ISSN: 2277-9655
Impact Factor: 3.785

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

IDENTIFICATION OF URBAN HEAT ISLANDS FROM MULTI TEMPORAL MODIS LAND SURFACE TEMPERATURE DATA IN THE SOUTHERN PART OF WEST BENGAL, INDIA

Naval Kishore Yadav *, Abhisek Santra, Amiya Kumar Samanta

* Department of Civil Engineering, Haldia Institute of Technology, I.C.A.R.E Complex, H.I.T Campus, Hatiberia, PO HIT, District Midnapore (E), Haldia, West Bengal 721657

Department of Civil Engineering, Haldia Institute of Technology, I.C.A.R.E Complex, H.I.T Campus, Hatiberia, PO HIT, District Midnapore (E), Haldia, West Bengal 721657

Department of Civil Engineering, National Institute of Technology, Durgapur West Bengal - India – 713209

DOI: 10.5281/zenodo.51847

ABSTRACT

Land surface temperature is the temperature of the earth's ground surface and is crucial for climate studies in different aspects like geology, engineering, phenology etc. Research on urban heat island is mainly dependent upon the land surface temperature studies and is highly useful from civil engineering perspective. An attempt has been made here to study the spatio-temporal dynamics of the land surface temperature and associated urban heat islands in the southern part of West Bengal, India. The authors extracted the major urban heat islands from mean monthly time series MODIS Land Surface Temperature data sets for the period from 2010 to 2015 and identified the pattern of change of land surface temperature in the study area. The urban heat island patterns have also been correlated with the classified land use and land cover information of the same area.

KEYWORDS: Land Surface Temperature, Urban Heat Island, MODIS, Globcover.

INTRODUCTION

The land surface temperature of an area is the skin temperature of the ground. Over the past several decades global process of urbanization has progressed dramatically rapid, thus gave rise to many problems for the urban environment and climate. When a large fraction of natural land cover in an area is replaced by built-up area, it traps incoming solar radiation during the day and reradiate at night, the resulting phenomenon is known as Urban Heat Island (UHI). UHI can be expressed in terms of temperature difference between urban and rural areas [1]. Thus, UHI was considered as the most well established example of anthropogenic impact on urban climate[2-3]. In recent years urban heat island (UHI) has become a topic of great interest both among the academicians and the governing bodies. Researchers throughout the world show their interests in understanding the various aspects of this phenomenon including its causes [4], impacts [5] and complexity [6]. UHI is increasingly gaining interest as it directly affects both environmental [7-8] as well as human health [9-10]. UHI puts adverse effects on the environment through pollution [11], increases the number of smog events [12], higher energy consumptions [13], while from human health perspectives, it causes high temperature related health problems [14] and affects human comfort [3; 15]. Therefore it is very essential to understand the UHI phenomena and its ill effect on the environment in order to mitigate this effect to some extent for betterment of environment and human race.

From the above mentioned references, it is evident that several valuable works have been done on urban heat islands throughout the world. However, few outcomes have been reported from West Bengal, India in this regard despite of the presence of highly urban and industrial areas specifically in the southern part of the West Bengal. In this paper an attempt has been made to identify the spatio-temporal pattern of summer time UHI of southern part of West

Bengal. Also the surface extents of the UHIs have been compared from the land use land cover information of the area.

MATERIALS AND METHODS

Study Area

The study area encompasses south Bengal and mainly focused on Kolkata, North and South 24 parganas, Purba Medinipur, Paschhim Medinipur, Birbhum, Bankura, Puruliya, Hugli, Haora and Barddhaman districts. The latitudinal and longitudinal extents of the area are approximately 22º35´ N to 24º N and 85º50´ E to 89º E respectively. Southern part of West Bengal includes densely populated mega city Kolkata and industrial hubs like Haldia, Kharagpur, Asansol, Durgapur etc as the major urban agglomerations. The study area (West Bengal) is located about 5 metres above mean sea level and it ranks 14th as per land area and 4th in population (India). The summer time atmospheric temperature of area ranges between 38º C and 45º C.

