Eco. Env. & Cons. 30 (January Suppl. Issue) : 2024; pp. (S219-S226)
Copyright@ EM International
ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2024.v30i01s.045

Monitoring land use land cover transformations and its effects on land surface temperature using geospatial approach in Jharsuguda District, Odisha, India

Abinash Mansingh[1], Monty Kujur[3], Satyabrat Sahoo[2], Laxmi Prasad Rath[1] and Nirius Jenan Ekka[1*]

[1]School of Life Sciences, Sambalpur University, Burla 768 019, India
[2]Department of Earth Sciences, Sambalpur University, Burla 768 019, India
[3]School of Biotechnology, Gangadhar Meher University, Sambalpur 768 004, India

(Received 2 June, 2023; Accepted 12 August, 2023)

ABSTRACT

The aim of the work was to analyse Land use land cover (LU/LC) changes and their correlation with the increased Land surface temperature (LST) in Jharsuguda district, Odisha using geospatial techniques and transformation analysis in ArcGIS 10.4 software. Remotely sensed data from Landsat 8 operational land imager (OLI) for March 2013 and Landsat 9 OLI for March 2023 were utilized to investigate LU/LC and LST changes. The satellite data was classified using the maximum likelihood supervised classification algorithm (MLSC) to derive LULC maps. The overall accuracy of these classified LULC maps was determined to be more than 85% in both years. In order to obtain LST information from the satellite images, the spectral radiance model was utilized. The findings of the study revealed a clear correlation between the loss of vegetation cover (VC) and the expansion of built-up areas, which consequently contributed to an increase in the urban heat islands (UHI). The LU/LC estimation indicates substantial changes in the landscape over the past ten years. Specifically, there was a notable net increase in urban area (UA) by 55.12%, while very dense forest (VDF) experienced a reduction of 49.28%, moderately dense forest (MDF) decreased by 18.60%, and open forest (OF) by 42.58% as well as non-forest (NF) by 1.76% between 2013 and 2023. Furthermore, the study observed that the maximum temperature of the city rises from 46.8°C in 2013 to 48.3°C in 2023. So, the municipal authority can take new decision policies and management to reduce the effects of LST for sustainable development in the further future.

Key words: *Land use land cover, Land surface temperature, Urban heat island, Landsat*

Introduction

Land surface temperature (LST) is one of the most important dynamic surface conditions for understanding the earth's surface energy balance (Rao *et al.,* 2019; Singh *et al.,* 2020). LST produced from remote sensing data is a unique source of information for defining urban heat islands (UHI) and has been widely employed as a UHI indicator in the studies (Tran *et al.,* 2017). According to Mallick *et al.* (2008) and Pal and Ziaul (2017), converting vegetation land into inaccessible built-up land harms the ecosystem, hydrological balance, biodiversity, and local climates. The LST is increasing globally due to land use and land cover conversion (Song *et al.,* 2018; Liu *et al.,* 2020; Moisa *et al.,* 2022). More over land use and land cover (LU/LC) is one of the most important parameters for correctly identifying a region (Rousta *et al.* 2018). According to Rousta *et al.* (2018), rapid surface changes caused by LU/LC alterations significantly impact the local and regional environment. Therefore, the most striking characteristic of the current era of rapid urban and industrial growth is the establishment of urban heat islands (Ranagalage *et al.* 2018a, b). As urban centres continue to expand, there is a growing concern about the ecological and environmental implications of this rapid urban growth (Xian and Crane, 2005). One of the primary consequences of urbanization on the local climate is the UHI effect, wherein urban areas experience higher land surface temperatures than their rural counterparts (Taha, 1997; Rizwan *et al.*, 2008; Tran *et al.*, 2017). The UHI effect is attributed to modifications in land cover, the proliferation of impervious surfaces, and increased heat generation from human activities.

