastern of the subdivision along with small pockets in the western part. Scattered vegetation can be seen in the peripheral areas of dense vegetation in the eastern and central part of the study area. Dominance of barren land can be seen in the western part of the study area. Most of the built-up area can be seen in the eastern portion of the study area. Pockets of smaller built-up areas can be seen all over the map. Waterbodies can be seen in the form of small pockets mainly along the eastern part of the study area.

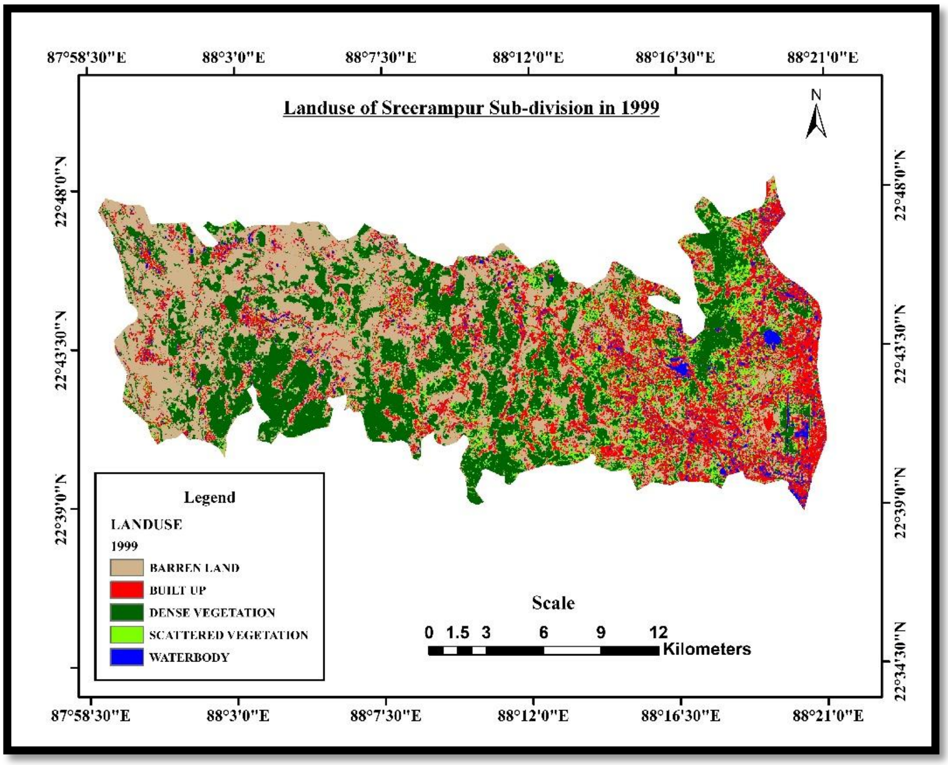

Figure 2: Land use and landcover map of Sreerampur sub-division in 1999.

Year 2009:

In the year 2009, out of the total area of 39850 hectares, 7937.5 hectares was covered with dense vegetation accounting for about 20% of total area. Out of the total area of 39850 hectares, 6459.5 hectares was covered with scattered vegetation accounting for about 16.2% of total area. Out of the total area of 39850 hectares, 9216.9 hectares was occupied by barren lands accounting for about 23.1% of total area. Built up area accounted for 36.6% of the total area where out of the total area of 39850 hectares, 14594.3 hectares was under built up area. Out of the total area of 39850 hectares, 1642.6 hectares was covered with waterbodies accounting for about 4.12% of total area. Hence, it can be seen that most of the area of Sreerampur sub-division was covered by built-up area in 2009.

As it can be seen from the figure 3, dense vegetation is occupying the central part and eastern of the subdivision along with small pockets in the western part. Scattered vegetation can be seen in the peripheral areas of dense vegetation in the eastern and central part of the study area. Dominance of barren land can be seen in the western part of the study area. Intrusion of barren land can also be seen within the dense vegetation area. Most of the built-up area can be seen in the eastern portion of the study area and has got intensified with time. Pockets of smaller built-up areas can be seen all over the map. Waterbodies can be seen in the form of small pockets mainly along the eastern part of the study area.