This high temperature in summer is a combined consequence of high population density and never ending emission of industries. As urbanisation and industrialisation will continue, it is very important to identify heat islands because the further increase in population and industries in those areas may lead to bad consequences over agriculture, living life and climatic cycle.

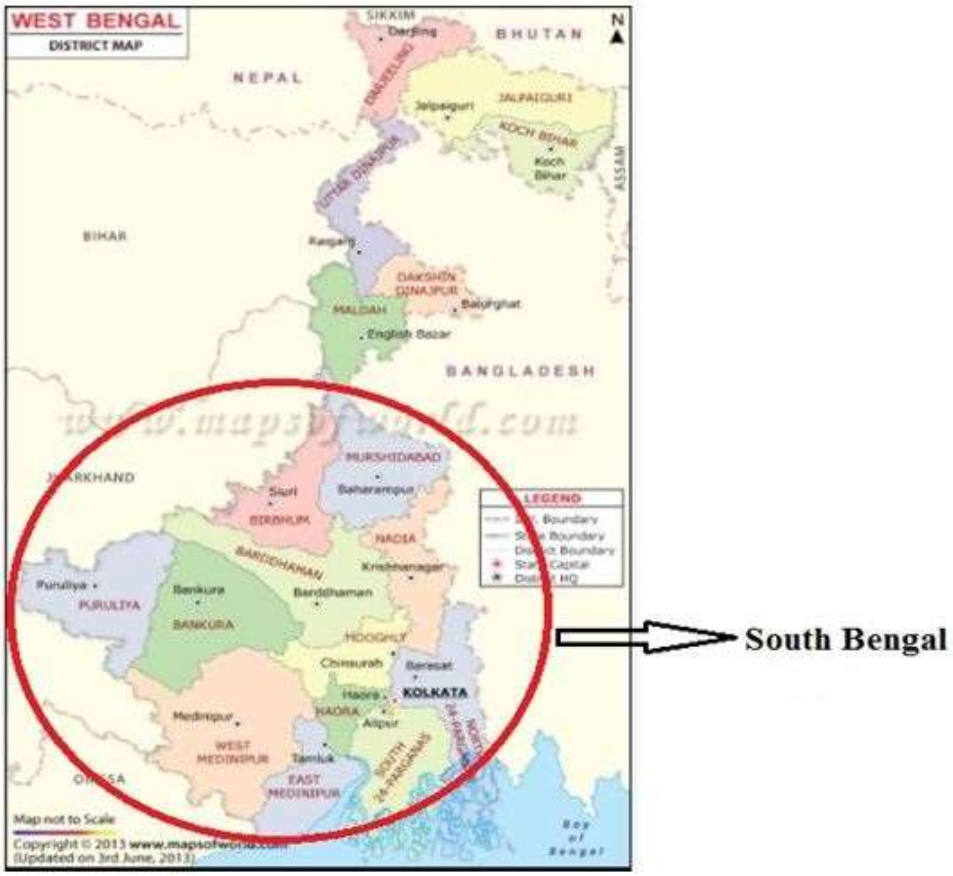

Figure 1. Study Area

Database and Methodology

Land surface temperature (LST) of the southern part of the Bengal is estimated from the MODIS monthly LST images acquired for the period from 2010 to 2015. The data has been freely acquired from NASA Earth Observation (NEO) website. The spatial resolution of the data is 11.132 Km (0.1 degree). The data is a geo-referenced product in

ISSN: 2277-9655
Impact Factor: 3.785

geographic latitude/longitude coordinate system and WGS84 datum plane. Since UHI is distinct in summer season, only four months from March to June have been considered for the identification and understanding of the dynamics of UHI for the study area.