Elevated land surface temperatures in urban areas can have several adverse effects, including altered weather patterns, increased energy consumption, reduced air quality, and potential health risks for the inhabitants (Meineke *et al.*, 2014; Plocoste *et al.*, 2014). Also, studies conducted in different parts of India confirmed that there is a substantially increasing trend of LST (Das and Angadi, 2020; Chetia *et al*,, 2020; John *et al.*, 2020; Saha *et al.*, 2021; Gohain *et al.*, 2021; Ashwini and Sil, 2022; Das *et al.*, 2022). The study aims to explore the relationship between LST fluctuations and LU/LC transformations using remote sensing and geographic information system (GIS) techniques. Integrating LU/LC analysis and LST assessment will offer a holistic view of the ongoing urbanization process and provide valuable information for decision-making and proactive measures to ensure the region's sustainability and resilient future. The manuscript aims to address (i) the effect of urbanization on land use land cover changes over the last decade (2013-2023) in this industrial district and (ii) to analyse the impact on LST.

Materials and Methods

Study area profile

The study area Jharsuguda popularly known as power house of Odisha is one of the northern located districts of the state Odisha. It is the industrial economic hub, lies between 83° 27' to 84° 23' east longitudes and 21° 31' to 22° 03' north latitude having geographical area of 2114 Sq. Km., occupies 1.36% of the total state's area (Fig. 1). The district shares its border with Sundargarh district in north, Sambalpur district in east, Bargarh district in south and Chattisgarh state in west. The district has a mean

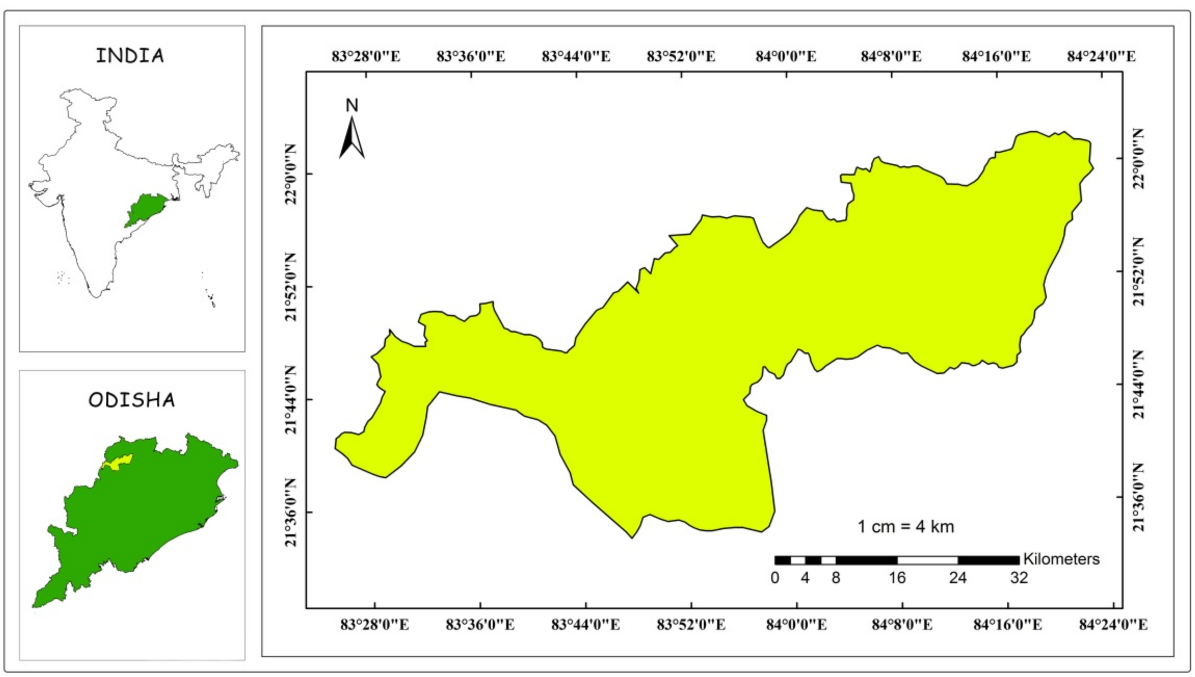

Fig. 1. Study area map of Jharsuguda district

elevation of 230 to 250 meters above sea level, and it experiences a predominantly hot and humid climate from March to June, while the months from October to February are characterized by colder weather. In 2020, the district recorded an actual annual rainfall of 1875.0 mm, which was higher than the normal rainfall of 1362.8 mm. As of the 2011 census, the total population of the district was 5.80 lakhs, accounting for 1.38% of the state's population. The level of urbanization stands at 39.89% of the total district population as against the 3.30% in the state Odisha. The population density of the district is 274 persons per Sq. Km. slightly higher of 270 persons per Sq. Km. of the state (District statistical hand book, Jharsuguda, 2020).

