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# The spatio-temporal analysis of land use land cover changes in Multan city, Pakistan

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## Abstract

This research is focused on evaluating the transformation of land use preferences in Multan City, Pakistan, for 30 years of study from 1993 to 2023. To accommodate the enhancement in population growth within the city, changes in land use patterns are rapid. With the temporal gap of 10 years, four specified years (1993, 2003, 2013, and 2023) are selected as study years. Supervised classification is applied to satellite images from different Landsat satellites for each study year. The analysis results indicate a considerable alteration in the land use priorities of Multan city over the study period. The expansion in the built-up area is substantial and increased from 9% in 1993 to 32% in 2023. This suggests urbanisation and infrastructure advancement in the city. Agricultural land has decreased significantly, dropping from 76% in 1993 to 66% in 2023. This reduction is attributed to urban expansion encroaching upon agricultural areas as the city grows. The area covered by water bodies has experienced a significant decline, decreasing from 4% of the total area in 1993 to only 1% in 2023. The research highlights the importance of monitoring these changes to ensure sustainable urban development.

**Keywords:** Landsat, Landsat satellite, image classification, satellite images, temporal changes, transformation of land use, urban expansion, land use patterns.

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## 1. Introduction

Globally, land use priorities and dynamics have changed drastically over the past four decades (Meraj & Javed, 2022). Consequently, natural and human-induced interventions have primarily affected patterns of using land for agricultural and other purposes (Hassan *et al.*, 2016). Within an urban setup, the conversion of land from different classes into urban infrastructure initiates the growth toward urbanization (Baqa *et al.*, 2021). In less developed countries, consistent urban expansion over ecologically important areas calls upon urban geographers and decision-makers to cope with such challenges (Dutta *et al.*, 2020). Likewise, exponential increase in urban population has further intensified spatial diversity in urban environment (Rousta *et al.*, 2018a).

The earth's land area continuously changes as urbanization spreads around the globe. Data on land use land cover (LULC) change is vital for many scientific disciplines and urban land use administration and planning (Ali *et al.*, 2019). Remotely sensed information is systematically analyzed using GIS, a stochastic tool for identifying and examining the spatial structure and dynamics of LULC (Teimouri *et al.*, 2023). The number, structure, and spatial division of LULC classes are significantly altered due to the speeding up of urbanization (Zhang *et al.*, 2023). Urbanization results in the destruction of habitats, depletion of resources, loss of biodiversity, decline in natural vegetation cover, disappearance of arable lands, depletion of water supplies, and fragmentation of the landscape (Ahmed, 2020). The LULC information on the Earth's uppermost layer is acquired through satellite imagery (Bhat *et al.*, 2017; Jana *et al.*, 2022). GIS and RS have been employed extensively and have proven to be efficient techniques for tracking the global spatial and sequential changes of LULC (Burke *et al.*, 2021).

The human-induced dynamics of LULC have long-term effects on the local environment and resources (Kayet *et al.*, 2019). According to human demands and behaviours, land use modifies the land's natural setting. The geographic traits of the surface, such as forestry, water, agriculture, and urban infrastructure, are known as land cover (LC). The temporal changes of LULC in any given area over an extended period of time have an impact on the local environment and resources (Nayak & Mandal, 2019). In order to comprehend the changed structure over time and to provide light on how human activities affect agriculturally rich land. This research specifies four features of LULC classes: built-up, land with vegetation, land with barren traits and water covers. Employing geospatial approaches examines encroachment around shore areas and transforming sand and soil into built infrastructure throughout a specified time (Msofe *et al.*, 2019). RS/GIS techniques provide a suitable stage for the numerous features needed by the researchers for the classification of LULC (Khan *et al.*, 2021; Zeilhofer & Topanotti, 2008). Using such systems in decision-making research helps to complete various parts of LULC feature information at spatiotemporal scales. GIS/RS offers different geographical catalogues with spatial and statistical geo-databases to establish the periodic alteration in LULC features (Saxena & Jat, 2020).

The specified aim of the current research study is to monitor the changes that occurred in the LULC pattern of Multan city, Punjab, Pakistan. As urban areas expand with enhancement in built-up areas, the agricultural land is used for development of urban infrastructure. This is an alarming situation for agricultural yield in Multan city. It is of great significance to evaluate transformation of land used for agriculture into built-up infrastructure, instigating the changes in LULC of the Multan city. This research has major implications for sustaining and protecting the agricultural usage of land from expansion into the built environment. Protection of agricultural land is inevitable to avoid shortage of food and surplus of agricultural products. The spatial outcomes of this study can benefit urban planners, managers, and stakeholders of the food and agriculture department in Multan city, Pakistan.