The downloaded data were stacked considering four months for each year. After that, data for each year consisting of four layers have been clipped with the exact boundary of the study area using the ERDAS Imagine software package. The exact boundary of the study area (AOI) has been digitised and extracted from the published maps of the Census of India (2011). ArcGIS software package has been used to reclassify the set of images in terms of different LST classes. After that the classified image of the study area collected from ENVISAT MERIS Globcover was considered to cross validate the spatial locations of UHIs. The classified data also clipped using the same study area of interest (AOI) layer in Erdas Imagine software. The methodology flow diagram (Figure 2) simplifies the broad framework of the research.

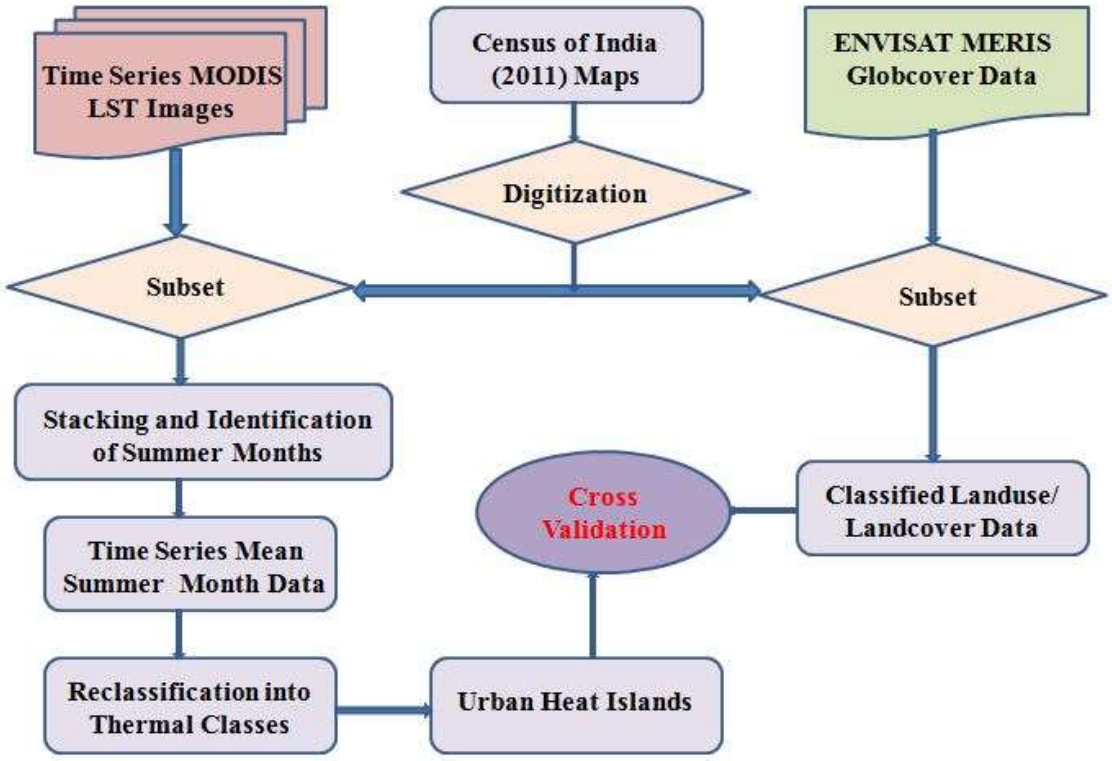

Figure 2. Methodology Flow Chart

In order to study the temperature values of the different month of particular years it was observed that the four month summer data shows a large variance with respect to data of remaining months from mean LST value, but these four month data has a very low variance value so we decided to choose these four month data for the finding of UHI. Then the mean of summer data of each individual year were calculated using modeller in ERDAS IMAGINE 9.2 and then these image outputs were reclassified into thermal classes using ArcGIS 10 software. We collected ENVISAT MERIS Glob Cover data. In the mean time we collected and digitized the census India map of south Bengal to locate our study area then by the use of two above set of mention data we obtained the south Bengal land use/land cover classified data. Again using this classified data along with reclassified mean summer data (thermal classes) we drew the comparison among the mean LSTs (year wise) to identify UHI within our AOI. The methodology is shown below in the form of flow chart.

