OPEN ACCESS
International Journal of Innovations in Science & Technology
RESEARCH & INNOVATION DIVISION
IJIST

Assessing Urban Expansion and Land Cover Change in City District Lahore using Multi-Stage Satellite Data

Mariam Sarwar, Shakeel Mahmood, Warda Habib
Government College University, Lahore
*Correspondence: Mariamsarwar29@gmail.com

Citation | Sarwar. M, Mahmood. S, Habib. W, "Assessing Urban Expansion and Land Cover Change in City District Lahore using Multi-Stage Satellite Data", IJIST, Vol. 07 Special Issue. pp 94-107, Aug 2025

Received | July 16, 2025 **Revised |** July 29, 2025 **Accepted |** Aug 03, 2025 **Published |** Aug 05, 2025.

Lahore, a metropolis and 2^{nd} second-largest city of Pakistan, has been experiencing rapid urban expansion over the past five decades. The socio-economic development and growth of the urban population have caused the rapid increase of urban expansion. The increase in the built-up area of Lahore has seen remarkable growth during the past decades. This study is aimed at detecting the Spatio-temporal changes in land use and land cover and evaluating the urban expansion of Lahore since 2003. The conversion of land to other uses is primarily because of growth in urban population, whereas the increase in economic activities is the central reason for the land-use changes. In this study, temporal Landsat imageries were used. The supervised image classification of the maximum likelihood algorithm was applied on Landsat ETM+ (2003) and OLI/TIRs (2023) images, whereas a post-classification comparison technique was employed to detect changes over time. The spatial and temporal analysis revealed that during the past twenty decades, the built-up area of Lahore city has expanded by 486 km^2. It was found from the analysis that in Lahore city, the urban expansion was primarily at the cost of loss of fertile agricultural land, vegetation, and other cultivable land use. The analysis further revealed that The Total agricultural area in 2003 was 725 KM^2. The agricultural land to Built-up area is about 325 km^2. Due to the population increasing, the newly added population needs more space to fulfill their basic needs. The Total Barren Land in 2003 was 7452 KM^2.The Barren land to Built-up color, which is about 255 km^2.Rapid Land use changes have been marked for a period of 20 years in Lahore. The increase in the area used for built-up land is 470 Km^2 in 2003 to 956 Km^2 in 2023 (overall increase is 28 %), respectively.

Keywords: Change Detection, Confusion Matrix, LULC Modeling, GIS, Remote Sensing

Introduction:

Most parts of countries in the world are currently experiencing wide-ranging changes in land use and land cover (LULC) [1]. These LULC changes have mostly been associated with the interaction between humans and the environment [2]. The resulting negative impacts on ecosystems and human wellbeing, which include erosion, increased run-off, flooding, loss of water resources, degrading water quality, and other negative impacts, have brought these changes to the attention of the world [3]. There are many indicators for understanding the relation between humans and the environment, one of which is land cover change [4]. The timely and accurate understanding and monitoring of land use and land cover changes, their intensity, direction, causes, and consequences are critical for sustainable development planning; hence, it is an essential goal in the field of land cover change science [5].

Land use is the projection of complex urban socio-economic activities on a land system. [6] Land use change is a complex process, and varying driving forces impact the changing land use patterns of the cities. Urban expansion is one of the important impacts of land use and land cover change. Expansion of urban area requires more land and promotes the conversion of land use into a changing pattern [7]. To examine the urban expansion, it is necessary to "quantify the spatial and temporal pattern of urbanization that requires spatial analysis" Although urban areas cover only 3% of the earth's surface but habitat destruction and increasing urbanization have widespread impacts on the land use pattern of the cities.

LULC means the use of land via agriculture, conservation, development, recreational places, wildlife habitats, and urban regions or any other activity and the outcome of human-environment interaction in a particular location, as influenced by climate change processes and socioeconomic dynamics [8]. LULC identification is crucial for evaluating global, Regional, and local environmental change [9]. and become a fundamental element for sustainability research. On land, both the human population and its influence have increased dramatically in the previous century [10], and the changes are a dynamic and continuous process over time. Updated and precise LULC maps are essential for sound planning, sustainable development, environmental monitoring, worldwide change, and the estimation of forest degradation [11]. The effective use and management of natural resources depend on reports on LULC changes.

On the other hand, various procedures have been established for detecting, measuring, and mapping urban temporal expansion from remotely sensed data [12]. examined the spatial dynamics of land use changes and recognized the urbanization process using multi-spatial & multitemporal resolutions of Landsat satellite data [13]. identified land use change and urban expansion trends using annual urban growth rate reinforced by two scenes of multi-spectral satellite images [14]. Change detection is valuable in many applications related to land use and land cover (LULC) change detection, including cultivation, urban expansion, and landscape changes. Understanding landscape patterns, changes, and interactions between human activities and natural phenomena is essential for proper land management and decision improvement [15].

In Pakistan, various scholars' studies on LULC are widely conducted, especially by using remote sensing and GIS techniques [16]. Lahore is one of the renowned districts of Punjab, Pakistan. The land use pattern has been changing due to rapid industrial and economic development.

This study aims to articulate the pattern of LULC changes in District Lahore. The main focuses of this study are i) to identify the LULC based on the satellite images of 2002 and 2022 using remote sensing and GIS application, and ii) to evaluate the factors of the LULC change in the study area. This study is expected to contribute to the decision maker in making a better emergency response and plan towards sustainable land development activity, as well as mitigating the challenges of the rapid growth of urbanization.

Study Area:

Lahore is the largest district of the Punjab province in terms of population size, comprising 82% of the urban population and the provincial capital as well. It is the second largest Metropolitan city of Pakistan after Karachi having estimated population of 13,979,000 (GOP 2023). Lahore is a hub of economic & cultural activities and an academic center of the country, which is often referred to as the heart of Pakistan and, therefore, a place of interaction of people from all across the country. Lahore is an old cultural center of Pakistan with a history of more than 10 centuries. It is situated within the geographic extents of 31° 13' and 31°43' N latitude and 74° 0' and 74° 39.5' E longitude. Lahore is located on the left bank of the River Ravi, covering an area of 1772 sq. km. The Lahore City District comprises nine towns, which are controlled by TMA (Town Municipal Administration) except Lahore cantonment Figure 1.