## 2. Methodology

This research is designed to detect changes in LULC of Multan city, Pakistan. First, the research period is finalized with a temporal gap of 10 years, from 1993 to 2023, making 30 years. The four years 1983, 2003, 2013 and 2023 are specified as study years. To detect the specified classes, supervised classification technique is used for this study. To initiate the classification, the required images are freely downloaded from the user portal of USGS "(https://earthexplorer.usgs.gov/)." The downloaded multi-temporal images are accessed from multiple Landsat satellites. Landsat 5 is used for 1983, Landsat 7 for 2003, Landsat 8 is accessed for the study period of 2013, and Landsat 9 is selected for the satellite-based image of 2023.

### 2.1. Accuracy assessments of data

The classifications produced using the algorithms for classifications outlined earlier do not always make perfect outcomes. In results, there are several errors in the categorized image due to various factors including band correlation, incorrect labelling of training areas, a flawed classification method, and undistinguishable classes. A classified image's accuracy rating indicates the level of data that may be gathered from spatial images.

An accuracy assessment is carried out by contrasting a map created using images of satellites with images from different sources. Rapid changes in the landscape are common. The matrix of classification errors and the creation of an error matrix are better ways to achieve classification accuracy.

Simple descriptive statistics can be used to construct several classification accuracy measures from the error matrix, as detailed below.

**(a) Error of omission**

It shows the pixels that carry the correct class but are not shown in the correct class.

**(b) Error of inclusion**

It shows the pixels for another class rather than the actual and correct class. As inclusion of barren pixels and forest pixels in cultivable or agricultural land.

**(c) Overall accuracy**

It is applied to specify the total pixels identified and referenced. This measure's limitation is that it does not provide information on how accurately various classes are categorized. The overall accuracy depends on the accurate measurement of the specified land use classes. Equation (1) is used for the estimation of overall accuracy.

$$Overall\ Accuracy = \frac{Total\ No.\ of\ Correct\ Identified\ Pixel}{Total\ Number\ of\ Reference\ Pixel} * 100 \quad (1)$$

**(d) Producer accuracy**

It is statistically estimated as identified pixels in a given category with total no. of pixels in the specified sample (column total).

**(e) User precision**

The user precision deals with specifying a pixel of specified land use in that particular class. As consideration of vegetation pixels for vegetation class only. User accuracy is calculated by using Equation (2).

$$User\ Accuracy = \frac{Total\ No.\ of\ Correctly\ Classified\ Pixel}{Total\ Number\ of\ Reference\ Pixel} * 100 \quad (2)$$

**(f) Kappa coefficient**

A discrete multivariate method for evaluating accuracy is the Kappa Coefficient. A proportion of correctly classified pixels will be produced in a classification process when classes are assigned at random. The statistical techniques account for random chances in the correctness of a classification. Equation (3) shows the formula of Kappa coefficient (Rousta *et al.*, 2018b).

$$Kappa\ Coefficient = \frac{N\sum_{r=1}^{i} X_{ii} - \sum_{r=1}^{i}(X_{i+} * X_{+i})}{N^2 - \sum_{r=1}^{i}(X_{i+} * X_{+i})} \quad (3)$$

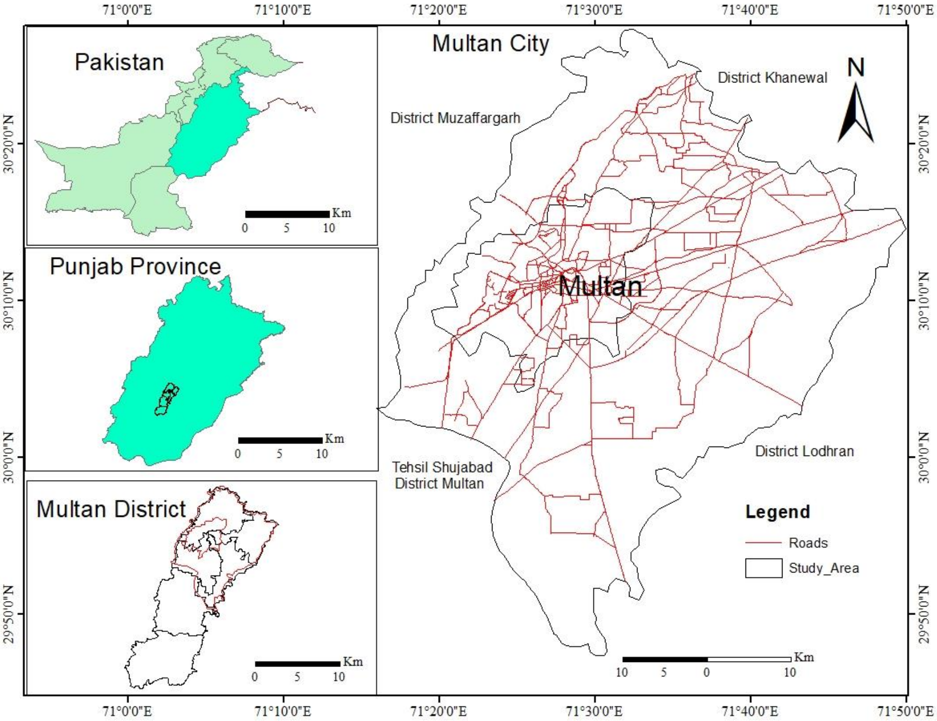
Table-1: Accuracy assessment of LULC map 1993, 2003, 2013 and 2023