Satellite data used

For this research, previous ten years of data (2013 and 2023) were selected. In this period, two Landsat Multi spectral satellite data were acquired from the United States Geological Survey (USGS) domain to estimate the changes in LU/LC and LST dynamics in the study area. All of these images were downloaded (Table 1) for the month of March to prevent the influences of seasonal variations (Al Rakib *et al.* 2020; Faisal *et al*. 2021; Kafy *et al.* 2020). In the image downloading process, maximum cloud coverage was set to less than 10% for ensuring a realistic estimation of LULC and LST. However, across the study region, it was near to zero percent. No additional geo-correction or image processing required for the pre-processing of images since there were no radiometric and geometric distortions in Landsat Satellite data.

Land cover classification

The study used appropriate band combinations to generate band composites for all the Landsat images. These band composites were employed to select training samples representing various LU/LC classes, following the spatial analyst toolset in ArcGIS 10.4 Software clarified by Trolle *et al*. (2019). The Landsat images collected for 2013 and 2023 were classified into six main LU/LC classes: VDF, MDF, OF, NF, built up and Water bodies (Table 2). The Maximum Likelihood Supervised Classification (MLSC) technique was used to estimate the LU/LC maps, approximately 25 training samples were selected for each LU/LC class. These training samples served as representative examples of the respective classes and were used to train the MLSC algorithm for accurate classification.

Table 1. Description of the images acquired from Landsat satellite sensors (https://earthexplorer.usgs.gov)

Satellite data	Date of acquisition	Sensor	Path/ Row	Band No. Landsat 8/9	Spectral range (Wavelength µm)	Spatial resolution (m)
Landsat 8	26th March, 2013	OLI/TRIS	141/045	Band 1 - Coastal /aerosol	0.43-0.45	30
Landsat 9	11th March, 2023	OLI/TRIS	141/045	Band 2 - Blue	0.45-0.51	30
				Band 3 - Green	0.53-0.59	30
				Band 4 - Red	0.64-0.67	30
				Band 5 - Near Infrared (NIR)	0.85-0.88	30
				Band 6 - Shortwave Infrared (SWIR) 1	1.57-1.65	30
				Band 7 - Shortwave Infrared (SWIR) 2	2.11-2.29	30
				Band 8 - Panchromatic	0.50-0.68	15
				Band 9 - Cirrus	1.36-1.38	30
				Band 10 - Thermal Infrared (TIRS) 1	10.6-11.19	100
				Band 11 - Thermal Infrared (TIRS) 2	11.50-12.51	100

Table 2. Descriptions of LULC classes

LULC Classes	Description
VDF	Forests with a canopy cover of more than 70%
MDF	Forests with a canopy cover between 40% and 70%
OF	Forests with a canopy cover between 10% and 40%
NF	Areas that do not meet the criteria for any of the above forest types
Built up	Residential, commercial and industrial services, transportation network
Waterbodies	River, wetlands, lakes, ponds, and reservoirs

In order to assess the accuracy of the classified LU/LC maps, available field data coordinates and google earth images to establish 150 ground truth points were taken. Kappa statistics and Confusion Matrix, recognized as reliable indicators for image classification accuracy, were employed in the accuracy assessment of the classified LU/LC maps (Congalton and Green, 2008; Foody, 2002; Pontius Jr and Millones, 2011; Story and Congalton, 1986).

Estimation of LST

The LST was estimated using the digital numbers (DN) of the thermal bands (Band 10 in Landsat 8-9 OLI/TIRS). The spectral radiances (λ) of the Landsat 8-9 OLI/TIRS bands were computed at the preliminary phase. L_λ was used to derive the LST in Degree Celsius using the top of atmosphere brightness temperature followed by normalized difference vegetation index (NDVI). Finally, LST was analysed using land surface emissivity and proportion of vegetation.