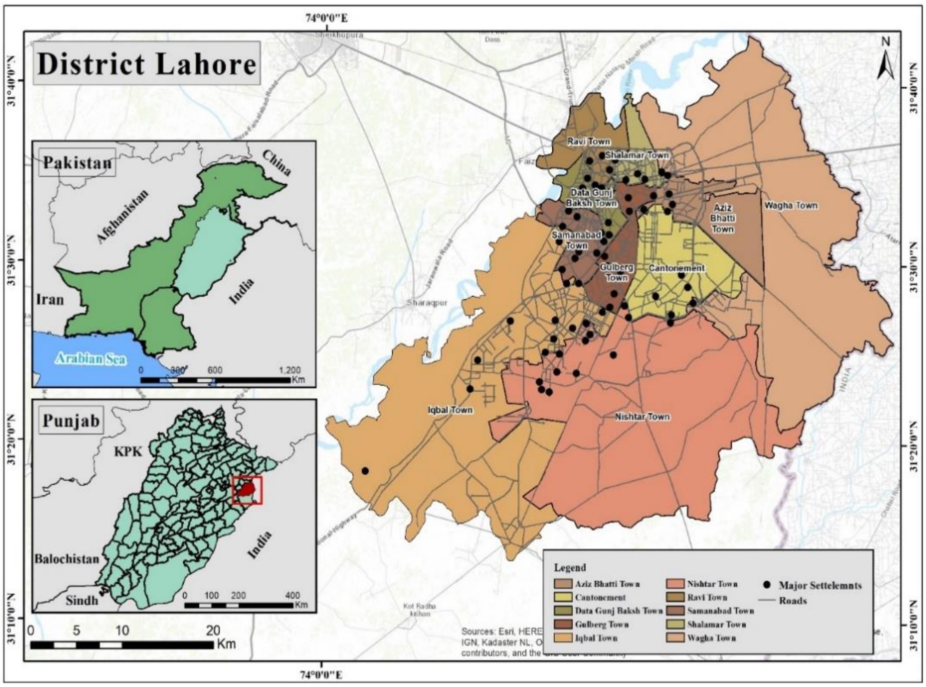

Figure 1. Location Study Area

Materials and Methods:

Data Acquisition:

In order to carry out the present study, Landsat 7ETM+, Landsat 8OLI at a resolution of 30 m satellite imagery for a period from 2003-2023 were both used for the classification of land use/cover. The Earth Explorer site (http://earthexplorer.usgs.gov/) provided the satellite data for the research region. Cloud-free images are not easy to find using free sources of data, so any cloud cover less than 10% was applied in the additional criteria tab while searching, and about 3–7% of cloud cover was found, which did not affect the result. The datasets were downloaded as TIF files and extracted from the zipped format.

Data Preparation:

A layer stack tool is used to combine the bands altogether and create one image, as bands come separated in raw images. Preprocessing is an important part of satellite picture interpretation, and in some cases, such as distortion correction and cloud removal, it's necessary. The images were obtained as standard products, i.e., radiometrically and geometrically corrected.

The other ancillary data files comprise of geo-registered vector layer of the district & towns' boundary. Spectral details of the above-mentioned Landsat images are given below in Table 1

Table 1. Images Description

Year	Sensor	Spatial Resolution	Path/Row	Date of Acquisition
2003	Landsat 7 image ETM+	30 m	149/38	April-12-2003
2023	Landsat 8 image OLI	30 m	149/38	April-14-2023

Data Analysis:

Image Classification:

To categorize satellite pictures, first and foremost, an adequate classification approach for the research region is necessary. As a consequence, several forms of LULC were classified using a modified classification approach in this study. Per-pixel supervised classifiers were employed, which classify satellite imaging pixels based on spectral reflectance properties that are similar or identical [17]. For the 2003 and 2023 Landsat images, the supervised classification approach employed the maximum likelihood algorithm in ERDAS Imagine to identify the land use land cover (LULC). The classification process is mainly conducted in three steps: training sample selection, classification, and evaluation or accuracy assessment. About 50 training samples were created for each class. A total of 80 training samples were taken for each map.

The most extensively used and well-known parametric classifier for land use and land cover change analysis is the maximum likelihood technique [18]. Based on Bayes' theorem, the primary technique for maximum likelihood classification determines where the cells in each class sample in the multidimensional space are regularly distributed [19]. Based on the Bayesian equation, the technique for calculating the weighted distance or probability D of an unknown measurement vector X belongs to one of the recognized classes, Mc is based on the Bayesian equation [20].

$$D = \ln(ac) - [0.5\ln(|covc|)]-[0.5(X-Mc)\ T(covc^{-1})\ (X-Mc)] \quad (1)$$

where c is a specific class; D is weighted distance (likelihood); X is the candidate pixel's measurement vector; Mc is the sample's mean vector, and ac is the likelihood in percent that any candidate pixel belongs to class C (defaults to 1.0, or is entered from a priori knowledge); Covc is the covariance matrix for the class c pixels in the sample; Covc is its determinant in matrix algebra, $Covc^{-1}$ is its inverse; ln is its natural logarithm function, and T is its transposition function (matrix algebra).

Change Detection:

Because of their cost-effectiveness and high temporal resolution, remote sensing and GIS-based change detection methods are frequently employed. Multi-temporal datasets can be used from different dates to discriminate each them and detect the changes. In order to find areas of change, the post-classification comparison technique includes classifying images and comparing the relevant classes. The post-classification comparison approach obtained the greatest classification accuracy in a comparative analysis of diverse techniques [21]. A method of post-classification comparison based on the MLC algorithm was used with Landsat data to validate land-use changes in Lahore. The post-classification comparison was conducted by converting the classified raster images into vector layers. The changes in LULC were calculated for each land cover type and represented in separate images in this investigation for better understanding.

