CHANGING LANDSCAPE PATTERNS AND ITS EFFECT ON RISING LAND SURFACE TEMPERATURE OF LAHORE-PAKISTAN

K. Shakrullah[1*] and S. A. Shirazi[2]

[1] Department of Geography, Forman Christian College (A Chartered University), Lahore, Pakistan
[2] Department of Geography, University of the Punjab, Lahore, Pakistan
*Corresponding Author E- mail: khadijashakrullah@fccollege.edu.pk

ABSTRACT: The study intaimsto evaluate the impact of landscape (Land use land cover) changes on Land surface temperature (LST) by using GIS and Remote sensing (RS) techniques in Lahore during 2017–2021.Supervised Maximum Likelihood classification method was used to classify the land use and land cover classes. For retrieval of Land surface temperature, the Landsat 8 (Band 10) product level 2 was used. Barren land and built- up area were identified as the most leading LULC classes respectively in the study area at the cost of vegetation cover and water bodies. The barren land class increased from 55.9% to 63.81% ,while the Built-up class also increases from 13.5% to 18.46% during 2017-2021.Whereas , vegetation and water bodies both are exhibiting the decline. The decline in vegetation class was reported from 29.58% to 17.6% over the time 2017 to 2021.Overall, 0.3 % decrease is observed in water bodies. In 2017 the 3◦C decline is observed in land surface temperature (LST) value than 2021.Built-up and Vegetation classes can contribute a significant role in variation of LST in comparison to the water bodies. These results will be very helpful to understand the LULC changes and eventually it will assist the land management authorities, policy maker and town planners as well.

Key Words: vegetation, Build-up Landsat, Supervised classification.

(Received 16.02.2022 Accepted 16.07.2022)

INTRODUCTION

Land is considered as an inevitable source for better human living (Scanlon *et al.*, 2002; Zahoor *et al.*, 2019).Land use land cover(LULC) changes (thereafter referred to as landscape changes) in response to anthropogenic activities over time outcome of numerous multi scale (i.e., micro to macro and regional to global) ecological consequences/results /impacts such as changes in surface energy balance and land surface temperature(LST) (Dutta *et al* 2019; Das *et al* 2020;Waleed and Sajjad ,2022).The context of these two terms; Land use and Land cover are entirely different but normally used together.

Land use denotes the utilization of the land for different/diverse socio-economic connotation e.g., cultivation, farming. infrastructure and in many diverse forms (Gregorio, 2016; Naz and Rasheed, 2017;Alawamy *et al* .,2020).Whereas land cover means /refers to the bio-physical state of earth like, mountains ,woodlands and wetlands etc (Cihlar and Jansen, 2001); Hassan *et al.*, 2016; Yonaba *et al* ,2022;Romaguera *et al.*, 2018).Human induced activities are considered the drivers of LULC modification on earth surface. In present decade, the studies related to Land-use modifications have gained more attention due to increase in environmental problems resultant from human induces activities e.g., urban sprawl, desertification, and transportation (Lin *et al* 2015; Song *et al.*, 2018; Hussain *et al.*, 2022) Moreover, due to accessibility and free of cost acquisition of Landsat imageries/data sets/products , make it more convenient to assess and evaluate the land use changing patterns and trends more effectively with regular time intervals. The studies related to Land change are also significant because it adhere/discourse/discuss the problems associated to/linked with Earth's energy balance and bio-chemical and physical processes, which directly affect the micro to meso scale urban climate and ecological processes(Dewan *et al.*, 2021a; Yohannes *et al.*, 2021).

Adnan *et al.*, 2020 stated that land-use modification considered a key element to describe the frequency and rate of degradation of various ecological processes.

Generally ,the effect of land cover changes are mainly perceived as an environmental phenomenon such as urban heat island (UHI), land surface temperature, loss of biodiversity, degradation, and flash flood.

It is observed and documented that land-use modification effect the micro climatic conditions of land surface due to ever-changing land-use patterns ,such as ,replacement from natural to impervious surfaces and consequently the underlying surface temperature will show the rising trend as impervious/dark surfaces absorb more heat (Gogoi *et al.*, 2019;Khan *et al.*, 2020). Therefore, cities are more vulnerable to the harsh climate

or experiencing higher temperature than surrounding suburbs due to the UHI effect induced mainly due to such modification in land use patterns (Rinner *et al.,* 2011; Roberts, 2015; Akbari and Kolokotsa,2016). Migration from rural to urban areas and urbanization requires more basic civic amenities of life like, housing, food, medical services, etc. Therefore, this enables more urban and structural development, and its badly affected the habitat life. Floods are associated directly with changes in land use patterns. The rate of water discharge is primarily linked with land cover type. For instance, with gray and impervious surfaces, the water can not easily percolate the surface, so the probability of flash floods is numerous in humid areas. (Adnan *et al.,* 2020). Several studied have reported that approximately 40 % of earth surface area is transformed to the other land use classes, and these transformation/modifications are primarily associated with the ecological or environmental problems we are facing on earth and predicted to be in near future such as the degradation of natural systems which are crucial for sustainable life on earth (Chaudhuri & Mishra 2016; Malik *et al.,* 2019).