Results

LU/LC and accuracy assessment

To analyse the LU/LC patterns during last ten years, the MLSC algorithm was applied for the present study. User accuracy, producer accuracy, overall accuracy and kappa coefficient were estimated to examine the classification accuracy. Overall accuracy of 88.66% for 2013 and 85.33% for 2023 demonstrated an excellent result with kappa coefficient of 0.84 was observed (Table 3). The classification result identified two significant changing patterns during the study period. One is gradual increase in the built-up area and a significant decrease in the vegetation cover. As illustrated graphically (Fig. 2 and 3) and statistically over the last decade +55.12% of the built-up area was increased, result-

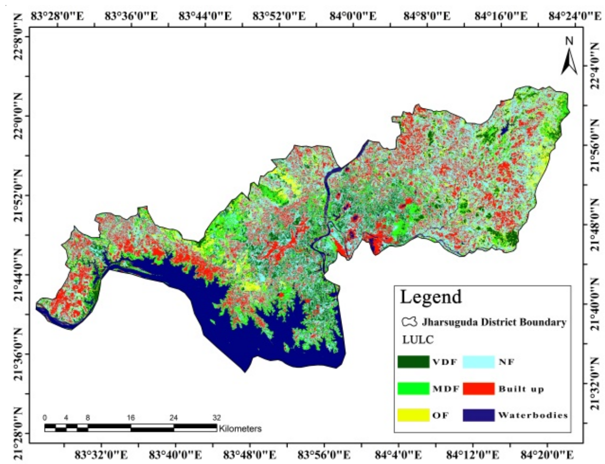

Fig. 2. LULC map of 2013

Table 3. Result of the accuracy of the classified images

LULC Classes	2013		2023	
	Prod. Acc. (%)	User Acc. (%)	Prod. Acc. (%)	User Acc. (%)
VDF	82.14	88.46	85.71	85.71
MDF	95.45	100.00	79.17	90.48
OF	94.12	76.19	85.71	81.82
NF	85.00	85.00	78.95	83.33
Built up	91.67	78.57	93.10	81.82
Waterbodies	79.49	91.18	86.11	88.57
Overall Accuracy (%)	86.66		85.33	
Kappa Coefficient	**0.84**		**0.82**	

Table 4. Statistics of LULC classes of the study area in Sq. Km. and percent

LULC Classes	Area 2013		Area 2023		Change in LULC
	Sq. Km.	(%)	Sq. Km.	(%)	2013-2023(%)
VDF	240.45	11.37	121.95	5.77	-49.28
MDF	205.79	9.73	167.51	7.92	-18.60
OF	165.71	7.84	95.16	4.50	-42.58
NF	731.37	34.60	718.48	33.99	-1.76
Built up	441.69	20.89	685.17	32.41	55.12
Waterbodies	328.98	15.56	325.74	15.41	-0.99
Total	2114	100	2114	100	