The following equation was used to calculate the degree of change (C) for each class:

$$C_i = L_i - B_i \quad (2)$$

The change in class is divided by the covered area base year and again multiplied by 100; a straightforward computation was used to calculate the percentage change (C%). And it has been conducted in each land-use class

$$P_i = \frac{L_i - B_i}{B_i} \times 100 \quad (3)$$

The number of classes in the image is indicated by I. Ci indicates how much class I has changed. Pi is the percentage change in class I. Li means "basic image" (2003). The most current picture is Bi (2023).

Accuracy Assessment:

The accuracy of the classification is crucial. For each of the 2003 and 2023 identified images, the accuracy evaluation tool of the supervised classifier randomly produced 200 reference points using stratified random sampling Figure 2. Each point had a color and pixel value that the software immediately identified. The classes in the categorized image were used as a starting point.

Error matrix as well as kappa statistics for the two classified images were also manually created using Microsoft Excel. Two categorized photos were subjected to this procedure (i.e., 2003 and 2023). The error matrix shows how accurate the categorization was [22]. The columns represent the classes described as 'user value' from the reference value, while rows correspond to the classes described as 'producer value' derived from the classified image. The total number of properly detected points for each class of classified data and reference data is indicated in the error metric's side-by-side cells. The off-diagonal cells describe pixels that were wrongly detected, indicating a mismatch between reference and classed data. Figure 3 shows the flow diagram of methodology.

During the categorization process, there are two sorts of mistakes that might occur: omission and commission errors. A commission error occurs when a categorization mechanism assigns points to a class to which they do not belong. In column cells above and below the primary diagonal of the class, it was possible to count the number of pixels that were mistakenly allocated to that class. The Producer's accuracy was also used to specify the number of commission errors (eq. 4). Pixels from one class were included in pixels from other classes, resulting in omission errors for each class. The confusion matrix's row cells on the left and right of the main diagonal were used to calculate the number of missing pixels. Another factor that characterizes omission mistakes is the user's accuracy. The accuracy assessment of land use classes is shown in table 2. The selected formulae determined the correctness of the user and the producer.

$$\textbf{User's Accuracy} = \frac{\text{Total number of correct Pixels in the category}}{\text{Total Number of pixels of that category derived from the reference data(Column total)}} \quad (4)$$

$$\textbf{Producer's Accuracy} = \frac{\text{Total number of correct Pixels in the category}}{\text{Total Number of pixels of that category derived from the reference data(Row total)}} \quad (5)$$

The following formulae were used to determine the two data sets' overall accuracy and kappa coefficient.

Overall Accuracy= (Sum of Digonal Eelements)/ (Total Number of accurate pixels) (6)

Table 2. Accuracy Assessment of Land Use Classes

Land Use Classes	Water Body	Built up	Green Cover	Barren Land	Total User
Water Body	19	0	0	1	**20**
Built up	0	17	1	2	**20**
Green Cover	0	0	18	2	**20**
Barren Land	0	0	1	19	**20**
Total (Producer)	**19**	**17**	**20**	**24**	**80**
User Accuracy	**Water Body**	**Built up**	**Green Cover**	**Barren Land**	
	95	85	90	95	
	Water Body	**Built up**	**Green Cover**	**Barren Land**	

Producer Accuracy	100	100	90	79.16666667	
Overall Accuracy	0.9125	0.9125*100=**91.25**			

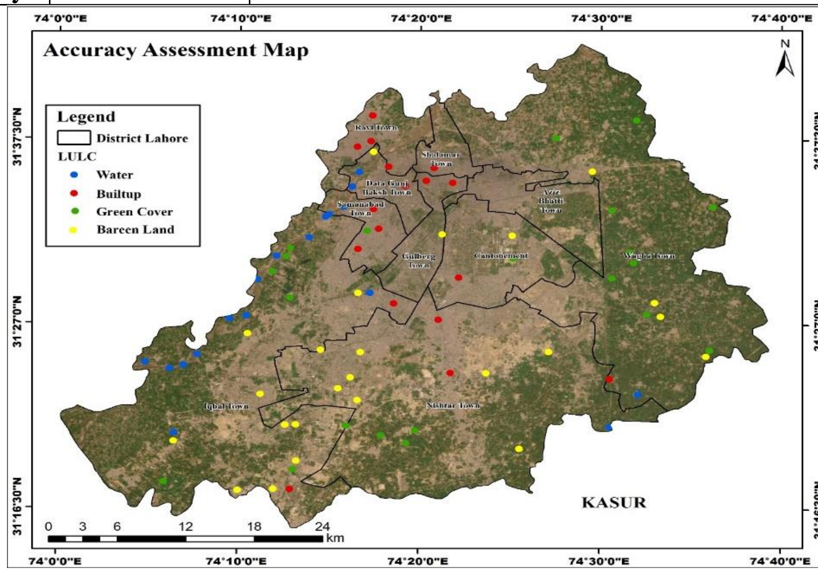

Figure 2. Assessment Point Map

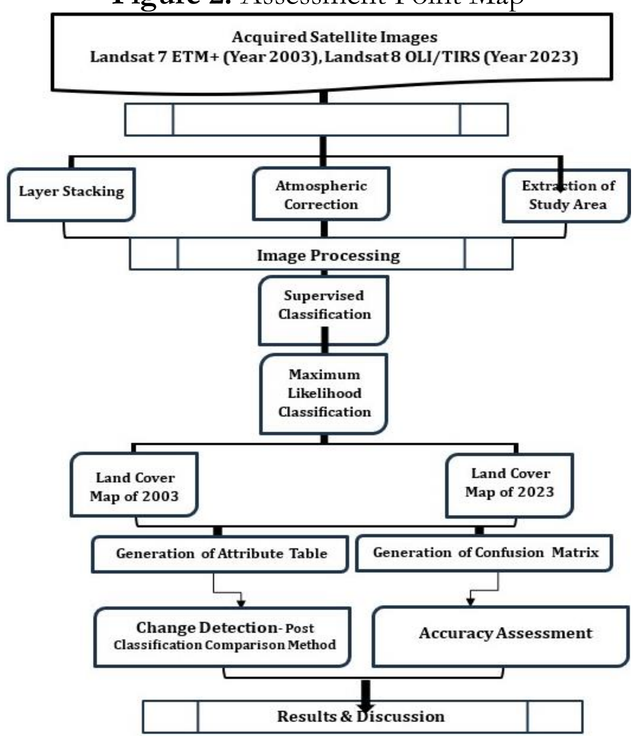

Figure 3. Research Methodology

Results and Analysis:

By using remote sensing and GIS techniques, the Land Use Changes of Lahore were identified. Supervised classification techniques were applied. The results show that there is a significant increase in urbanization.