ISSN: 2277-9655
Impact Factor: 3.785

RESULTS AND DISCUSSION

As a good indicator of the earth's energy balance at the surface of the earth, LST controls the physics of the land surface processes directly or indirectly both on global and regional scale. It integrates the surface atmospheric interactions and energy fluxes between the atmosphere and the ground surface. The reclassified area gives the number of pixels contained in each temperature range. It has been observed that the temperature values of the four summer months have less variance with the mean summer temperature values. The mean summer temperature of the study area for 2010 to 2015 was calculated using the modeler tool of Erdas Imagine software package. The range of temperature adopted is below 30ºC, 30-35ºC, 35-40ºC and 40ºC onwards. Here it would be more relevant to draw the comparison among the class 4 area values as this class is high temperature range (Table 1).

Table 1. Year wise land surface temperature values for the highest land surface temperature class

Year	Area in Sq. Km.
2010	16481.36
2011	991.36
2012	1239.20
2013	7806.96
2014	15985.68
2015	247.84

The maps generated (Figure 3) show the spatio-temporal dynamics of the land surface temperature. The prevailing aridity shows the high land surface temperature in and around Puruliya district. The years 2010 and 2014 show high spatial distribution of the very high temperature class probably due to environmental and climatic reasons. The results also reveal a four yearly cyclic pattern of LST change in the study area. However, it is clear from the figure 3; two heat islands have evolved in and around Kolkata and Haldia areas surrounded by cooler temperature regime. These two are the possible results of high urbanisation and industrial development in those areas.