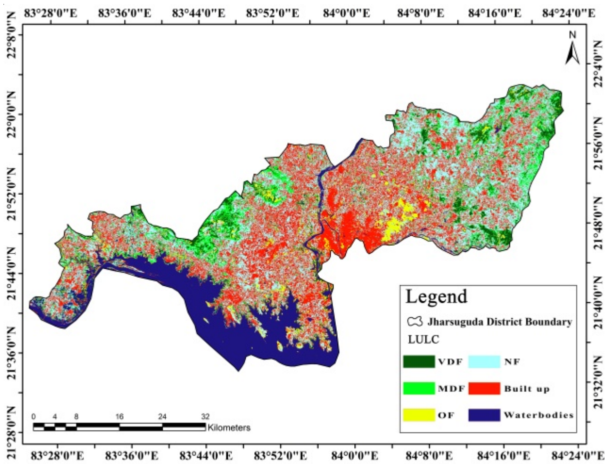

Fig. 3. LULC map of 2023

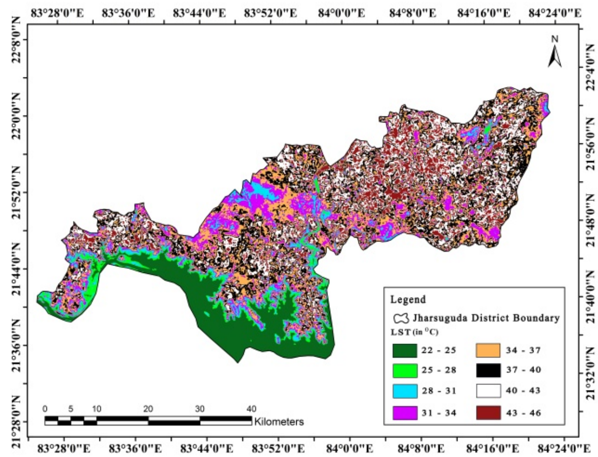

Fig. 4. LST map of 2013

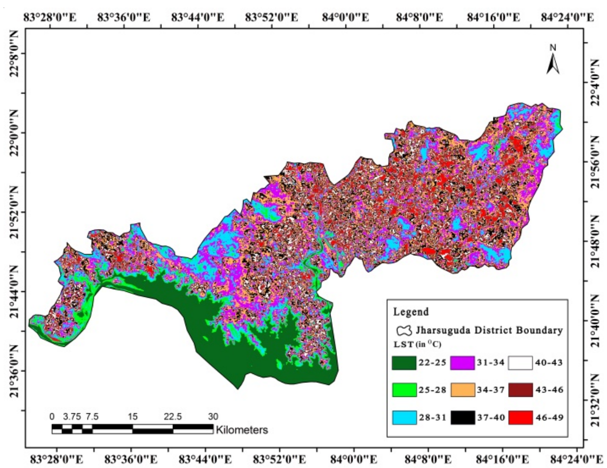

Fig. 5. LST map of 2023

ing -49.28%, -18.60%, -42.58, -1.76 and - 0.99% decrease in VDF, MDF, OF, NF and waterbodies respectively from 2013 to 2023 (Table 4).

Land surface temperature (LST)

The analysis of LST revealed a notable transformation of lower recorded temperature zones in 2013 into higher temperature zones in 2023, which indicates a significant impact on local microclimates due to changes in land cover. Specifically, the maximum temperature of the city experienced an upward trend, rising from 46.8 °C in 2013 to 48.3 °C in 2023. Moreover, an increasing trend of temperature in the range of 22 ºC to 37 ºC and 46 ºC to 49 ºC was observed and on the contrary decreasing trend seen in 37 ºC to 46 ºC may be for the weather condition of that particular day for which the satellite data was downloaded (Table 5, Fig. 4 and 5). This rise in maximum temperature highlights the urban heat island effect and underscores the importance of addressing the environmental consequences of unplanned urban growth and land use changes in the region.

Table 5. Classified LST of the study area in Sq. Km. and Percent

LST Classes(ºC)	Area 2013		Area 2023		Change in LST
	Sq. Km.	(%)	Sq. Km.	(%)	2013-2023(%)
22 – 25	257.75	12.19	276.08	13.06	7.11
25 – 28	73.79	3.49	93.75	4.43	27.06
28 – 31	113.97	5.39	229.85	10.87	101.68
31 – 34	246.79	11.67	374.73	17.73	51.84
34 – 37	381.90	18.07	409.89	19.39	7.33
37 – 40	500.20	23.66	324.05	15.33	-35.22
40 – 43	410.03	19.40	224.10	10.60	-45.35
43 – 46	129.58	6.13	124.87	5.91	-3.64
46 – 49	0	0.00	56.68	2.68	56.68
	2114	100	2114	100	

Discussion

Jharsuguda district, located in the western region of Odisha, has witnessed considerable changes in its land use land cover over the last decade due to increasing urbanization and industrialization. The district's strategic location and economic potential have attracted a surge in population, resulting in the expansion of urban areas and transformation of the surrounding landscape (Ranjan *et al.*, 2021). This urbanization process often leads to changes in land cover, such as converting natural and agricultural lands into built up areas which, in turn, can profoundly impact the local climate and environment. Ranjan *et al*. (2021) and Sahu *et al.* (2022) studied how vegetation cover changes in different years from 1995 to 2020 using only LU/LC practices in Jharsuguda District. We used both LU/LC and LST to assess the consequence of urbanization. Areas with more built-up lands are often warmer than their surroundings. Our finding on built up area has experienced higher LST is similar with other previous researchers like Tran *et al.* (2017), Karakus, (2019), Simwanda *et al.* (2019), Hassan *et al.* (2021) and Ullah *et al.* (2023).

Due to increased mining area with an annual change of +0.03%, the vegetation cover of Jharsuguda district continuously decreased with an annual change of -0.04% from 2006 to 2018 (Ranjan *et al.* 2021). Sahu *et al.* (2022) also got same result in decrease of vegetation from 1995 to 2020. The present study also revealed the same trend of increased built-up area by 243.48 Sq. Km. over the last decade from 2013 to 2023 and the increasing trend of LST seen in more built-up areas.