Land Cover Pattern of 2003:

According to the analysis, Green Cover (725.88 km², or 42.69% of the total studied area) is the largest land use group, and Built-up (470.48 km², 27.67% of the total area) is the second-largest land use group. The other land use classification is barren land (452.37 km², 26.61% of the total area), waterbody (49.31 km², 2.90% of the total area). The area distribution of land types in square kilometers, and percentages, along with the producer accuracy, user accuracy, and overall accuracy, for the year 2003 as shown in figure 4.

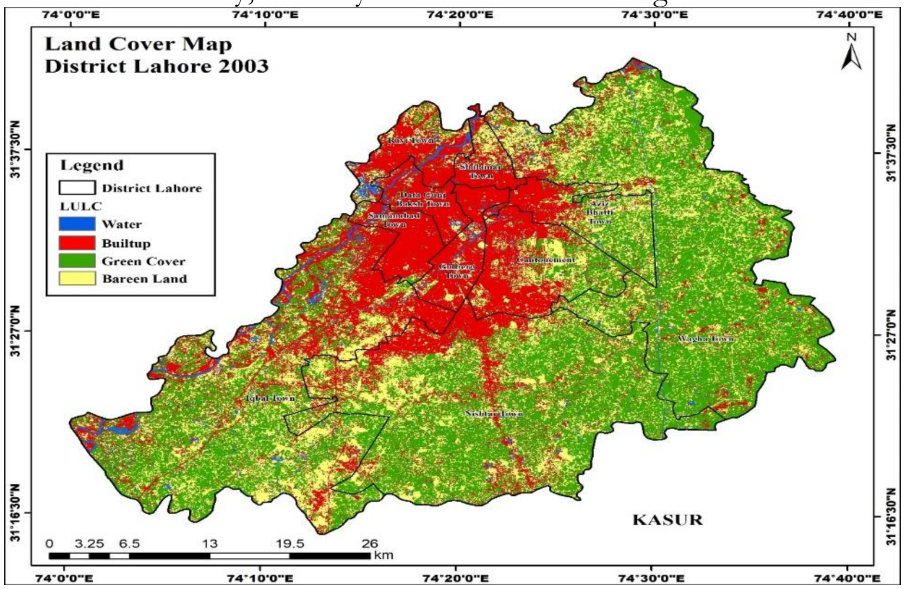

Figure 4. Land Cover 2003

Land Cover Pattern of 2023:

The Landsat 8 data collection has been used to create the categorized picture for 2023 Figure 5. Green Cover (317.89 km², 18.64% of total area) and Built-up (956.27 km², 56.23% of total area) dominated the land area in 2023, according to the statistics. Buildup area (956.27 km², 56.23% of total area), barren Land (385.49 km², 22.64 % of total area), and water (42.36 km², 2.47% of the total area). Supplementary Table 3 shows the land use groups in square kilometers, percentage, producer accuracy, user accuracy, and overall accuracy for the year 2023. The LULC patterns altered dramatically between 2003 and 2023. The study found that one category, i.e., built-up area, recorded an increase in the area, while the other three categories, i.e., agricultural land and barren land, and water body, recorded a decline in their respective areas as shown in figure 6 and 7.

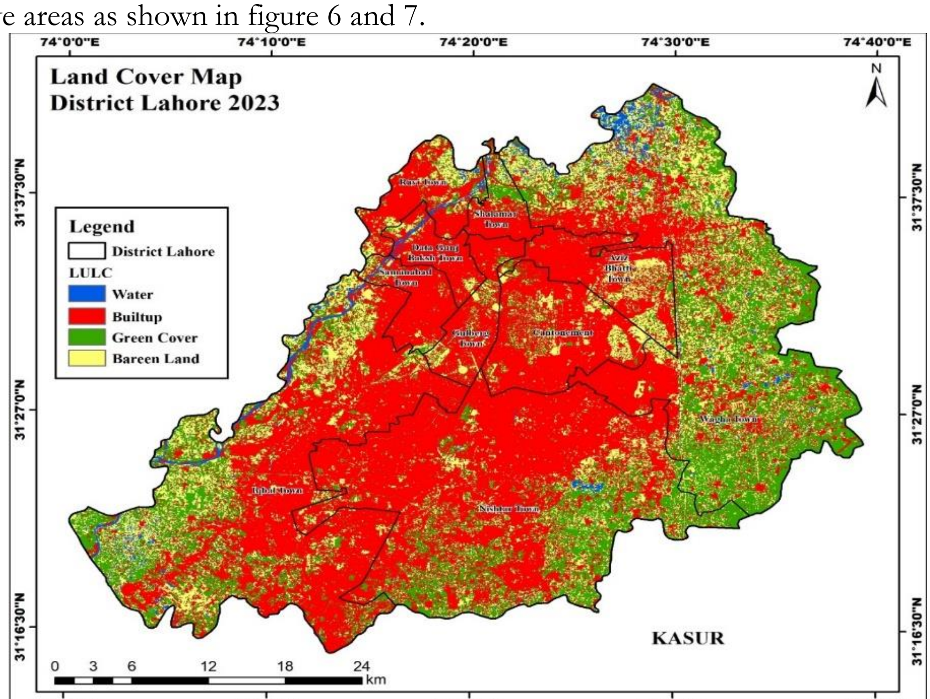

Figure 5. Land Cover 2023

Table 3. Land Cover Statistics of Lahore 2003 and 2023

Land Cover Indicator	2003		2023		Percentage Change
	Area (Sq.km)	%	Area (Sq.km)	%	
Built-Up	470	27.67	956	56.23	-28.55
Barren Land	452	26.61	385	22.647	3.96
Vegetation	725	42.69	317	18.64	24.05
Water	49	2.90	42	2.47	0.43