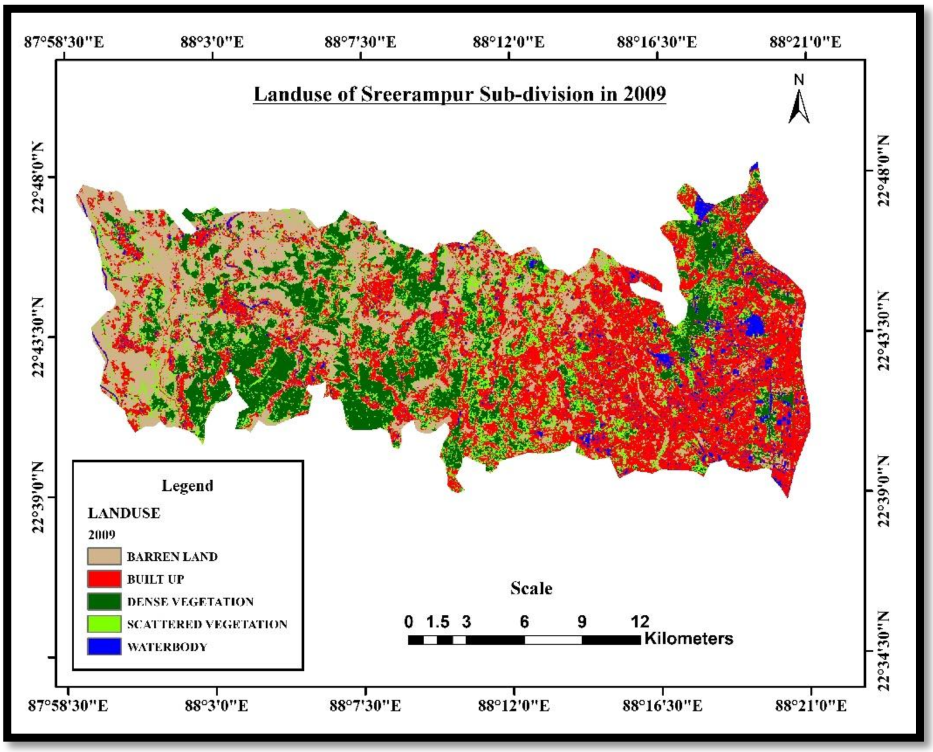

Figure 3: Land use and landcover map of Sreerampur sub-division in 2009.

Year 2019:

In the year 2019, out of the total area of 39850 hectares, 1709.01 hectares was covered with dense vegetation accounting for about 4.29% of total area. Out of the total area of 39850 hectares, 10323.8 hectares was covered with scattered vegetation accounting for about 25.9% of total area. Out of the total area of 39850 hectares, 4505.7 hectares was occupied by barren lands accounting for about 11.3% of total area. Built up area accounted for 52.8% of the total area where out of the total area of 39850 hectares, 21079.5 hectares was under built up area. Out of the total area of 39850 hectares, 2232 hectares was covered with waterbodies accounting for about 5.6% of total area. Hence, it can be seen that most of the area of Sreerampur sub-division was covered by built-up area in 2019.

As it can be seen from the figure 4, dense vegetation has turned into small pockets. Scattered vegetation can be seen in the central and western part of the map. Dominance of barren land can be seen in the western part of the study area. Most of the built-up area can be seen in the eastern portion of the study area. Pockets of smaller built-up areas can be seen all over the map. Dense cluster of built-up area can also be noticed in the eastern parts of the map. Waterbodies can be seen in the form of small pockets mainly along the eastern part, central and southern part of the study area.