The changing trend of LST in Jharsuguda district revealed that urbanization significantly helps in the formation of UHI. This approach reduces vegetation cover, agricultural land and non-forest space. So, as a result of urbanization, there are fewer cool and cold locations and more hot and extremely hot areas (Hassan *et al.* 2021). The development of industrial estates, small workshops, resulting decrease of a large amount of natural vegetation cover, provides an optimal environment for the birth and spread of UHIs in this district. Emissions from these industrial land uses now contribute to the temperature enhancement between the industrial chain and the surrounding environment. To minimize the impact of UHI, it is vital to consider the proper ratios of open space and green areas in cities.

Conclusion

The findings of this research will provide valuable insights into the extent that the rate of urbanization in the district and its implications for the local climate and environment gradually increasing. Larger vegetation cover is divided into smaller fragmented patches of varying sizes are often separated by non-forest areas, such as agricultural fields, roads or urban areas tends to habitat loss, disruption of ecological processes, increased vulnerability to disturbances and reduced ecosystem services. This isolation can prevent species from moving between fragments, leading to a reduction in gene flow and biodiversity. Furthermore, understanding the spatial patterns and trends of urbanization and its associated land surface temperature changes will assist stakeholders, policymakers, urban planners, and environmentalists in formulating effective strategies for sustainable urban development, conserving natural resources, and mitigating the adverse effects of the UHI effect. The conclusion of the study will also contribute to the growing body of knowledge concerning the complex relationship between urbanization, land use and the local climate.

Acknowledgements

The authors would like to express gratitude to the Forest Division, Jharsuguda and US Geological Survey for assisting this research with datasets.Thanks to the late Prof. N. Behera and Prof. S. P. Mishra, School of Life Sciences, Sambalpur University for their initiative and study design of this work.

Conflict of interest

The authors declared that they have no known competing financial interests or personal relationships that might seems to have influenced the work reported in this paper.

Funding information

The research does not receive any funding.

References

Al Rakib, A., Akter, K.S., Rahman, M.N., Arpi, S. and Kafy, A.A. 2020. Analyzing the pattern of land use land cover change and its impact on land surface temperature: a remote sensing approach in Mymensingh, Bangladesh. In: Proceedings of the 1st

International Student Research Conference. Dhaka University Research Society (DURS), University of Dhaka, Bangladesh.

Ashwini, K. and Sil, B. S. 2022. Impacts of land use and land cover changes on land surface temperature overcachar region, northeast India-a case study. *Sustainability*. 14 (21): 14087.

Chetia, S., Saikia, A., Basumatary, M. and Sahariah, D. 2020. When the heat is on: urbanization and land surface temperature in Guwahati, India. *Acta Geophysica*. 68: 891-901.

Congalton, R.G. and Green, K. 2008. Assessing the Accuracy of Remotely Sensed Data: Principles and Practices, Second Edition (2nd ed.). CRC Press. https://doi.org/10.1201/9781420055139.

Das, S. and Angadi, D. P. 2020. Land Use-land Cover (Lulc) Transformation and Its Relation with Land Surface Temperature Changes: A Case Study of Barrackpore Subdivision, West Bengal, India. *Remote Sensing Applications: Society and Environment*. 19: 100322. https://doi.org/10.1016/j.rsase.2020.100322

Das, T., Jana, A. and Mandal, B. 2022. Spatio-temporal pattern of land use and land cover and its effects on land surface temperature using remote sensing and GIS techniques: a case study of Bhubaneswar city, Eastern India (1991–2021). *GeoJournal* 87 (Suppl 4): 765–795. https://doi.org/10.1007/s10708-021-10541-z

District Statistical Hand Book, Jharsuguda. 2020. Directorate of Economics and Statistics. Government of Odisha. http://www.desorissa.nic.in/pdf/dshb-jharsuguda-2020(merged).pdf. Assessed on 1st August 2023.

Faisal, A.A., Kafy, A. Al, Al Rakib, A., Akter, K.S., Raikwar, V., Jahir, D.M.A., Ferdousi, J. and Kona, M.A. 2021. Assessment and prediction of seasonal land surface temperature change using multi-temporal Landsat images and their impacts on agricultural yields in Rajshahi, Bangladesh.*Environmental Challenges.* 4: 100147. doi: 10.1016/j.envc.2021.100147.