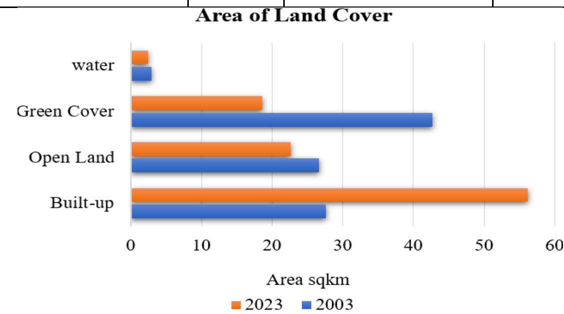

Figure 6. Area of Land Cover

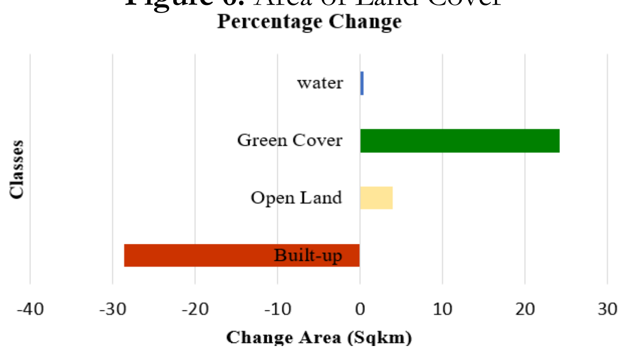

Figure 7. Percentage Changes in Land Cover

Spatiotemporal Variations in Land Cover:

Changes in Agriculture:

Change in vegetational land has been shown in Figure 8. The green color area describes the unchanged vegetation area, which is about 317 km². The agricultural land to Built-up has been described by the Red color, which area is about 325 km. Due to the population increasing, the newly added population needs more space to fulfill their basic needs. To fulfill their needs, human encroachment occurred. In this process, most of the area of Vegetation Land is now converted into industrialized areas, human settlements, and other uses.

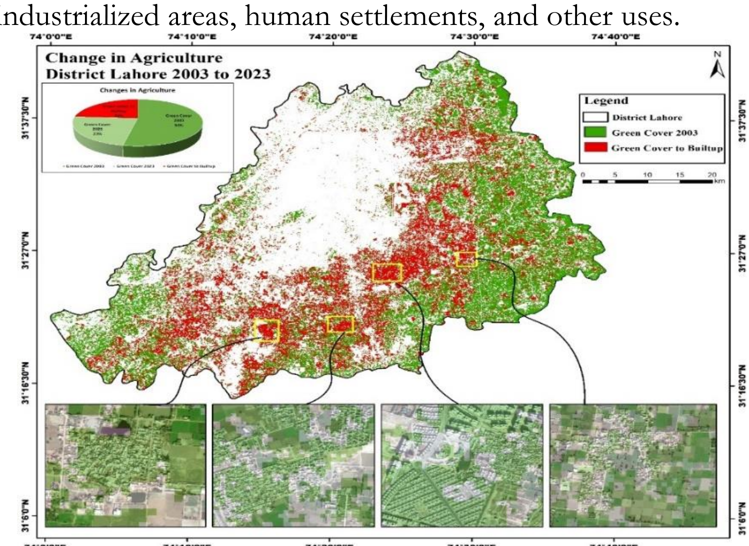

Figure 8. Changes in Agriculture

Changes in Barren Land:

Change in the Barren Land has been shown in Figure 9. The Yellow color area describes the unchanged Barren Land, which is about 385 km². The Barren land to Built-up has been described by the Red color, which is about 255 km. Barren land is also observed in this study in a lot of areas. The reason behind this may be deforestation, industrialization, and urbanization.

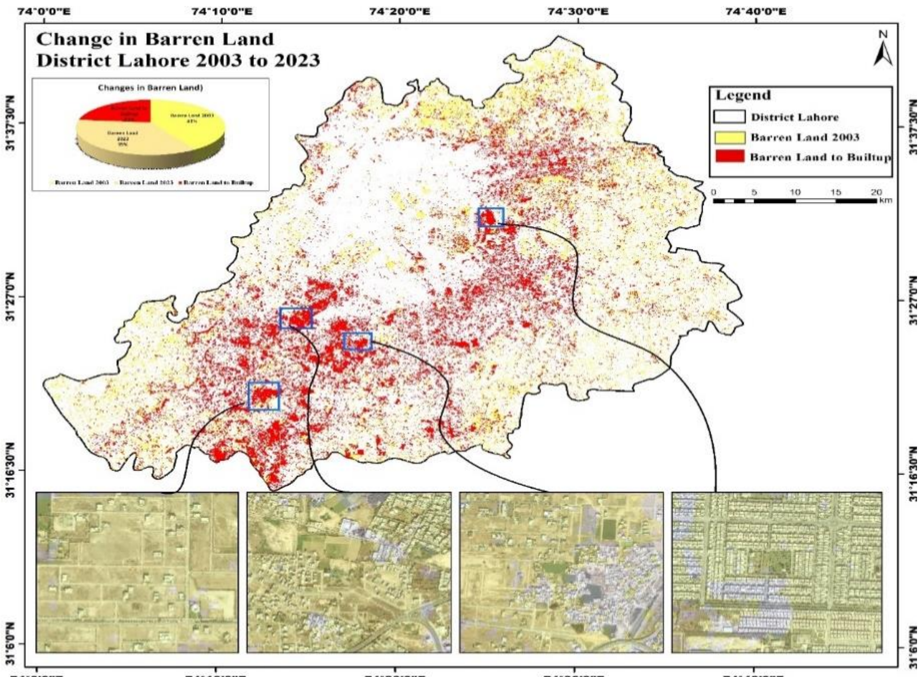

Figure 9. Changes in Barren Land

Discussion:

Urban Expansion in District Lahore:

A prominent temporal expansion of the urban area of Lahore is shown in the classified image datasets Figure 10. The major expansion of the city can be observed in the direction of south-east, south, and south-west. The River Ravi blocks the sides of the north and north-east of the city, while a zone in the district in the east is bounded by the Pak-India border. These natural barriers impose limitations on further urban expansion in all its features. The major expansion in the city of Lahore is observed along the major roads, resulting in high-density population, haphazard growth, air, noise, and water pollution, and distribution of infrastructure along Ferozpur, Riwind, and Canal Road Figure 10. This haphazard growth and expansion led to a change in the land use profile of Lahore from agriculture to urban use. The land use patterns of Lahore have been considerably modified due to urban expansion in the last few decades. The urban built-up area of Lahore has significantly increased at the cost of vegetation cover or partially barren land.