| Years | Overall Accuracy (%) | User Accuracy (%) | Procedure Accuracy (%) | Kappa Coefficient |
|---|---|---|---|---|
| 1993 | 94.69 | 92.34 | 90.21 | 0.92 |
| 2003 | 92.22 | 90.43 | 89.13 | 0.87 |
| 2013 | 91.21 | 93.33 | 91.21 | 0.88 |
| 2023 | 92.5 | 96.23 | 94.43 | 0.89 |

## 3. Study area

Multan city is located on the left bank of river Chenab in the southern part of Punjab province, Pakistan. It is located between 29° 59’ 2’’ to 30° 45’ 7’’ North Latitude and between 71°29’ 5’’ to 71° 49’5’’ East Longitude (Figure 1). As per the 2017 Census, the population of the study area is 2259115, out of which 1161032 are male and 1097834 are females. The city covers a total area of 304.0 km$^2$ and population density in the city is 7,431 persons per square kilometre. Annual change of population in comparison with the census of 1998 confirms 2.6% of annual growth. The urban population represents 1827001 (80.9%) while 432114 (19.1%) characterizes the rural population. The main source of livelihood in the city is agriculture based commercial activities.

Figure 1: Location of Multan City, Punjab, Pakistan




## 4. Results and discussions

### 4.1. LULC changes of Multan 1993

To detect the change in LULC for Multan city in the first study year, the satellite image is taken from Landsat 5 with a resolution of 30 m. The image is then classified with the procedure of supervised classification to ensure the distribution in classes. The classes were further sub-categorized into built-up area, agriculture, barren areas and water bodies. The total area of the study area is about 1943.537 km$^2$. Out of the total land covered area in Multan city, the classified classes covered the areas as; 185.63 km$^2$ of built-up making 9%, 1472.9 km$^2$ of agriculture making 76%, 71.6166 km$^2$ water body with 4% and 213.381 km$^2$ (11%) of barren land (Figure 2; Table-2).

### 4.2. LULC changes 2003

To identify the study area into classes of LULC changes, the Landsat 7 image with a resolution of 30 m is used. Between the two techniques of classification, supervised classification is practiced here. Built-up, agricultural area, barren land, and water bodies are the sub-categories for the given map. The overall area of the city is about 1941.537 km$^2$. The total land use area from the total covered land attributed that area under built-up is 218.443 km$^2$ making 12%, 1668 km$^2$ is under agriculture making 86%, 27.384 km$^2$ area is under water body making 1% and 27.2461 km$^2$ (1%) of barren land (Figure 2; Table-2).

### 4.3. LULC changes 2013

To monitor the land use preferences in Multan city for the third specified year of the study period, Landsat 8 image with the resolution of 30 m is used after downloading from USGS site.

By using the image classification tool from ArcGIS, the image is classified with supervised classification technique. The given classes for supervision on the map were agricultural land, barren areas, built-up and water bodies. After classification, the data depicted that the agricultural land in the study was 1612.48 km$^2$ with a percentage of 83. The barren land covered 27.404 km$^2$ of land with 1%. The built-up area according to this map was 292.62 (15%). The water body was 9.0342 with 1% of the total land (Figure 2; Table-2).

**4.4. Land use land cover (LULC) change 2023**

To monitor the agricultural land, barren land, built-up infrastructure and water covers in the year 2023 within the study area of the current research, the Landsat 9 image with 30m resolution is used. The supervised classification under the image classification tool guided the land categorization of the given classes. The classification depicted that out of 1941.537 km$^2$ of total covered land, the agricultural land in Multan city is 1291.38 with 66%, and the area under barren land is 10.6128 km$^2$ making 1%. The area under built- up infrastructure and water bodies in the given year are 630.725 and 8.8247 km$^2$ respectively (Figure 2).