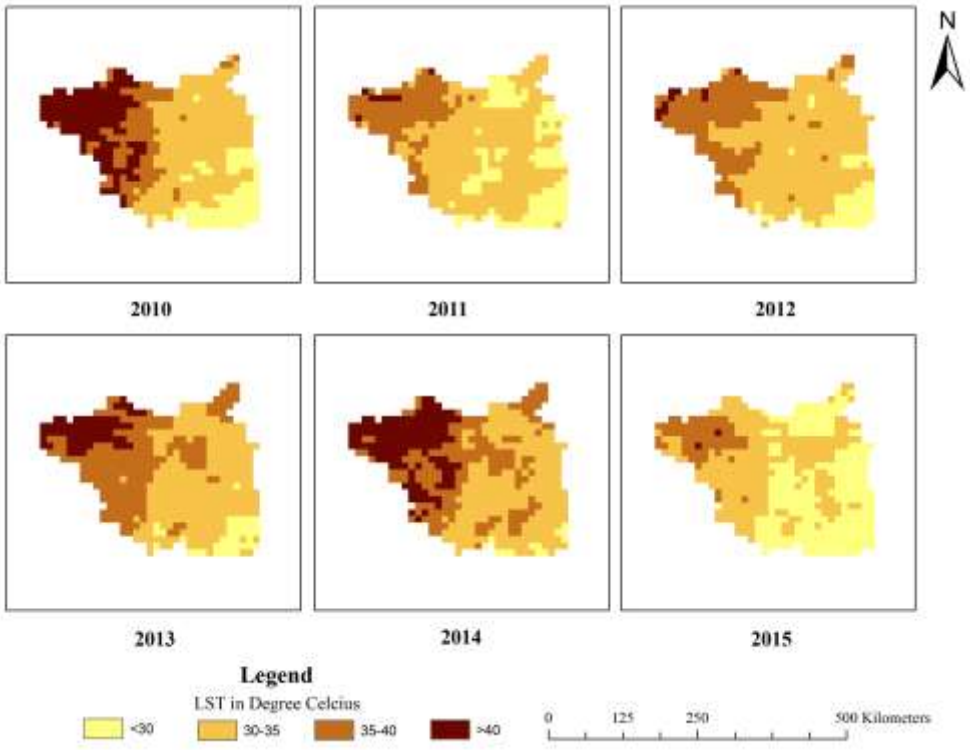

Figure 3. Spatio-Temporal Pattern of the Land Surface Temperature

ISSN: 2277-9655
Impact Factor: 3.785

The land use and land cover data of the area depicts mostly cultivated and irrigated lands (fig. 4). Some patches of forested lands can also be seen. Mangroves dominate at the lower parts of South 24 Parganas district. Four urban areas can be distinctly located at Kolkata – Howrah, Barddhaman – Asansol – Durgapur, Kharagpur – Medinipur and Haldia. These four areas are of primary concern from UHI point of view. However, among these four urban agglomerations, only two – Kolkata – Howrah and Haldia areas can be visible as UHIs at the coarse spatial resolution from the thermal images. The prevailing aridity and small scale of the data are probably hindering the visibility of the other two urban regimes and heat islands. However, high spatial resolution thermal images at the larger scale may isolate them as heat islands.

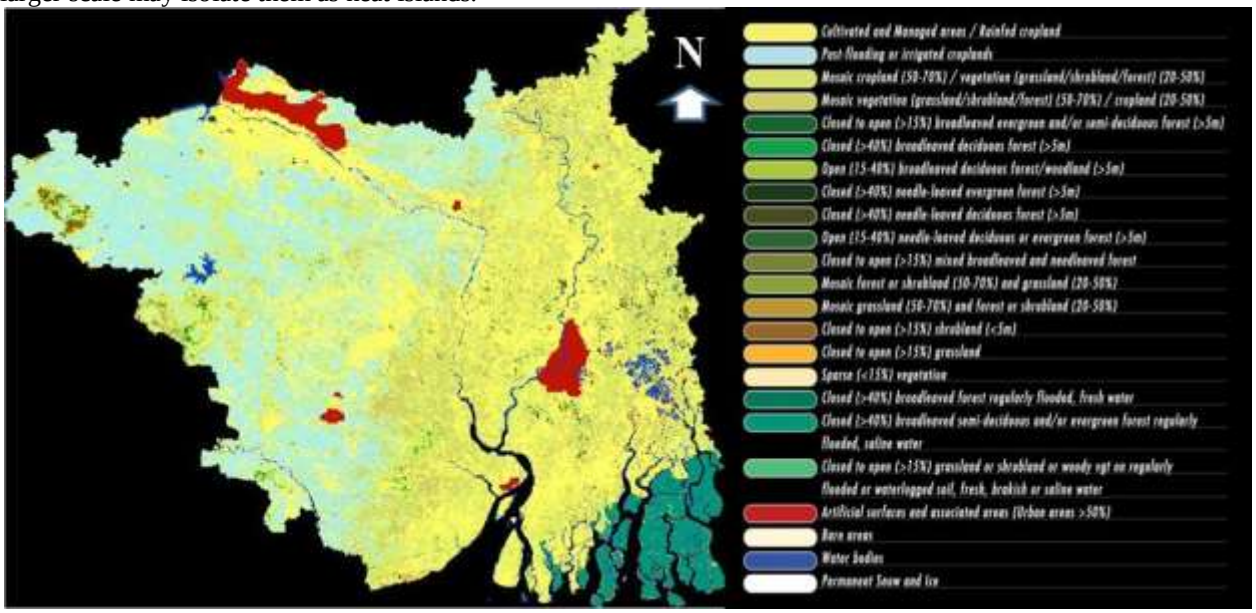

Figure 4. Land Use and Land Cover

CONCLUSION

The present research demonstrates the importance of thermal remote sensing as a valuable source of temperature information for cities and urban agglomerations. However, the scale of the images is the first and foremost criteria in this regard to fill up the gaps of lack of information. The paper indentifies the spatio-temporal changes of LST in this area. It also pinpoints the impact of summer months on LST. However, for a large area the coarser resolution images may be used to identify probable UHIs. After that, the high resolution satellite images with thermal bands may be applied to see the small urban heat islands within an urban area. In this way, the temperature characteristics of the cities can be identified in relation to the urban land use and expansion. The relevance of such studies is not immediately obvious and deserves closer inspection.