Urban Expansion (Urban Change Detection):

The urban/built-up area of Lahore district was 470 Km² in 2003. It increased to 956 Km² in 2023, thus recording a growth of 28% (Table 3). While there is a loss of agricultural and barren land, 18.64% and 22.64% respectively. This rapid population growth is one of the major factors for urban expansion in the city of Lahore, and another reason for radical changes in the land use of Lahore. The major expansion took place along Ferozpur Road, Riawind Road, and Canal Road. The expansion and physical growth of the city is observed in the southeast, south, and southwest directions. The Key factor behind the urban expansion in these directions is the availability of open spaces & large parcels of land, connected roads, a pollution-free environment and accessibility, and possibilities for the residents who reside far away from the center of the city. A larger number of housing schemes are introduced towards the southwest direction of Lahore. An assessment can be made as a corridor for the future development of the urban areas and their respective loss of agricultural lands. In this phase of Lahore, both private and public housing schemes are being set up in a rapid and scattered way. This growth trend led to the ribbon expansion along Ferozepur Road and G.T. Road. It was observed that Lahore city had grown in Aziz Bhatti Town, Data Ganj Baksh Town, Wagha Town, and Nishtar Town.

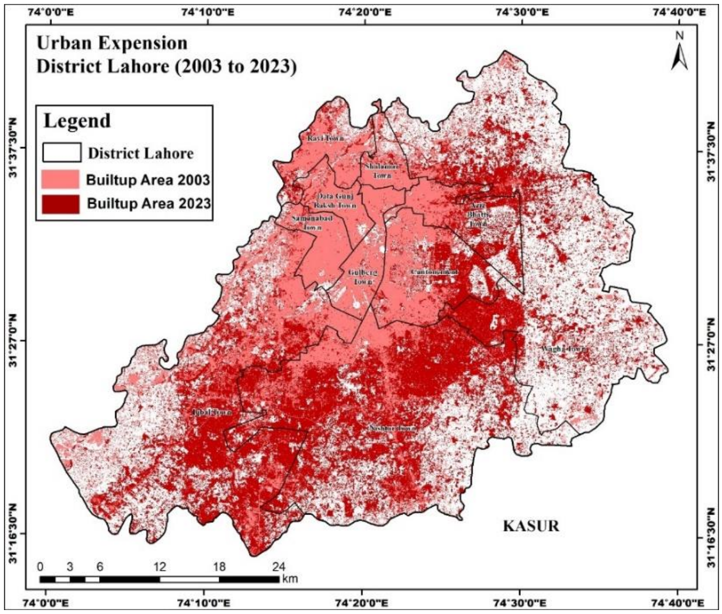

Figure 10. Urban Expansion 2015-2023

Conclusion:

The urban expansion is seen as one of the potential challenges to sustainable development, where urban planning with effective resource utilization, allocation of natural resources, and infrastructure initiatives are key concerns. The study aimed to analyze the urban Expansion of Lahore division year 2003 to 2023 from remote sensing data with different techniques. The supervised classification technique proves to be more effective and accurate. In the future, the Spatio-temporal modeling of urban expansion may be done and will help us to better understand the evolved urban patterns of Lahore division. Remote sensing technology is essential for dealing with dynamic phenomena, like urban sprawl. Without remote sensing data and GIS analysis, one may not be able to monitor and estimate the urban sprawl effectively over a time period, especially for an elapsed time period.

Rapid Land use changes have been marked for a period of 20 years in Lahore. The increase in the area used for built-up land is 470 Km² in 2003 to 956 Km² in 2023 (overall increase is 28 %), respectively. The agricultural land to Built-up area has changed, which is about 325 km. Due to the population increasing, the newly added population needs more space to fulfill their basic needs. Vegetation cover has also altered with the passage of the years. And the Barren land to the Built-up area has changed, which area is about 255 km. Subsequently, the area used for agricultural purposes and barren/open land has decreased in the study area. This situation is alarming. Economic development, increasing population growth, industrial growth & employment opportunities were the chief driving factors of changing land use and rapid urban expansion in Lahore, Pakistan. The expansion area was mainly distributed along both sides of the Ferozpur, Riwind, and Canal road. The urban expansion trends can be seen in the directions of south-east, south, and south-west. These natural barriers impose limitations on further urban expansion and the spread of population in those directions. The south-west direction of the city is the main focus of a number of housing schemes. These assessment on the part of the urban planner invites future development schemes related to vegetation loss and urban expansion. Integrating remote sensing & GIS provided valuable evidence on the nature & rate of land use changes, especially the spatial distribution and area of different temporal land use changes.

Discussion:

This study was carried out to observe the LULC changes and urban expansion in Lahore from 2003–2023 using the supervised classification method assisted with the maximum likelihood classifier algorithm, which provided an acceptable level of accuracy. GIS and remote sensing techniques are very helpful in assessing the direction of the urban expansion and its effect on existing land use types, as the change in urban land is a major geographic phenomenon in today's world. Figure 2 presents the pattern of LULC for Lahore for the years 2003- 2023, which indicates the area covered by built-up land, vegetation cover, water bodies, and barren land. Except for built-up land, other land cover classes decrease from 2003-2023, which led to the effect of surface UHI. An overall negative change has been observed for vegetation cover, water bodies, and barren land with 24.05%, 0.43%, and 3.96%, respectively, while built-up land has gained 28.52 of % area. Transformation of vegetation cover and barren land was due to illegal development, housing schemes, and commercial buildings by local developers and Lahore development authority (LDA) (Metro bus; orange train) [23]. It also indicates the conversion of rural areas into urban areas for new development and infrastructure.