Figure 2: LULC categorization in Multan city, 1993 – 2023

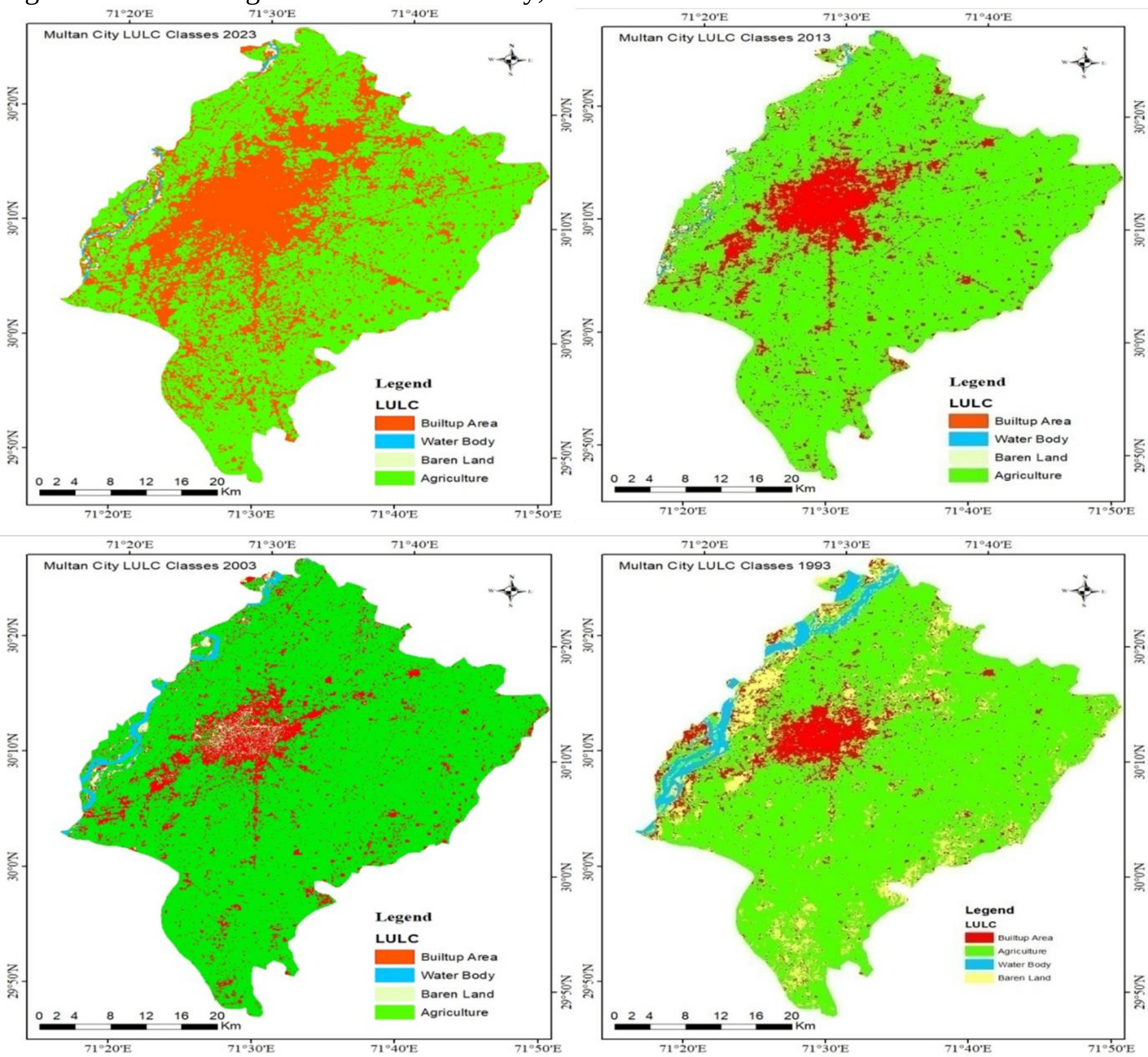


Table-2: LULC classes 1993 – 2023 in Multan city

| LULC Classes 1993 | | | LULC Classes 2003 | | |
|---|---|---|---|---|---|
| LULC Classes | Area ($Km^2$) | Area in (%) | LULC 2003 | Area ($Km^2$) | Area in (%) |
| Agriculture | 1472.9 | 76 | Agriculture | 1668.23 | 86 |
| Barren Land | 213.381 | 11 | Barren Land | 27.2461 | 1 |
| Built-up Area | 183.639 | 9 | Built-up Area | 218.443 | 12 |
| Water Body | 71.6166 | 4 | Water Body | 27.2384 | 1 |
| Total Area | 1941.537 | 100% | Total Area | 1941.537 | 100% |
| LULC Classes 2013 | | | LULC Classes 2023 | | |
| LULC Classes | Area ($Km^2$) | Area in (%) | LULC Classes | Area ($Km^2$) | Area in (%) |
| Agriculture | 1612.48 | 83 | Agriculture | 1291.38 | 66 |
| Barren Land | 27.404 | 1 | Barren Land | 10.61 | 1 |
| Built-up Area | 292.62 | 15 | Built-up Area | 630.72 | 32 |
| Water Body | 9.0342 | 1 | Water Body | 8.82 | 1 |
| Total area | 1941.537 | 100 | Total area | 1941.537 | 100 |