Urbanization is not only considered as an inevitable anthropogenic activity linked with these changes but also the main factor of spatio temporal LULC changes (Msofe *et al.,* 2019) .In previous decades, rapid increase in population and economic growth have accelerated the urbanization process. It is estimated/ projected that by 2050 approximately 2.5 billion or 70% of world population will be residing in cities and defined urban centers. On the other hand, in 2018 only 55% global population were inhabited in cities while the share of Asia and Africa in global population is 90% (Kundu and Pandey, 2020). Furthermore, this prevailing situation would further increase the urban growth, by altering the Earth's surface on large/massive scale. Consequently, several challenges linked to microclimate and sustainable ecosystem services.

Land use Land cover change detection mapping in the context/setting of rapid urbanization and its correlated impact on climate/climatic parameters (i.e., LST) to comprehend climatic data is considered to a key factor and fundamental approach for efficient and sustainable development. The modification of land use and land cover from impermeable to built-up area(from agricultural, forest and open spaces to gray structure) as a result of rapid urban growth induces local climate,increasing

The LST leading to urban heat island (UHI), vulnerability to floods, ecological degradation, and habitat loss. Moreover, LULC changes have sever consequences on ecosystem services at the cost of compromised comfort of urban areas (Wiggins, 2000).

Thus, the monitoring and assessment of LULC modification offers prospects to comprehend its continuing/ongoing association/relation with LST, which is a robust climate change indicator (Van Vliet *et al.,* 2016; Akinyemi and Mashame, 2018; Sabagh *et al.,* 2020).In addition, efficient evaluation of LULC changes provides important statistics and data about urban expansion, desertification, disaster assessment, planning, and management of existing land resources. Land use land cover maps analysis and interpretation is easy, so maps are considered the essential tool for policy makers, architect and town planners.

For LULC change detection and analysis, geographic information systems (GIS)and Remote sensing methods are considered an ideal and reliable tool over traditional manual means like land and statistical records. Furthermore, the integration of Remote sensing and GIS techniques are well recognized/documented for their cost friendly, efficient, and accurate data retravel and for acquisition of reliable findings (Kafy *et al*., 2020; Mumtaz ,2020)

Study area: The present study was carried out in Lahore, due to its growing population influx, economic development, and faster urbanization during previous years. The geographical coordinates (UTM) are: 31° 15' and 31° 43' N latitude and 74° 10' and 74° 39' E longitude. The total area of Lahore is 1772 square kilometers and 217 meters elevated from sea level (GoP,2002).

Rapid population growth and rural-to-urban migration are the main drivers of urbanization. On the other hand, the city has to manage the growing demands for land to accommodate the increasing population influx and pressure. Due to the urbanization which led to infrastructural growth and expansion has been remarkably contributed towards LULC modification resulting the change in other LULC classes to residential and built-up areas, which eventually effects climatic conditions on micro or local scale such as differences in land surface temperature(LST) (Mundhe *et al*., 2014; Kafy *et al.,* 2021). During this process, unplanned growth and expansion of built-up/residential areas, mostly in urban centers/ mega cities like Lahore, has created many problems related to urban expansion, deterioration of ecosystem services, and multiple environmental issues (Chen *et al.,* 2019; Han, 2020; Sarkodie *et al.,* 2020).To address/Adhere such issues and to support sustainable urban planning, it is important to assess the spatio temporal trends and patterns of diverse land use types in Lahore and its linkages with LST, if any

Table: 1: LULC Classes.

Class	Description
Built-up	Residential, commercial, building, infrastructural development, industries, transportation etc.
Vegetation	Mixed forest, shrubs, bushes, cultivated area. Crop fields, aquatic vegetation, agricultural land etc.
Barren land	Open land, fallow land, open spaces etc.
Water bodies	Lakes, ponds, swamps, ponds, canals, reservoirs etc.

MATERIALS AND METHODS

Landsat 8 product or data set (path 149/row 38) cloud- free imagery obtained for the years 2017 and 2021 , were downloaded free of cost from the United States Geological Survey's (USGS) Erath Explorer website (https://earthexplorer.usgs.gov). In order to acquire the cloud- free imagery for land surface estimation the month of June is selected as it considered dry and hot month in the study area. The Landsat 8 , image spectral resolution is 30 x 30 meters. The obtained Landsat imageries were already georeferenced or projected by using World Geodetic System(WGS) 1984 UTM and 43 N zone coordinate systems which is suitable for the study area.

LULC classification technique is most extensively used for finding or retrieving the data from satellite imageries. Moreover, there are two image classification methods are usually adopted for land cover classification: supervised and unsupervised (Lang *et al*., 2008).

For this study, the Maximum likelihood supervised classification algorithm was applied/adopted using ArcGIS software 10.3.Built-up area, vegetation, barren land, and waterbodies four LULC classes were identified based on classification scheme.