Foody, G.M. 2002. Status of land cover classification accuracy assessment. *Remote Sensing of Environment*. 80:185-201.

Gohain, K. J., Mohammad, P. and Goswami, A. 2021. Assessing the impact of land use land cover changes on land surface temperature over Pune city, India. *Quaternary International*. 575: 259-269.

Hassan, T., Zhang, J., Prodhan, F. A., Sharma, T. P. P. and Bashir, B. 2021. Surface Urban Heat Islands Dynamics in Response to Lulc and Vegetation Across South Asia (2000–2019). *Remote Sensing.* 16(13): 3177. https://doi.org/10.3390/rs13163177.

John, J., Bindu, G., Srimuruganandam, B., Wadhwa, A. and Rajan, P. 2020. Land use/land cover and land surface temperature analysis in Wayanad district, India, using satellite imagery. *Annals of GIS*. 26(4): 343-360.

Kafy, A.A., Rahman, M.S., Islam, M., Al Rakib, A., Islam, M.A., Khan, M.H.H., Sikdar, M.S., Sarker, M.H.S., Mawa, J. and Sattar, G.S. 2020. Prediction of seasonal urban thermal field variance index using machine learning algorithms in Cumilla, Bangladesh. *Sustainable Cities and Society.* 64:102542. doi: 10.1016/j.scs.2020.102542.

Karaku, C.B. 2019. The Impact of Land Use/Land Cover (LULC) Changes on Land Surface Temperature in Sivas City Center and Its Surroundings and Assessment of Urban Heat Island. *Asia-Pacific Journal of Atmospheric Sciences*. 55: 669–684. https://doi.org/10.1007/s13143-019-00109-w.

Liu, J., Hagan, D. F. T. and Liu, Y. 2020. Global land surface temperature change (2003–2017) and its relationship with climate drivers: AIRS, MODIS, and ERA5-land based analysis. *Remote Sensing*. 13(1): 44.

Mallick, J., Kant, Y. and Bharath, B. D. 2008. Estimation of land surface temperature over Delhi using Landsat-7 ETM+. *Journal of Indian Geophysical Union.* 12(3): 131-140.

Meineke, E. K., Dunn, R. R. and Frank, S. J. 2014. Early Pest Development and Loss of Biological Control Are Associated with Urban Warming. *Biology Letters.* 11(10): 20140586. https://doi.org/10.1098/rsbl.2014.0586.

Moisa, M. B., Dejene, I. N., Roba, Z. R. and Gemeda, D. O. 2022. Impact of urban land use and land cover change on urban heat island and urban thermal comfort level: a case study of Addis Ababa City, Ethiopia. *Environmental Monitoring and Assessment*. 194(10): 736.

Pal, S. and Ziaul, S. K. 2017. Detection of land use and land cover change and land surface temperature in English Bazar urban centre. *The Egyptian Journal of Remote Sensing and Space Science*. 20(1): 125-145.

Pontius, R.G. and Millones, M. 2011. Death to Kappa: birth of quantity disagreement and allocation disagreement for accuracy assessment. *International Journal of Remote Sensing*. 32:4407-4429.

Ranagalage, M., Dissanayake, D. M. S. L. B., Murayama, Y., Zhang, X., Estoque, R. C., Perera, E. N. C. and Morimoto, T. 2018a. Quantifying surface urban heat island formation in the world heritage tropical mountain city of Sri Lanka. *ISPRS International Journal of Geo-Information*. 7(9): 341. http://doi.org/10.3390/ijgi7090341

Ranagalage, M., Estoque, R. C., Zhang, X. and Murayama, Y. 2018b. Spatial changes of urban heat island formation in the Colombo District, Sri Lanka: Implications for sustainability planning. *Sustainability*. 10(5): 1367. http://doi.org/10.3390/su10051367

Ranjan, A. K., Sahoo, D. and Gorai, A. K. 2021. Quantitative assessment of landscape transformation due to coal mining activity using earth observation satellite data in Jharsuguda coal mining region, Odisha, India. *Environment, Development and Sustainability*. 23: 4484-4499. doi: 10.1007/s10668-020-00784-0