## 4.5. LULC: change detection methods

LULC change detection passes on to the process of specifying and analyzing changes in the way land is used or the types of vegetation, water or built-up infrastructure that cover the land surface. This is important for understanding the impact of human-induced actions and environmental factors on the landscape and monitoring and managing land resources.

To detect changes in land use classes for the specified time period and study years, the comparison of satellite based remotely sensed images provides the essential data. For this purpose, the analysis and interpretation of such images after supervised classification in GIS give the desired results. This classification makes differentiation and comparison easy and attractive.

The analysis of images based on visual interpretation of the images with different land use classes and the changes can be evaluated temporally for two or more study years. The colour, texture and shapes help in this regard. The pixels carrying different data of LULC are the central point in identifying such changes. The images show the categories of land spatially.

## 4.6. Changes in LULC from 1993 – 2003

The change detection method is used to distinguish the transformations in classes between the first two years of the study period, which are 1993 and 2003. The change is monitored for every class including agriculture area, barren areas, built-up land, and water body areas. The provided data shown in table-3 represents LULC changes that occurred in 1993 and 2003, along with the corresponding area changes in square kilometres.

Agriculture – Water body, area change: 2.555791 $km^2$. This shows that agricultural lands encroached upon water bodies, resulting in a decrease in water area. Agriculture – Barren land, area change: 2.710579 $km^2$. Some agricultural areas transformed into barren land. Barren land – Barren land, area change: 4.770807 $km^2$. This indicates the stability or limited change in barren land areas. Agriculture – Water body, area change: 6.585706 km$^2$. Agricultural lands expanded into water bodies, leading to a loss of water area. Water body – Barren land, area change: 8.59395 km$^2$. Barren land expanded into water bodies, resulting in a reduction in water area. Barren land – Water body, area change: 6.326613 km$^2$. Water bodies encroached upon barren land, leading to a decrease in barren land area. Water body – Built-up area, area change: 6.70458 km$^2$. Built-up areas encroached upon water bodies, resulting in decreased water area. Water body– Water body, area change: 12.07681 km$^2$. This represents the stability or limited change in water bodies.

Built-up area – Barren land, area change: 13.90525 km$^2$. Barren land expanded into built-up areas. Water body – Agriculture, area change: 46.71918 km$^2$. Agricultural land encroached upon water bodies, leading to a decrease in water area. Barren land – Built-up area, area change: 56.66813 km$^2$. Built-up areas expanded into barren land. Agriculture – Built-up area, area change: 68.15354 km$^2$. Some agricultural areas were converted into built-up or developed areas. Built-up area – Agriculture, area change: 81.17333 km$^2$. Agricultural land expanded into built-up areas. Built-up area – Built-up area, area change: 86.62466 km$^2$. This indicates the stability or limited change in built-up areas. Barren land – Agriculture, area change: 142.4282 km$^2$. Some barren land converted into agricultural areas. Agriculture – Agriculture, area change: 1395.536 km$^2$. This represents the conversion of agricultural areas within the study years. The total LULC change during this period amounted to 1941.537 km$^2$.

The results illustrate the significant transformations in land cover, with changes in agricultural areas, water bodies, built-up areas, and barren land. Monitoring and understanding LULC changes are essential for assessing the impacts on ecosystems, natural resources, and human activities. It facilitates land management and conservation efforts.