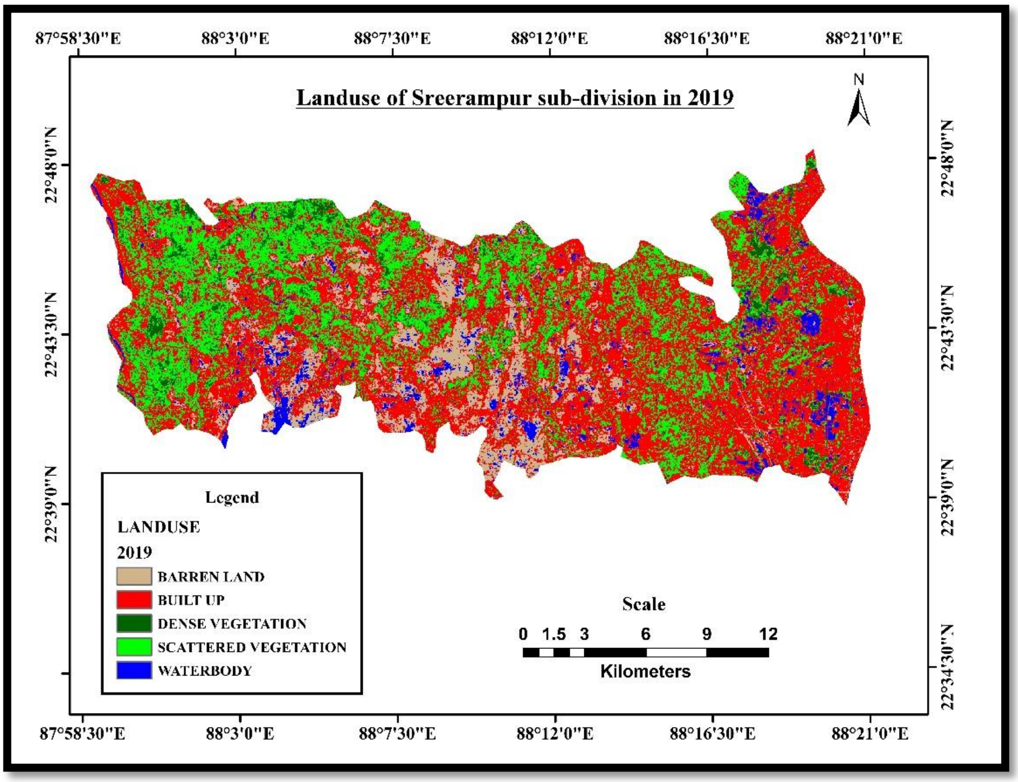

Figure 4: Land use and landcover map of Sreerampur sub-division in 2019.

Temporal Change of Land-use and landcover pattern of Sreerampur sub-division from 1999 to 2019:
In order to have a clear idea about the changing scenario of land-use and landcover pattern of Sreerampur sub-division between the years of 1999, 2009 and 2019, a comparative analysis of several land-use and landcover were performed.

- **Dense Vegetation-** In 1999, about 31% of the total land area of the Sreerampur sub division was covered with dense vegetation which sharply declined to become 20% in 2009 and declined further to 4.28% in 2019 (Figure 5). This large-scale decline in areal coverage of dense vegetation was due to destruction of vegetation for urbanisation. Many dense vegetated areas have been cleared off and converted into barren lands for agriculture or for construction of residential complexes. A considerable portion of dense vegetation area has also been converted into scattered vegetation.
- **Scattered Vegetation-** In 1999, about 9.2% of the total land area of Sreerampur sub-division was covered with scattered vegetation which have increased to become 16.2% in 2009 and further increased to have become 25.9% in 2019 (Figure 5). The reason responsible for this continuous rising trend of scattered vegetation in the area is that a huge part of dense vegetated area has been converted into scattered vegetation areas for some developmental activity which got delayed owing to certain unavoidable circumstances.
- **Barren Land-** In 1999, about 36.5% of the total land area of the study area was covered with barren land which declined to 23.1% in 2009 and further declined to 11.3% in 2019 (Figure 5). The reason responsible for this declining trend of barren land with time is that a large part of the barren land is converted into built up areas while a considerable portion of the barren land that remained unutilised have developed vegetation cover and have entered into the category of scattered vegetation.
- **Built up-** In 1999, about 20% of the total area of the study area was covered with built up which increased to 36.6% in 2009 and made a meteoric rise to 52.8% in 2019 (Figure 5). This continuously rising trend of built-up area is owing to large scale conversion of barren lands and dense vegetation areas into built up areas. This rapid rise in built-up area within the study area between 1999 and 2019 is a clear indication of rapid urbanisation of Sreerampur sub-division.
- **Waterbodies-** In 1999, about 3.4% of the total land area of Sreerampur sub-division was covered with waterbodies which increased to 4.1% in 2009 and further increased to become 5.6% in 2019 (Figure 5). Filling up of low-lying areas around waterbodies and barren lands with water is held responsible for such an increase in area of the waterbodies.