Land use land cover changes have a significant impact on land surface temperature [24]. Due to diverse reflectance properties of LULC [25]. It can be observed from LST results Figure 5 that in the last 30 years, the maximum LST continuously increased, while the minimum LST had some variations. The rise in LST is also observed in previous studies conducted in Lahore and other parts of South Asia [26], which may be because of the anthropogenic materials, that is, high-rise buildings, asphalt, and concrete for urban expansion. From Figures 6 and 7, we can observe that built-up land increased significantly from 2003 to 2023 due to the loss of vegetation cover and barren land. Transition of LULC classes from barren land, water body, and vegetation cover to built-up land can influence LST [27] because roughness and surface reflectance properties depend on LULC classes. The results from Figures 8 and Figure 9, and 10 indicate that built-up land and LST increased in parallel, which shows the direct relationship between them [28]. [29] Have also observed the increasing trend of LST and revealed that urban expansion has caused the rise in LST. The difference between urban and rural buffer indicates the influence of Surface UHI [30]. Surface UHI has also been calculated with the difference between the mean LST of built-up land and the mean LST of the rural area. The impact of SUHI has been observed in this study due to rapid urbanization, which has been observed previously in other studies [31].

Recommendations:

The study on geo-spatial analysis of land use patterns and urban expansion in Lahore from 2003-2023 using GIS and remote sensing techniques offers critical insights. Given the alarming decrease in agricultural and open land, urgent measures are needed.

Firstly, urban planning authorities in Lahore should prioritize sustainable development strategies to mitigate the adverse effects of rapid urban expansion.

Establishing green belts and conservation zones, particularly along the south-east, south, and south-west directions, can serve as effective barriers to uncontrolled growth.

Furthermore, policies addressing economic development, population growth, and industrial expansion must be revisited to strike a balance between urbanization and environmental preservation. Collaborative efforts between the government, private sector, and community stakeholders are essential. To address the focus on housing schemes in the south-west, stringent regulations should be imposed, promoting eco-friendly and resource-efficient urban designs.

Also, future urban development plans should integrate advanced geo-spatial technologies continuously. Regular monitoring using GIS and remote sensing tools will provide real-time data for informed decision-making. This includes tracking vegetation loss and assessing the impact on urban expansion. A comprehensive, adaptive urban development plan, informed by these recommendations, will be crucial for sustaining Lahore's growth while preserving its ecological balance.

References:

[1] M. Matsa, O. Mupepi, T. Musasa, and R. Defe, "A GIS and remote sensing aided assessment of land use/cover changes in resettlement areas; a case of ward 32 of Mazowe district, Zimbabwe," *J. Environ. Manage.*, vol. 276, p. 111312, 2020, doi: https://doi.org/10.1016/j.jenvman.2020.111312.

[2] A. B. Mamadou Traore, Mai Son Lee, Azad Rasul, "Assessment of land use/land cover changes and their impacts on land surface temperature in Bangui (the capital of Central African Republic)," *Environ. Challenges*, vol. 4, p. 100114, 2021, doi: https://doi.org/10.1016/j.envc.2021.100114.

[3] B. M. G. Sonam Wangyel Wang, "Land Use and Land Cover Change Detection and Prediction in the Kathmandu District of Nepal Using Remote Sensing and GIS," *Sustainability*, vol. 12, no. 9, p. 3925, 2020, doi: https://doi.org/10.3390/su12093925.

[4] E. M. Attua and and J. B. Fisher, "Historical and Future Land-Cover Change in a Municipality of Ghana," *Earth Interact.*, vol. 15, no. 9, p. 2, 2011, [Online]. Available: https://journals.ametsoc.org/view/journals/eint/15/9/2010ei304.1.xml

[5] D. Lu, P. Mausel, E. Brondízio, and E. Moran, "Change detection techniques," *Int. J. Remote Sens.*, vol. 25, no. 12, pp. 2365–2401, Jun. 2004, doi: 10.1080/0143116031000139863.

[6] J. Cheng and I. Masser, "Urban growth pattern modeling: a case study of Wuhan city, PR China," *Landsc. Urban Plan.*, vol. 62, no. 4, 2003, doi: https://doi.org/10.1016/S0169-2046(02)00150-0.

[7] M. A. K. Sher Muhammad Malik, Muhammad Usman Khan, Muhammad Miandad, "Spatio-temporal Valuation of Urban Expansion and Landuse Changes in Bahawalpur," *Pakistan Geogr. Rev.*, vol. 74, no. 2, pp. 127–141, 2019, [Online]. Available: https://pu.edu.pk/images/journal/geography/pdf/4_V74_No2_2019.pdf

[8] M. K. J.S. Rawat, "Monitoring land use/cover change using remote sensing and GIS techniques: A case study of Hawalbagh block, district Almora, Uttarakhand, India," *Egypt. J. Remote Sens. Sp. Sci.*, vol. 18, no. 1, pp. 77–84, 2015, doi: https://doi.org/10.1016/j.ejrs.2015.02.002.

[9] H. G. Coskun, U. Alganci, and G. Usta, "Analysis of land use change and urbanization in the Kucukcekmece Water basin (Istanbul, Turkey) with temporal satellite data using remote sensing and GIS," *Sensors*, vol. 8, no. 11, pp. 7213–7223, Nov. 2008, doi: 10.3390/S8117213.

[10] M. Hasan, L. Hassan, M. A. Al, M. H. Abualreesh, M. H. Idris, and A. H. M. Kamal, "Urban green space mediates spatiotemporal variation in land surface temperature: a case study of an urbanized city, Bangladesh," *Environ. Sci. Pollut. Res.*, vol. 29, no. 24, pp. 36376–36391, May 2022, doi: 10.1007/S11356-021-17480-9/METRICS.

[11] J. P. Tarulata Shapla, "Agricultural Land Cover Change in Gazipur, Bangladesh, in Relation to Local Economy Studied Using Landsat Images," *Adv. Remote Sensing,* vol. 4, no. 3, 2015, [Online]. Available: https://www.scirp.org/journal/paperinformation?paperid=58994

[12] C. N. Mundia and M. Aniya, "Analysis of land use/cover changes and urban expansion of Nairobi city using remote sensing and GIS," *Int. J. Remote Sens.*, vol. 26, no. 13, pp. 2831–2849, Jul. 2005, doi: 10.1080/01431160500117865;JOURNAL:JOURNAL:TRES20.