Figure 3: Change detection of LULC in Multan City 1993 – 2003

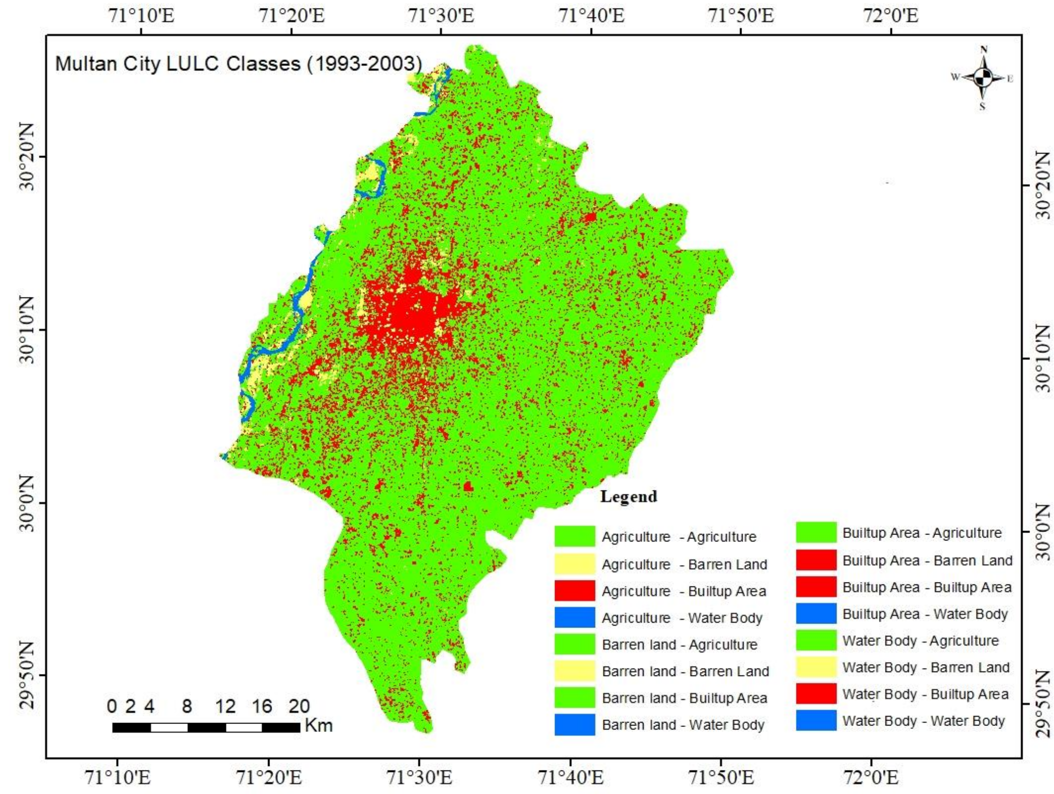


Table-3: Changes in LULC from 1993 – 2003 in Multan City

| LULC classes 1993 -2003 | Area change ($Km^2$) |
|---|---|
| Agriculture – Water body | 2.555791 |
| Agriculture – Barren land | 2.710579 |
| Barren land – Barren land | 4.770807 |
| Agriculture– Water body | 6.585706 |
| Water body – Barren land | 8.59395 |
| Barren land – Water body | 6.326613 |
| Water body –Built-up area | 6.70458 |
| Water body – Water body | 12.07681 |
| Built-up area – Barren land | 13.90525 |
| Water body – Agriculture | 46.71918 |
| Barren land – Built-up area | 56.66813 |
| Agriculture –Built-up area | 68.15354 |
| Built-up area – Agriculture | 81.17333 |
| Built-up area –built-up area | 86.62466 |
| Barren land – Agriculture | 142.4282 |
| Agriculture – Agriculture | 1395.536 |
| Total | 1941.537 |

### 4.7. Changes inland use priorities from 2003 – 2013

LULC change refers to the transformation of different types of land cover over a specific period. Table-4 shows the area change in $km^2$ that occurred between 2003 and 2013. Water Body – Agriculture, area change is 8.380015 $km^2$. This indicates that agricultural land expanded into water bodies, leading to a loss of water area. Water body – Built-up area, area change: 3.762483 $km^2$. Built-up areas encroached upon water bodies, resulting in decreased water area. Water body – Water body, area change: 3.618899 $km^2$. This represents the overall stability of water bodies, with a minimal change in area. Water body – Barren land, area change: 7.814648 $km^2$. Barren land expanded into water bodies, leading to a reduction in water area. Agriculture – Agriculture, area change: 1527.312333 $km^2$. This indicates the expansion of agricultural land within the study period. Agriculture – Built-up, area change: 121.623305 $km^2$. Some agricultural areas were converted into built-up or developed areas. Agriculture – Water body, area change: 4.003957 $km^2$. Agricultural land encroached upon water bodies, resulting in a decrease in water area. Agriculture – Barren land area change: 10.754435 $km^2$. Barren land expanded into agricultural areas. Built-up Area – Agriculture, area change: 65.176367 $km^2$. Some built-up areas were transformed into agricultural land. Built-up area – Built-up area, area change: 147.532361 $km^2$. This represents the stability or limited change in built-up areas. Built-up area – Water body, area change: 0.839559 $km^2$. Built-up areas encroached upon water bodies, leading to decreased water area. Built-up area – barren land, area change: 4.321422 $km^2$. Barren land expanded into built-up areas. Barren land – Agriculture, area change: 4.162205 $km^2$. Some barren area was transformed into agricultural areas. Barren area – Built-up area, area change: 17.939693 $km^2$. Built-up areas expanded into barren land. Barren Land – Water body, area change 0.6293 $km^2$. Barren land encroached upon water bodies, leading to a decrease in water area. Barren land – Barren land, area change:4.306375 $km^2$ in these two periods. This represents the stability or limited change in barren land areas.