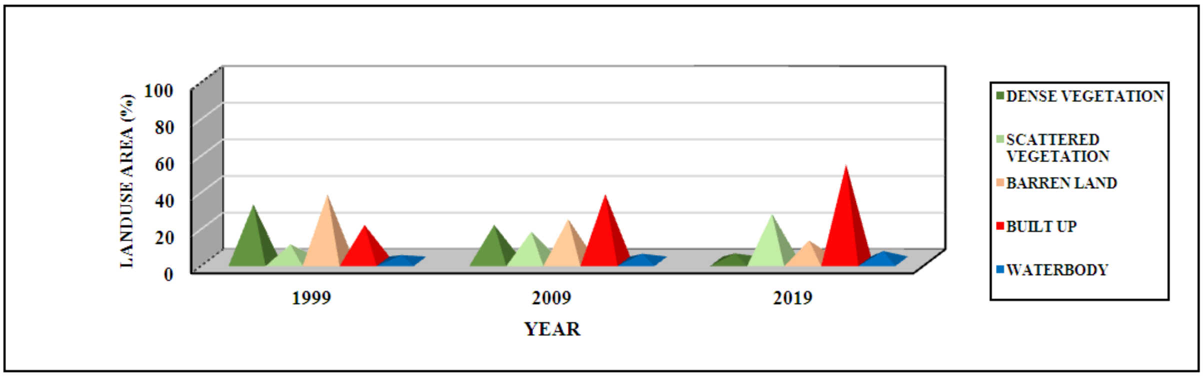

Figure 5: Temporal change in Land-use and landcover of Sreerampur sub-division (1999-2019)

Portrayal of the scenario of Urban Heat Island of the study area:

A comparative analysis was made between the Land Surface Temperature Maps to have a clear idea about the scenario of urban heat island of the study area (Sen and Bhattacharjee, 2021). Urban Heat Island is a phenomenon that can be noticed in the city areas as they experience more temperature than their rural counterparts. Increasing concretization and urbanisation are primarily considered responsible for such an increase in Urban Heat Island effect because a large part of the outgoing terrestrial radiation remains trapped within the buildings and concretized roads and thus help in increasing the temperature range within the city areas. Besides, barren lands also trap a huge portion of the heat that also triggers the urban heat island effect. Through the analysis of maximum and minimum temperature data of the study area for the last 38 years for the month of March, it has been found that the maximum temperature of Sreerampur sub-division was 36.2°C while the minimum temperature was 20°C. Thus, it can be stated that the range of temperature for the last 38 years of the study area was 16.2°C.

On preparing the Land Surface Temperature Maps of the study area for the month of March in the three years taken for study it can be seen that all the temperature parameters remained much above the average values. In 1999, the maximum temperature of the study area was 44°C (7.8°C more than the average value of 36.2°C) while the minimum temperature turned out to be 23.2°C which is 3.2°C more than the average value of 20°C (Figure 6A). In the year 2009, the maximum temperature of the study area was 44°C (7.8°C more than the average value of 36.2°C) while the minimum temperature turned out to be 22.8°C which is 2.8°C more than the average value of 20°C (Figure 6B). Finally, in 2019, the maximum temperature of the study area was 42.2°C (6°C more than the average value of 36.2°C) while the minimum temperature turned out to be 22.3°C which is 2.3°C more than the average value of 20°C (Figure 6C).

Besides, the range of temperature in these three years taken for study also remained much higher than the average value of 16.2°C. In 1999, the range of temperature was 20.8°C; in 2009, it turned out to be 21.2°C and in 2019, the temperature range turned out to be 19.9°C.

Hence, from the above discussions, it can be stated that, in all the years that has been taken into account for study, the temperature (maximum, minimum and range) exhibited much higher values that their average in spite of minor fluctuations. Such deviation is the manifestation of urban heat island effect of the study area with change in time (Sen and Bhattacharjee, 2021).