The detail or description of these classes is mentioned in Table (1). The aforementioned, LULC classes are further validated by using Google earth Pro .Accuracy assessment is a significant feature of Image classification. Accuracy assessment techniques i.e., Kappa coefficient ,error matrix and indices-based techniques have been used in numerous studies to generate LULC classification maps (Manandhar *et al*., 2009; Rahman *et al*.,2019; Shahfahad *et al.*, 2020; Talukdar *et al*., 2020).Accuracy assessment and Kappa Coefficient technique were used in this study to calculate the accuracy of LULC maps of Lahore. By using Google earth pro almost 40 and 48 points were selected randomly from each land LULC classes has been taken for the year 2017 and 2021 to obtain the accurate results .Over all accuracy assessment of this study was 92.5% and 95.5% for the years 2017 and2021 respectively. The Kappa Coefficient value was 90 % for 2017 94% for 2021. Accuracy assessment and Kappa values indicted that the classification technique and collected ground control (truth) points were used in useful and appropriate way. The post classification Accuracy assessment is one the imperative feature of LULC classification method that is widely used to investigate the accuracy and authenticity of the classified maps**.** So, the classification accuracy method not only validate the quality of maps but also helps to assess the applicability classified map for future use.

Normalized Difference Vegetation Index (NDVI): To assess or estimate the greenery density on land, the researcher must observe the visible and near-infrared wavelength reflected by the vegetation cover. NDVI is primarily used to figure out the vegetation abundance. The outcome of this method is known as Normalized difference vegetation index that can be calculated by following equation (Mohammed *et al*., 2019).

$$NDVI = \frac{(NearIRed - Red)}{(NearIRed + Red)}$$

The value range lies between -1 to +1 for calculation for NDVI from Landsat images The value for soil may have nearby zero, whereas the water bodies having negative values (John *et al.,* 2020). With the increase in vegetation the value of NDVI will also increase in positive way (Spisni *et al.,* 2012; Spadoni *et al.,* 2020).

Retrieval of Land Surface Temperature (LST): The following steps have been executed to calculate the land surface temperature from Landsat 8 level 2 product. The Landsat 8 images for the month of 14th and 9th June 2017 and 2021 were downloaded from USGS. First the image was clipped to the study area shape file. As per USGS data source the calculation of surface reflectance from Landsat (collection 2) has scale factor of 0.0000275 and an added offset of -0.2 per pixel. On the other hand, to compute the surface temperature of the study area the Landsat (for collection 2) the Band 10 is multiplied by 0.0000341802 for the scale factor and then 149.0 is additional off set to get 302.6 kelvin after the scale factor is applied.

RESULTS AND DISCUSSION

The table 2 illustrated the changes occurred in LULC classes over time 2017 to 2021.The total extent of "Barren land" in 2017 was 996.8 square kilometers(55.9%) and in 2021 the barren land occupied the highest class with 1104 square kilometers(63.81%).On the other hand, vegetation class is also showing the decline trend during the selected time period. In 2017 the area covered by vegetation was 511.7 square kilometers (29.58%)

while it was showing the decreasing trend in 2021.In 2021 the total vegetation cover was reported 295.2 square kilometers(29.58%).The overall decrease in vegetation class was documented 11.98%.The major reason of this rapid decline in vegetation cover was the removal of vegetation cover for infrastructure and settlement purposes to meet the demand of growing population and rural urban migration from suburbs to the Lahore.

Table 2.

Barren land	996.8	1104	55.9	63.81	-7.91
Vegetation	511.7	295.2	29.58	17.6	11.98
Built-up	234.4	319.4	13.55	18.46	-4.91
Water bodies	16.74	11.45	0.96	0.66	0.3

Land-use and Land cover change matrix 2017-2021

The built- up class is also showing the increasing trend from 2017 to 2021.In 2017 the total built-up area was reported 234.4 square kilometers(13.5%)and in 2021 the total built-up area is 319.4 square kilometers(18.46%).

Therefore, the decrease in built-up area was (4.91%) .During past few decades vegetation class was altered into the built-up area since many housing societies are developed and constructed in South and Western sides. The decreasing trends were also observed in water bodies class same as vegetation class. In 2017 the area covered by water bodies were16.7 square kilometers (0.96%) and in the year 2021 the extant of water bodies were 11.45 square kilometers (0.66%).The overall 0.3% change was detected in water bodies class in the study area. Moreover, during the past 5 years (2017-2021) the built-up area and barren land both indicting the rising trend in Land use and Land cover classes. While the vegetation and water bodies classes were showing the decline in area. Both land cover classes i.e., Barren land and Built-up were showing growing trend due to massive alteration into other two classes respectively vegetation and water bodies. Due to the anthropogenic activities the LULC changes are noticed in the study area. As a result of this LULC changes the large-scale transformation the vegetation cover (natural surface) into the built-up area (impervious surfaces) has been increasing he land surface temperature in the study period (Figure 3).