Rao, Y. S., Liang, S., Wang, D., Yu, Y., Song, Z., Zhou, Y. and Xu, B. 2019. Estimating Daily Average Surface Air Temperature Using Satellite Land Surface Temperature and Top-of-atmosphere Radiation Products Over the Tibetan Plateau. *Remote Sensing of Environment.* 234: 111462. https://doi.org/10.1016/j.rse.2019.111462

Rizwan, A., Dennis, L. Y. and Liu, C. 2008. A Review on the Generation, Determination and Mitigation of Urban Heat Island. *Journal of Environmental Sciences*. 1(20): 120-128. https://doi.org/10.1016/s1001-0742(08)60019-4

Rousta, I., Sarif, M. O., Gupta, R. D., Olafsson, H., Ranagalage, M., Murayama, Y. and Mushore, T. D. 2018. Spatiotemporal analysis of land use/land cover and its effects on surface urban heat island using Landsat data: A case study of Metropolitan City Tehran (1988–2018). *Sustainability*. 10(12): 4433. http://doi.org/10.3390/su10124433.

Saha, S., Saha, A., Das, M., Saha, A., Sarkar, R. and Das, A. 2021. Analyzing spatial relationship between land use/land cover (LULC) and land surface temperature (LST) of three urban agglomerations (UAs) of Eastern India. *Remote Sensing Applications: Society and Environment*. 22: 100507.

Sahu, S., Rawat, K., Singh, S. and Bahuguna, A. 2022. Land use land cover (LU/LC) change analysis using earth observation data sets over Jharsuguda districts of Odisha. *AIP Conference Proceedings*. 2481. 020040. 10.1063/5.0117977.

Simwanda, M., Ranagalage, M., Estoque, R.C. and Murayama, Y. 2019. Spatial analysis of surface urban heat islands in four rapidly growing African cities. *Remote Sensing.* 11: 1645.

Singh, R. P., Paramanik, S., Bhattacharya, B. K. and Behera, M. D. 2020. Modelling of evapotranspiration using land surface energy balance and thermal infrared remote sensing. *Tropical Ecology*. 61: 42-50.

Song, Z., Li, R., Qiu, R., Liu, S., Tan, C., Li, Q., Ge, W., Han, X., Tang, X. and Shi, W. 2018. Global Land Surface Temperature Influenced by Vegetation Cover and PM2.5 from 2001 to 2016. *Remote Sensing.* 10: 2034. https://doi.org/10.3390/rs10122034.

Story, M. and Congalton, R.G. 1986. Accuracy assessment: a user's perspective. *ISPRS Journal of Photogrammetry and Remote Sensing.* 52: 397-399.

Taha, H. 1997. Urban Climates and Heat Islands: Albedo, Evapotranspiration, and Anthropogenic Heat. *Energy and Buildings.* 2(25): 99-103.https://doi.org/10.1016/s0378-7788(96)00999-1

Tran, D. X., Pla, F., Latorre-Carmona, P., Myint, S. W., Caetano, M. and Kieu, H. V. 2017. Characterizing the relationship between land use land cover change and land surface temperature. *ISPRS Journal of Photogrammetry and Remote Sensing.* 124: 119–132. https://doi.org/10.1016/j.isprsjprs.2017.01.001

Trolle, D., Nielsen, A., Andersen, H.E., Thodsen, H., Olesen, J.E., Børgesen, C.D., Sgaard, J.C., Sonnenborg, T.O., Karlsson, I.B. and Christensen, J.P. 2019. Effects of changes in land use and climate on aquatic ecosystems: coupling of models and decomposition of uncertainties. *Science of the Total Environment.* 657: 627-633.

Ullah, W., Ahmad, K., Ullah, S., Tahir, A. A., Javed, M. F., Nazir, A. and Mohamed, A. S. 2023. Analysis of the Relationship Among Land Surface Temperature (Lst), Land Use Land Cover (Lulc), And Normalized Difference Vegetation Index (Ndvi) With Topographic Elements in The Lower Himalayan Region. *Heliyon*. 2(9): e13322. https://doi.org/10.1016/j.heliyon.2023.e13322

Xian, G. and Crane, M. 2005. Assessments of urban growth in the Tampa Bay watershed using remote sensing data. *Remote Sensing of Environment*. 97 (2): 203-215.