The results highlight the dynamic nature of the land cover and the various transformations that occurred during the specified timeframe. It is crucial to monitor and analyze LULC changes to understand the impact on ecosystems, natural resources, and human activities in the affected regions.

Figure 4: Change detection of LULC in Multan City during 2003 - 2013

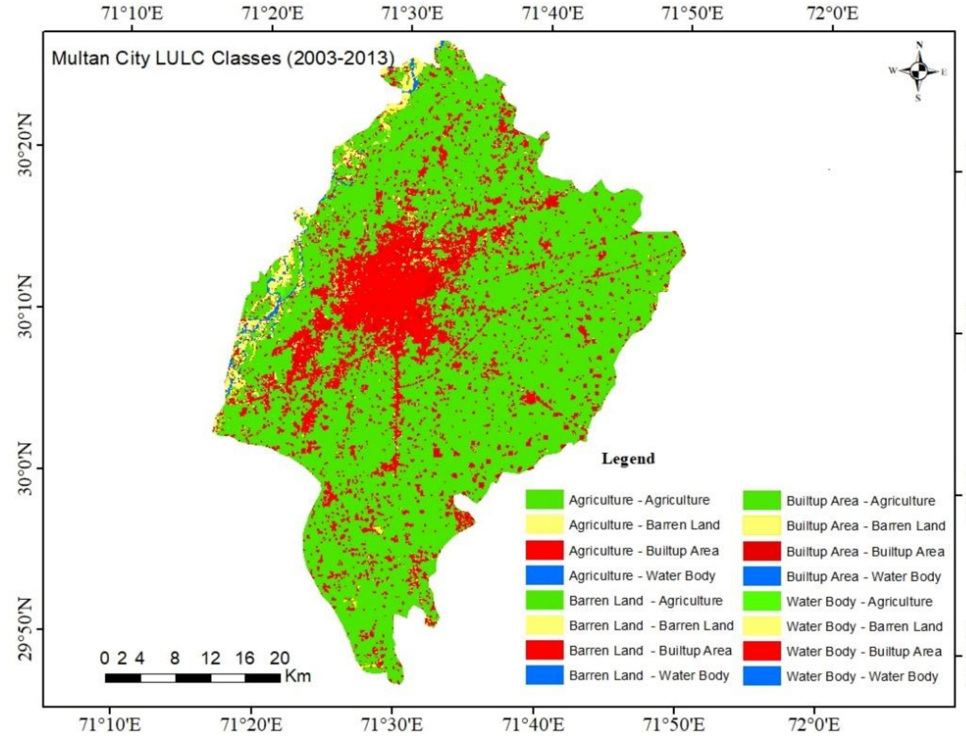



Table-4: LULC area change in Multan City, 2003 – 2013

| LULC change in 2003-2013 | Area change ($Km^2$) |
|---|---|
| Water body – Agriculture | 8.380015 |
| Water body – Built-up area | 3.762483 |
| Water body – Water body | 3.618899 |
| Water body – Barren land | 7.814648 |
| Agriculture – Agriculture | 1527.312333 |
| Agriculture – Built-up area | 121.623305 |
| Agriculture – Water body | 4.003957 |
| Agriculture – Barren land | 10.754435 |
| Built-up Area – Agriculture | 65.176367 |
| Built-up Area – Built-up Area | 147.532361 |
| Built-up area – Water body | 0.839559 |
| Built-up area – Barren land | 4.321422 |
| Barren land – Agriculture | 4.162205 |
| Barren land – Built-up area | 17.939693 |
| Barren land – Water body | 0.6293 |
| Barren land – Barren land | 4.306375 |