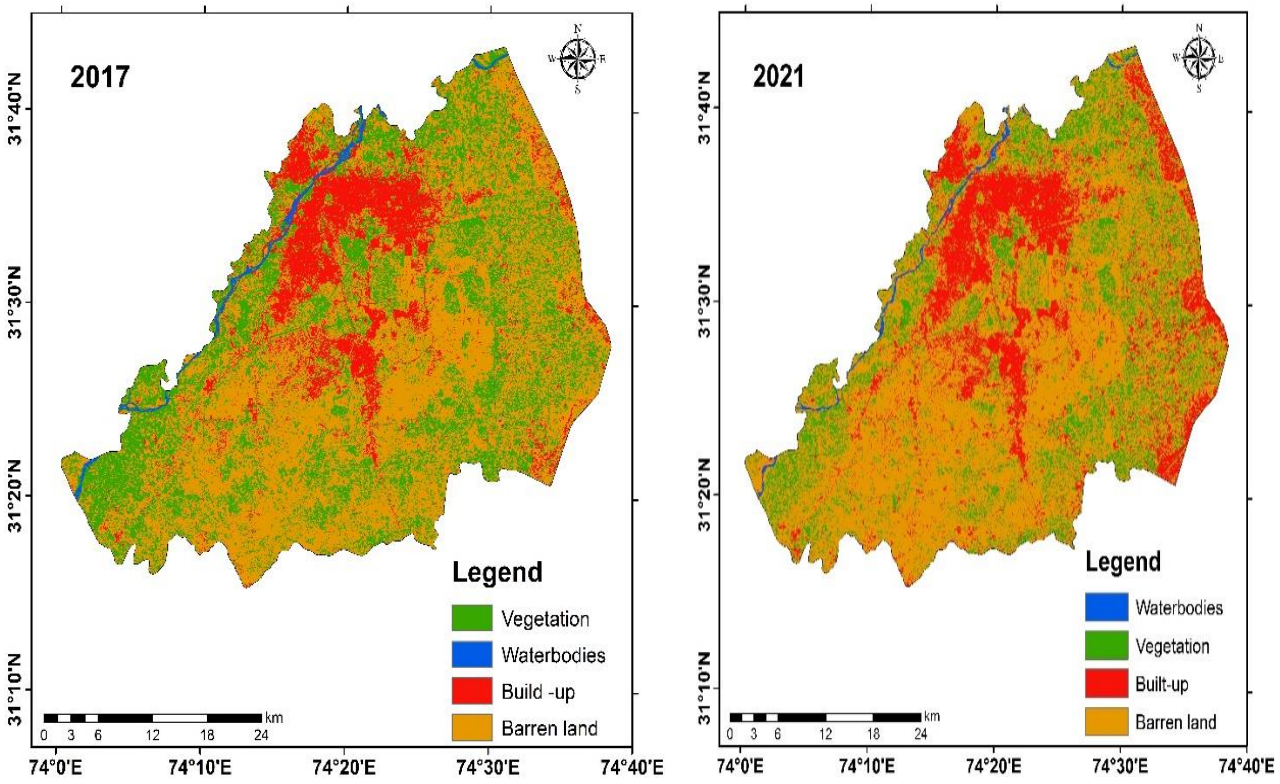

Figure: 1 Land use and land cover maps 2017 on left side and 2021 on right side.