ACKNOWLEDGEMENTS

The authors are thankful to National Institute of Technology, Durgapur and Haldia Institute of Technology, Haldia for the support to develop this article.

REFERENCES

[1] R. Joshi, H. Raval, M. Pathak, S. Prajapati, A. Patel, V. Singh, M.H. Kalubarme, "Urban heat island characterization and isotherm mapping using geo-informatics technology in Ahmedabad city, Gujarat state, India", International Journal of Geosciences, Vol. 6, pp. 274-285, 2015.

[2] A.J. Arnfield, "Two decades of urban climate research : A review of turbulence, exchanges of energy and water, and the urban heat island", International Journal of Climatology, Vol. 23, pp. 1-26, 2003.

[3] R. Sharma, P.K. Joshi, "Identifying seasonal heat islands in urban settings of Delhi (India) using remotely sensed data – An anomaly based approach", Urban Climate, Vol. 9, pp. 19-34, 2014.
[4] G. Huang, W. Zhou, M.L. Cadenasso, "Is everyone hot in the city? Spatial pattern of land surface temperatures, land cover and neighbourhood socioeconomic characteristics in Baltimore, MD", Journal of Environmental Management, Vol. 92, No. 7, pp. 1753–1759, 2011.
[5] M.L. Imhoff, P. Zhang, R.E. Wolfe, L. Bounoua, "Remote sensing of the urban heat island effect across biomes in the continental USA", Remote Sensing of Environment, Vol. 114, pp. 504-513, 2010.
[6] P.A. Mirzaei, F. Haghighat, "Approaches to study urban heat island – abilities and limitations", Building and Environment, Vol. 45, No. 10, pp. 2192-2201, 2010.
[7] G. Ferguson, A.D. Woodbury, "Urban heat island in the subsurface", Geophysical Research Letters, Vol. 34, pp. L23713, 2007.
[8] R. Sharma, P.K. Joshi, "Monitoring urban landscape dynamics over Delhi (India) using remote sensing (1998–2011) inputs", Journal of the Indian Society of Remote Sensing, Vol. 41, No. 3, pp. 1-10, 2012.
[9] C.P. Lo, D.A. Quattrochi, "Land-use and land-cover change, urban heat island phenomenon, and health implications: a remote sensing approach", Photogrammetric Engineering & Remote Sensing, Vol. 69, pp. 1053-1063, 2003.
[10] C.J. Tomlinson, L. Chapman, J. Thomes, C.J. Baker, "Including the urban heat island in spatial heat health risk assessment strategies: a case study for Birmingham, UK", International Journal of Health Geographics, Vol. 10, No. 42,pp., 2011.
[11] D.K. Papanastasiou, C. Kittas, "Maximum urban heat island intensity in a medium-sized coastal Mediterranean city", Theoretical and Applied Climatology, Vol. 107, pp. 407-416, 2012.
[12] J.F.C. Sham, T.Y.L. Lo, S.A. Memon, "Verification and application of continuous surface temperature monitoring technique for investigation of nocturnal sensible heat release characteristics by building fabrics", Energy and Buildings, Vol. 53, pp. 108-116, 2012.
[13] M. Kolokotroni, X. Ren, M. Davies, A. Mavrogianni, "London's urban heat island: impact on current and future energy consumption in office buildings", Energy and Buildings, Vol. 47, No., pp. 302-311, 2012.
[14] S.L. Harlan, D.M. Ruddell, "Climate change and health in cities: impacts of heat and air pollution and potential co-benefits from mitigation and adaptation", Current Opinion in Environmental Sustainability, Vol. 3, pp. 126-134, 2011.
[15] G.J. Steeneveld, S. Koopmans, B.G. Heusinkveld, L.W.A. van Hove, A.A.M. Holtslag, "Quantifying urban heat island effects and human comfort for cities of variable size and urban morphology in the Netherlands", Journal of Geopgysical Research, Vol. 116, No. 14, 2011.