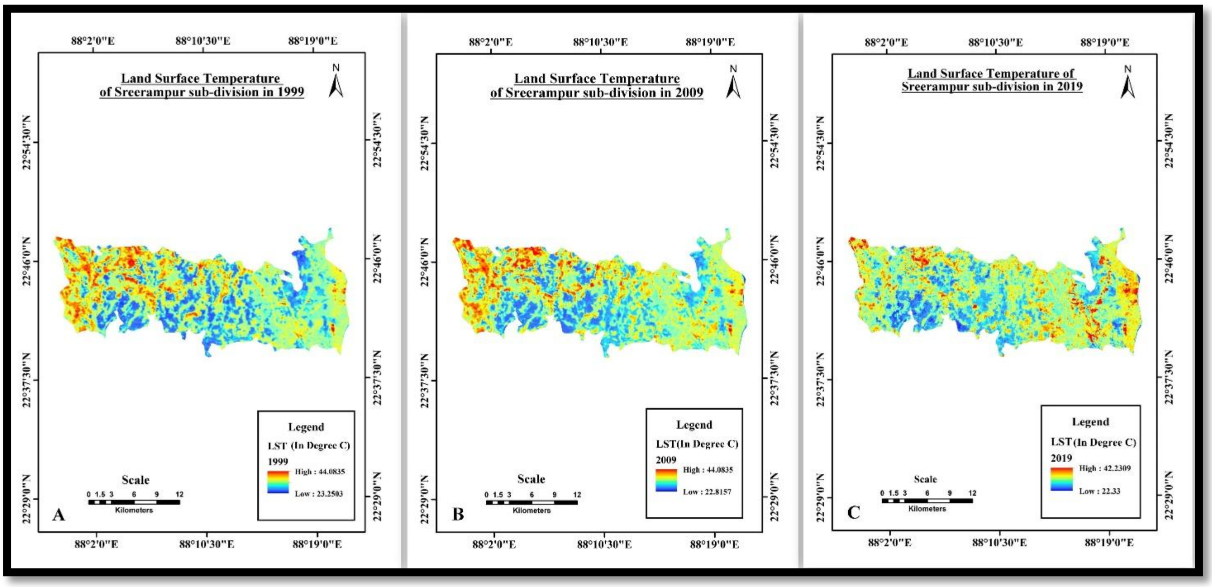

Figure 6: Scenario of Land Surface Temperature of Sreerampur sub-division (1999-2019)

Relationship between land-use change and urban heat island effect:

As it is already known that urbanisation is largely responsible for the creation of urban heat island, the Sreerampur sub-division has undergone certain changes in its land use pattern over time that has triggered the development of urban heat island. The masonry structures like buildings, cemented pavements, skyscrapers etc. (Singh, 2011). trap a lot of heat by absorbing it. This stored energy is responsible for increasing the temperature within the urban set up and thus it gives rise to an urban heat island (Chatterjee, 2020). In the Sreerampur sub-division, high range of temperature that has been noted in the study years is held responsible for the increase in urban heat island phenomena. The study area has experienced a constant increase in its built-up area coverage in the years 1999, 2009 and 2019. In 1999, about 20% of the total area of the study area was covered with built up which increased to 36.6% in 2009 and made a meteoric rise to 52.8% in 2019 (Figure 5). This continuously rising trend of built-up area is owing to large scale conversion of barren lands and dense vegetation areas into built up areas. Besides, the study area also has got a good proportion of barren lands which although has exhibited a declining trend is also held responsible for increase in the event of urban heat island phenomenon over time (Macarof and Florian, 2017). This is because barren lands absorb about 70% to 80% of solar radiation incident on it. Decline in the areal coverage of dense vegetation over time (12360.8 hectares in 1999, 7937.5 hectares in 2009 and 1709.01 hectares in 2019) is also held responsible for increase in the event of urban heat island over time. This is because trees and vegetation lower the temperature by providing shed and through evapotranspiration.

IV. CONCLUSION

From the above discussion, it becomes clear that change in land use is responsible for increasing the phenomenon of urban heat island in the study area. There is no doubt of the fact that urbanisation is a precursor of human development (Roy, 2020). However, while undertaking and planning urban developmental strategies, it is very essential that the ecological issues has to be kept in mind. Unplanned urbanisation and unscientific urban expansion must be restricted. Urban Heat Island not only creates discomfort in the life of the urban dwellers but also it has significant impact upon the vegetation health. So, urbanisation planning has to be done in such a way that it caters the need of the people on one hand and also maintains the ecological balance on the other. Development of rooftop gardening and creation of urban greenspace can be adopted to achieve the strategy of balanced urbanisation in the future.

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