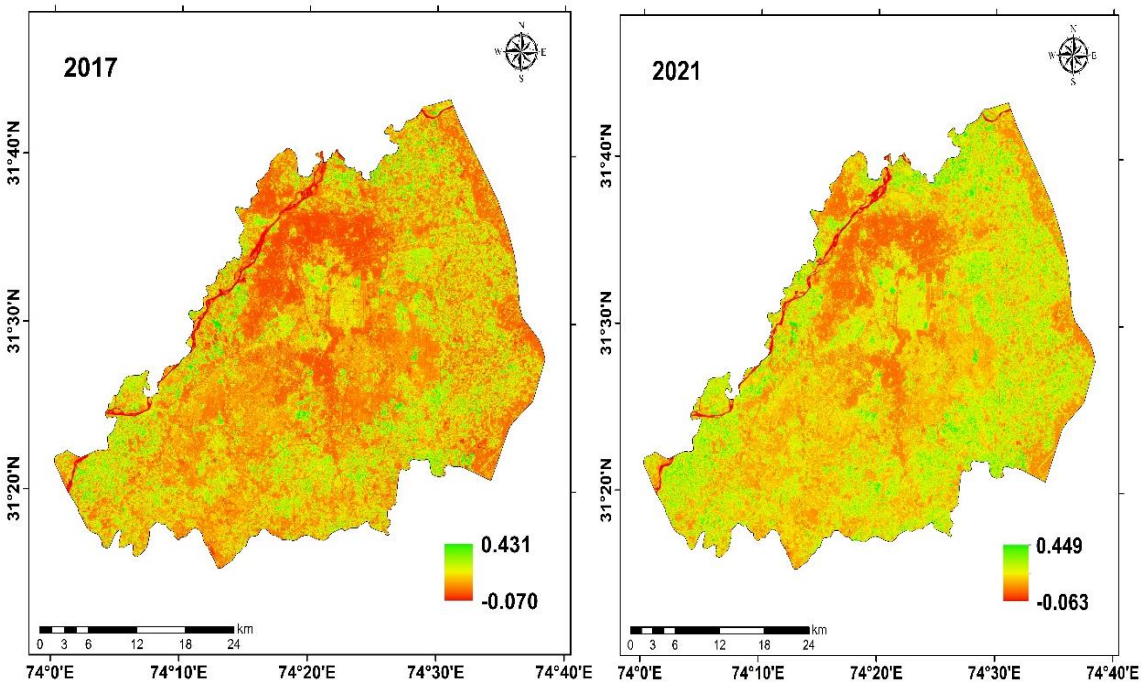

Figure 2:NDVI maps 2017 on left side and 2021 on right side.

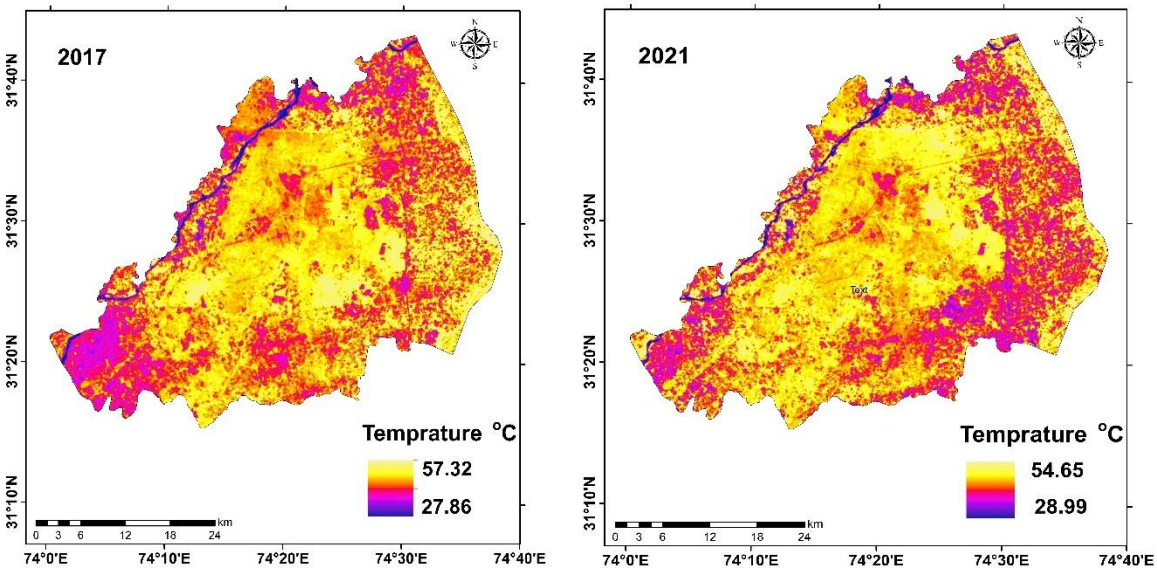

Figure 3: Land surface maps 2017 on left side and 2021 on right side.

The normalized Difference vegetation index (NDVI) was assessed by using Landsat images of 2017 and 2021 as given in (Figure 2). Arc GIS software (10.3) was used to classify/obtain the vegetation cover. In 2017 ,the NDVI value ranged between -0.070 to +0.431 whereas in 2021 it is derived that NDVI ranged between -0.063 to + 0.449 in the study area.

Land Surface Temperature Pattern (2017-2021): The study area Land surface temperature pattern was estimated /assessed for the month of June for the years 2017 and 2021.The results indicated/exhibited that maximum temperature is continuously increasing, the maximum surface temperature was calculated 57.3◦C and 54.6◦C for the year 2017 and 2021 respectively. The overall 3◦C surface temperature variation is observed during the study period. Figure 3, highlighted the brighter yellow colour showing the maximum/higher temperature while the bluish shade is showing the minimum /lower temperature. Since 2017 the built-up area and Land Surface temperature increase in similar pattern. Due anthropogenic activities and rapid urban growth vegetation cover is transforming into built-up

infrastructure as they absorb more heat and energy than the natural surfaces. On the other hand, the re-radiation process is bit slowly which is the main reason of higher surface temperature. Many studies reported that there is direct relationship between urban landscape and Land Surface Temperature(LST) (Ullah *et al*., 2019; Bokaie *et al*., 2016)In this study, the maximum temperature is decreasing in year 2021 that is totally revers or unlike from previous studies. The reason was the outbreak of Covid 19.It was declared the global pandemic and due to lock down the emission of energy from industries, vehicles and other sources was less to the atmosphere. Moreover, it is reported and documented in many studies that LST is showing the constantly rising trend in Lahore as vegetation cover is changing into built-up area (Aqil., 2022; Mumtaz .*et al* 2020)