[13] Z. H. Jieying Xiao, Yanjun Shen, Jingfeng Ge, Ryutaro Tateishi, Changyuan Tang,

Yanqing Liang, "Evaluating urban expansion and land use change in Shijiazhuang, China, by using GIS and remote sensing," *Landsc. Urban Plan.*, vol. 75, no. 1–2, pp. 69–80, 2006, doi: https://doi.org/10.1016/j.landurbplan.2004.12.005.

[14] B. Y. Nnyaladzi Batisani, "Urban expansion in Centre County, Pennsylvania: Spatial dynamics and landscape transformations," *Appl. Geogr.*, vol. 29, no. 2, pp. 235–249, 2009, doi: https://doi.org/10.1016/j.apgeog.2008.08.007.

[15] M. K. J.S. Rawat, Vivekanand Biswas, "Changes in land use/cover using geospatial techniques: A case study of Ramnagar town area, district Nainital, Uttarakhand, India," *Egypt. J. Remote Sens. Sp. Sci.*, vol. 16, no. 1, pp. 111–117, 2013, doi: https://doi.org/10.1016/j.ejrs.2013.04.002.

[16] R. S. Kumiko Fujita, Gulsan Ara Parvin, "4 - Social background in char areas, Bangladesh: Implication for Japanese hazard mapping technology," *Sci. Technol. Disaster Risk Reduct. Asia*, pp. 39–55, 2018, doi: https://doi.org/10.1016/B978-0-12-812711-7.00004-3.

[17] "Remote Sensing and Image Interpretation, 7th Edition | Wiley." Accessed: Jun. 24, 2024. [Online]. Available: https://www.wiley.com/en-sg/Remote+Sensing+and+Image+Interpretation%2C+7th+Edition-p-9781118343289

[18] M. Z. Iqbal and M. J. Iqbal, "Land Use Detection Using Remote Sensing and GIS (A Case Study of Rawalpindi Division)," *Am. J. Remote Sens. 2018, Vol. 6, Page 39*, vol. 6, no. 1, pp. 39–51, Apr. 2018, doi: 10.11648/J.AJRS.20180601.17.

[19] P. K. Srivastava, D. Han, M. A. Rico-Ramirez, M. Bray, and T. Islam, "Selection of classification techniques for land use/land cover change investigation," *Adv. Sp. Res.*, vol. 50, no. 9, pp. 1250–1265, Nov. 2012, doi: 10.1016/J.ASR.2012.06.032.

[20] K. S. Lakshmi N. Kantakumar a, Shamita Kumar, "Spatiotemporal urban expansion in Pune metropolis, India using remote sensing," *Habitat Int.*, vol. 51, pp. 11–22, 2016, doi: https://doi.org/10.1016/j.habitatint.2015.10.007.

[21] Z. Sun, R. Ma, and Y. Wang, "Using Landsat data to determine land use changes in Datong basin, China," *Environ. Geol.*, vol. 57, no. 8, pp. 1825–1837, Jun. 2009, doi: 10.1007/S00254-008-1470-2/METRICS.

[22] Giles M. Foody, "Status of land cover classification accuracy assessment," *Remote Sens. Environ.*, vol. 80, no. 1, pp. 185–201, 2002, doi: https://doi.org/10.1016/S0034-4257(01)00295-4.

[23] Z. ur Rahman *et al.*, "Faecal and nitrate contamination in the groundwater of Mardan district, Pakistan," *Environ. Geochem. Health*, vol. 43, no. 9, pp. 3615–3624, Sep. 2021, doi: 10.1007/S10653-021-00848-8/METRICS.

[24] B. K. Goksel *et al.*, "Abducens nerve palsy and optic neuritis as initial manifestation in brucellosis," *Scand. J. Infect. Dis.*, vol. 38, no. 8, pp. 721–725, Aug. 2006, doi: 10.1080/00365540500466614,.

[25] Muhammad Nasar-u-Minallah, "Retrieval of Land Surface Temperature of Lahore Through Landsat-8 TIRS Data," *Int. J. Econ. Environ. Geol.*, vol. 10, no. 1, pp. 70–77, 2019, doi: 10.46660/ijeeg.Vol10.Iss1.2019.220.

[26] K. Mehmood, Saifullah, M. Iqbal, Z. Rengel, and M. M. Abrar, "Pakistan and India Collaboration to Improve Regional Air Quality Has Never Been More Promising," *Integr. Environ. Assess. Manag.*, vol. 16, no. 5, pp. 549–551, Sep. 2020, doi: 10.1002/IEAM.4292;CTYPE:STRING:JOURNAL.

[27] C.-W. C. Y.-J. Su, K.-C. Kuo, T.-W. Wang, "Gender-based differences in COVID-19," *New Microbes New Infect.*, vol. 42, p. 100905, 2021, doi: https://doi.org/10.1016/j.nmni.2021.100905.

[28] M. Bokaie, M. Simbar, S. Ardekani, and H. Majd, "Women's beliefs about infertility and sexual behaviors: A qualitative study," *Iran. J. Nurs. Midwifery Res.*, vol. 21, no. 4, p. 379, Jul. 2016, doi: 10.4103/1735-9066.185579.

[29] J. Z. Talha Hassan, "Surface Urban Heat Islands Dynamics in Response to LULC and Vegetation across South Asia (2000–2019)," *Remote Sens*, vol. 13, no. 16, p. 3177, 2021, doi: https://doi.org/10.3390/rs13163177.
[30] Y. M. Manjula Ranagalage, "The Impacts of Landscape Changes on Annual Mean Land Surface Temperature in the Tropical Mountain City of Sri Lanka: A Case Study of Nuwara Eliya (1996–2017)," *Sustainability*, vol. 11, no. 19, p. 5517, 2019, doi: https://doi.org/10.3390/su11195517.
[31] M. Imran and A. Mehmood, "Analysis and mapping of present and future drivers of local urban climate using remote sensing: a case of Lahore, Pakistan," *Arab. J. Geosci. 2020 136*, vol. 13, no. 6, pp. 1–14, Mar. 2020, doi: 10.1007/S12517-020-5214-2.