Conclusion: For this research, supervised image classification maximum Likelihood method was executed for Land use land cover change (LULC) classification and analysis. Landsat 8 dataset have been acquired atrained/obtained over the time 2017 and 2021 to retrieve/calculate the LST and NDVI in Lahore.It was detected that "Barren land" class increased from 55.9% to 63.81% for the years 2017 and 2021. The built-up class also increased from 13.55% to 18.46%. in 2017 and 2021 correspondingly Furthermore, the extent of vegetation class had decrease from 29.58% (2017) to 17.46% (2021). The 0.33% decrease was detected in water bodies class. The radiation characteristics of each land use land cover class is entirely different owing/due to its diverse nature.Consequently, the urban development and other human induced activities affect the surface temperature. Transition from natural surfaces(water bodies or vegetation) to impervious surfaces (Built up and Barren land) is the key factor of higher Land surface temperature .On the hand, the alteration of areas from impervious surface to into natural surfaces has helped to lesser the LST. This study will also provide the useful and significant insight to government and decision makers to initiate the eco-friendly strategies like development of urban green spaces and insertion of vertical plants and green roofs ideas to mitigate higher Land Surface Temperature in Lahore.

Acknowledgment: The authors are grateful to scientists and the research staff of the Punjab University, Centre for Remote Sensing-Remote Sensing, GIS and Climatic Research Lab(RSGCRL) who rendered technical support is carrying out image analysis and related map making.

REFERENCES

Abdulla, A., S.C.D Milan, A. Abdullah-Al, E. Zullyadini, A. F. Rahaman, T.R. Muhammad, D.H Liu, Md. A.I Fattah, A. Abdullah. Ahmad Dousari J , S. Nafiz Rahaman K , Md H. Zakaria , M.K Ahasanul and M. Ahasan (2022). Predicting the impacts of land use/land cover changes on seasonal urban thermal characteristics using machine learning algorithms. Building and environment 217(2022)109066.

Adnan, M.S.G., A.Y.M., Abdullah, A. Dewan, and J.W., Hall (2020). The effects of changing land use and flood hazard on poverty in coastal Bangladesh. Land Use Pol.99https://doi.org/10.1016/j.landusepol.2020.104868.

Akbari, H., and. D. Kolokotsa, (2016). Three decades of urban heat islands and mitigation technologies research. Energy Build., 133, 834–842.

Akinyemi, F.O., and G., Mashame (2018). Analysis of land change in the dryland agricultural landscapes of eastern Botswana. Land Use Policy 76, 798–811. https://doi.org/10.1016/j.landusepol.2018.03.010.

Alawamy, J. S., S. K., Balasundram, A. H, Hanif, and C. T. B. Sung, (2020). Detecting and Analyzing Land Use and Land Cover Changes in the Region of Al-Jabal Al-Akhdar, Libya Using Time-Series Landsat Data from 1985 to 2017. Sustainability, 12(11), 4490

Bokaie, M., M. K., Zarkesh, P. D., Arasteh, and A. Hosseini, (2016). Assessment of Urban Heat Island Bassed on the Relationship between Land Surface Temperature and Land Use/Land Cover in Tehran. Sustain. Cities Soc. 23, 94–104. doi: 10.1016/j.scs.2016.03.009

Chaudhuri, G., Mishra, N.B., (2016). Spatio-temporal dynamics of land cover and land surface temperature in Ganges-Brahmaputra delta: a comparative analysis between India and Bangladesh. Appl. Geo. 68, 68–83. https://doi.org/10.1016/j. apgeog.2016.01.002.

Chen, D., Lu, X., Liu, X., Wang, X., (2019). Measurement of the eco-environmental effects of urban sprawl: theoretical mechanism and spatiotemporal differentiation. Ecol. Indicate. 105, 6–15

Cihlar, J., and Jansen, L. J. M. (2001). From land cover to land use: A methodology for efficient land-use mapping over large areas. The Professional Geographer, 53, 275–289.

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. Rem. Sens. Appl.: Soc. Environ. 19, 100322. https://doi.org/10.1016/j.rsase.100322

Dewan, A., Kiselev, G., Botje, D., Mahmud, G.I., Bhuian, M.H, and Hassan, Q.K., (2021b). Surface urban heat island intensity in five major

cities of Bangladesh: patterns, drivers and trends. Sustain. Cities Soc. 71, 102926. https://doi.org/10.1016/j.scs.2021.102926.

Dutta, D., Rahman, A., Paul, S. K., and Kundu, A. (2019). Changing pattern of urban landscape and its effect on land surface temperature in and around Delhi. Environmental Monitoring and Assessment, 191, 551

Forkel, M., N. Carvalhais, J. Verbosely, M. Mahecha, C. Neigh, and M. Reichstein (2013). Trend change detection in NDVI time series: effects of inter-annual variability and methodology. Rem. Sens. 5 (5),2113–2144. https://doi.org/10.3390/rs5052113. Government of Pakistan ,2002

Gogoi, P., P. Vinoj, D. Swain, G. Roberts, J. Dash, and S. Tripathy (2019). Land use and land cover change effect on surface temperature over Eastern India. Scientific Reports, 9, 8859

Gregorio, A. D. (2016). Land cover classification system, classification concepts. Food and Agriculture Organization of the United Nations/Rome. http://www.fao. org/3/a-i5232e.pdf.

Hassan, Z., R. Shabbir, S. Ahmad, A. Malik, N. Aziz, A., Butt (2016). Dynamics of Land Use and Land Cover Change (LULCC) Using Geospatial Techniques: A Case Study of Islamabad Pakistan, 5. Springer Open., Springer Plus, pp. 1–11. https://doi.org/10. 1186/s40064-016-2414-z.

John, J., G. Bindu, B. Srimuruganandam, W. Abhinav, and R. Poornimam (2020). Land use/ land cover and land surface temperature analysis in Wayanad district, India, using satellite imagery. Ann. GIS. https://doi.org/10.1080/19475683.2020.1733662 .

Kundu, D and A.K., Pandey (2020). World urbanisation: trends and patterns. In: Kundu, D., Sietchiping, R., Kinyanjui, M. (Eds.), Developing National Urban Policies: Ways Forward to Green and Smart Cities. Springer Singapore, 13–49. https://doi.org/10.1007/978-981-15-3738-7_2.

Lang, R., Shao, G., Pijanowski, B. C., and Farnsworth, R. L. (2008). Optimizing unsupervised classifications of remotely sensed imagery with a data-assisted labelling approach. Computers & Geosciences, 34, 1877–1885.

Lin, C., Wu, C.C., Tsogt, K., Ouyang, Y.C, and Chang, C.I., (2015).Effects of atmospheric correction and pan sharpening on LULC classification accuracy using WorldView-2 imagery. Info. Process. Agri. 2 (1), 25–36. https://doi.org/10.1016/j. inpa.2015.01.003.

Malik, R., Dhir, R, and Mittal, S.K., (2019) Remote sensing and Landsat image enhancement using multi objective PSO based local detail enhancement. J. Ambient Intell. Hum. Comput. 10, 3563–3571. https://doi.org/10.1007/s12652-018-1082-y.

Manandhar, R., Odeh, I. O. A., and Acnev, T. (2009). Improving the accuracy of land use and land cover classification of Landsat data using post-classification enhancement. Remote Sensing, 1, 330–344.

Msofe, N. K., Sheng, L, and Lyimo, J. (2019). Land use change trends and their driving forces in the kilombero valley floodplain, south-eastern Tanzania. Sustainability, 11(2), 505.

Muhammad S. Khan., Sami Ullah, Tao Sun., Arif UR Rehman, and Liding C., (2020). Land-Use/Land-Cover Changes and Its Contribution to Urban Heat Island: A Case Study of Islamabad, Pakistan Sustainability 2020, 12, 3861; doi:10.3390/su12093861

Mumtaz, F., Tao, Y. Bashir, B. Ahmad, A. Li, and Hassan, H.U. (2020). The relationship between vegetation dynamics and land surface temperature by using different satellite imageries; A Case study of Metropolitan cities of Pakistan. N. Am. Acad. Res., 3, 1–15

Mundhe, R.G., N.N. Jaybhaye and Mundhe (2014). Impact of urbanization on land use/land covers change using Geo-spatial techniques, Int. J. Geomatics Geo sci. 5 (1) 50–60 [Online]. Available: https://www.researchgate.net/publication/ 281320790.

Mazhar, N., and H. Rasheed (2017). Modelling the rice land suitability using GIS and multi-criteria decision analysis approach in Sindh, Pakistan. J. Basic Appl. Sci. 13, 26–33. https:// doi.org/10.6000/1927-5129.2017.13.05.

Nasar-u-Minallah, M (2019). Retrieval of land surface temperature of Lahore through Landsat-8 TIRS data. International Journal of Economic and Environmental Geology, 10(1), 70-7.

Rahman, M. S., H., Mohiuddin, A., Al Kafy, P. K., Sheel, and L. Di (2019). Classification of cities in Bangladesh based on remote sensing derived spatial characteristics. Journal of Urban Management, 8(2), 206–224.

Rinner, C., and M. Hussain (2011) Toronto's Urban Heat Island—Exploring the Relationship between Land Use and Surface Temperature. Remote. Sens. 2011, 3, 1251–1265.

Roberts, D., P.E., Dennison, K.L Roth, K.L., Dudley, K., and G. Hulley (2015) Relationships between dominant plant species, fractional cover and Land Surface Temperature in a Mediterranean ecosystem. Remote. Sens. Environ. 2015, 167, 152–167.

Rahman, M. S., H. Mohiuddin, Al Kafy, A., P. K. Sheel, and L..Di(2019) Classification of cities in Bangladesh based on remote sensing derived spatial characteristics. Journal of Urban Management, 8(2), 206–224.

Romaguera, M., R.G. Vaughan, J. Ettema, E.I. Verdiguier, C.A. Hecker, F.D. Meer, (2018). Detecting geothermal anomalies and evaluating LST geothermal component by combining thermal remote sensing time series and land surface model data. Remote Sens. Environ. 204, 534–552. https://doi.org/10.1016/ j.rse.2017.10.003

Yonaba. R., A, M. Koïta, L.A. Mounirou, F. Tazen. Queloz, A.C. Biaou A, D. Niang A, C. E A Zour , H. Karambiri A, and H. Yacouba (2022) Spatial and transient modelling of land use/land cover (LULC) dynamics in a Sahelian landscape under semi-arid climate in northern Burkina Faso Spatial and transient modelling of land use/land cover (LULC) dynamics in a Sahelian landscape under semi-arid climate in northern Burkina Faso Land use policy 103(2021)105305

Sabagh, A.E., A. Hossain, M.S. Islam, M.A Iqbal, S. Fahad, D. Ratnasekera, and A. Llanes (2020). Consequences and mitigation strategies of heat stress for sustainability of soybean (Glycine max L. Merr.) production under the changing climate. In: Plant Stress Physiology. Intech Open. https://doi.org/10.5772/intechopen.92098.

Sarkodie, S.A., P.A Owusu and T. Leirvik (2020). Global effect of urban sprawl, industrialization, trade, and economic development on carbon dioxide emissions. Environ. Res. Lett. 15 (3), 034049.

Scanlon, T.M., J.D. Albertson, K.K Caylor, and C.A Williams (2002). Determining land surface fractional cover from NDVI and rainfall time series for a savanna ecosystem. Remote Sens. Environ

82(2–3),376 -388.https://doi.org/10.1016/S0034-4257 (02)00054-8.

Shahfahad, M., M. Kumari, B. Tayyab, M. Paarcha and A., Asif (2020). Indices based assessment of built-up density and urban expansion of fast-growing Surat city using multi-temporal Landsat data sets. Geo journal. https://doi.org/10.1007/s10708-020-10148-w 2020

Spadoni, G. L., A. Cavalli, L. Congedo and M. Munafò (2020). Analysis of Normalized Difference Vegetation Index (NDVI) Multi-Temporal Series for the Production of Forest Cartography. Remote Sens. Appl. Soc. Environ. 20, 100419. doi: 10.1016/j.rsase.2020.100419

Spisni, A., V. Marletto and L. Botarelli (2012). Indici vegetational da satellite per il monitoraggio in continuo del territorio. Italian J. Agrometeorology 3, 49–55

Song, X.P., M.C. Hansen, S.V. Stehman, P.V. Potapov, A. Tyukavina, E.F. Vermote and J.R. Townshend (2018a). Global land change from 1982 to 2016. Nature 560 (7720), 639–643.

Tariq, A., and H. Shu (2020). CA-Markov Chain Analysis of Seasonal Land Surface Temperature and Land Use Land Cover Change Using Optical Multi-Temporal Satellite Data of Faisalabad, Pakistan. Remote Sens. 12, 3402. doi:10.3390/ rs12203402

Talukdar, S., P. Singha, S. Mahato, B. Praveen, and A. Rahman (2020). Dynamics of ecosystem services (ESs) in response to land use land cover (LU/LC) changes in the lower Gangetic plain of India. Ecological Indicators, 112, 106121.

Van .V., J. Magliocca, N.R. Büchner, B. Cook, J.M Benayas, E.Ellis,A., Heinimann. Keys, T.M. Lee, J Liu, J., Mertz, O., P .Meyfroidt, M. Moritz, C. Poeplau, C., B.E Robinson, R. Seppelt, R K.C. Seto and P.H .Verburg (2016). Meta studies in land use science: current coverage and prospects. Ambio 45, 15–28. https://doi.org/10.1007/s13280-015-0699-8.

Waleed, A., and M. Sajjad (2022). Leveraging cloud-based computing and spatial modelling approaches for land surface temperature disparities in response to land cover change: Evidence from Pakistan, Remote sensing :Society and Environment 25(2020)100665

Wiggins, S., (2000). Interpreting changes from the 1970s to the 1990s in African agriculture through village studies. World Dev. 28, 631–662. https://doi.org/ 10.1016/S0305-750X(99)00153-9.

Yohannes, H., T. Soromessa, M. Argaw and A. Dewan (2021). Impact of Landscape Pattern Changes on Hydrological Ecosystem Services in the Beressa Watershed of the Blue Nile Basin in Ethiopia. Science of The Total Environment, p. 148559.

Zahoor, S.A., S. Ahmad, A. Ahmad, A. Wajid, T. Khaliq, M. Mubeen, S. Hussain, M.S.U Din, A. Amin, M. Awais, and W. Nasim (2019). Improving water use efficiency in Agronomic crop production. In: Agronomic Crops. Springer, Singapore, pp. 13–29. https://doi.org/10.1007/978-981-32-9783-8_2.