## 4.8. Changes in LULC from 2013 – 2023

The provided data shown in Table-5 represents the LULC changes that occurred in 2013 and 2023, along with the corresponding area changes in square kilometres. Let us examine each category of change. Agriculture – built-up area, area change: 356.217222 $km^2$. Agricultural land is converted into built-up or developed areas, indicating urban expansion or infrastructure development. Agriculture – Water body, area change: 3.314665 $km^2$. Agricultural land encroached upon water bodies, resulting in a decrease in water area. Agriculture – Barren land. area change: 3.832133 $km^2$. Some agricultural areas transformed into barren land. Agriculture – Agriculture, area change: 1241.595965 $km^2$. This represents the expansion of agricultural land within the study period. Built-up area – Built-up area, area change: 254.520835 $km^2$. This indicates the stability or limited change in built-up areas. Built-up area – Water body, area change: 0.94736 $km^2$. Built-up areas encroached upon water bodies, leading to decreased water area. Built-up area – Barren land, area change: 1.16434 $km^2$. Some built-up areas expanded into barren land. Built-up area – Agriculture, area change: 34.228476 $km^2$. Agricultural land expanded into built-up areas. Water body – Built-up area, area change: 3.382088 $km^2$. Built-up areas encroached upon water bodies, resulting in decreased water area. Water body – Water body, area change: 1.595827 $km^2$. This represents the stability or limited change in water bodies. Water body – Barren land, area change: 1.755896 $km^2$. Barren land expanded into water bodies. Water body – Agriculture, area change: 2.362927 $km^2$. Agricultural land encroached upon water bodies, leading to a decrease in water area. Barren land – Built-up Area, area change: 11.865199 $km^2$. Built-up areas expanded into barren land. Barren land – Water body, area change: 2.109574 $km^2$. Barren land encroached upon water bodies, resulting in a decrease in water area. Barren land – Barren land, area change: 2.89261 $km^2$. This indicates the stability or limited change in barren land areas. Barren Land – Agriculture, area change: 10.333681 $km^2$. Some barren land was converted into agricultural areas.

The results demonstrate the ongoing transformations in land cover, highlighting the urban expansion, changes in agricultural areas, and the impact on water bodies and barren land. Monitoring and understanding LULC changes are vital for sustainable land management, conservation efforts, and informed decision-making regarding land use planning and resource allocation.

Figure 5: LULC: Area change in Multan City from 2013 – 2023

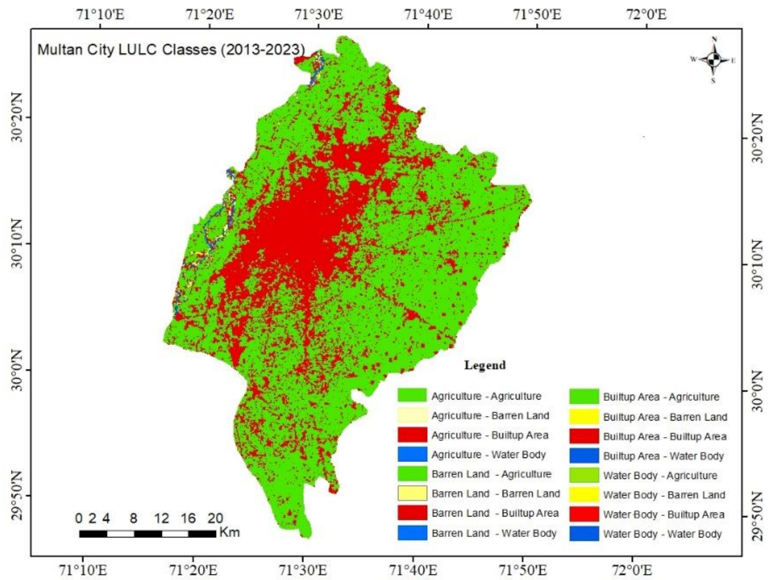


Table-5: Change in LULC area during 2013 – 2023 in Multan City

| LULC Change in 2013-2023 | Area Change ($Km^2$) |
|---|---|
| Agriculture – Built-up area | 356.217222 |
| Agriculture – Water body | 3.314665 |
| Agriculture – Barren land | 3.832133 |
| Agriculture – Agriculture | 1241.595965 |
| Built-up area – Built-up area | 254.520835 |
| Built-up area – Water body | 0.94736 |
| Built-up area – Barren land | 1.16434 |
| Built-up area – Agriculture | 34.228476 |
| Water body – Built-up area | 3.382088 |
| Water body – Water body | 1.595827 |
| Water body – Barren land | 1.755896 |
| Water body – Agriculture | 2.362927 |
| Barren land – Built-up area | 11.865199 |
| Barren land – Water body | 2.109574 |
| Barren land – Barren land | 2.89261 |
| Barren land – Agriculture | 10.333681 |

## 5. Conclusion

This research aimed to detect the spatial changes in land use land cover (LULC) in Multan city for 30 years from 1993 to 2023. LULC change is a complex and dynamic procedure that affects the nature-based environment, societies and economies. The management of proper land utilization according to sustainable practices and ecosystem-based approaches is the need of time. To facilitate the increasing population for housing and socio-economic betterment is although the basic needs and rights but, proper strategies and policies play a vital role in the utilization of land for infrastructures. This study therefore focused on the basic LULC classes including built-up areas, agricultural land, barren land and water bodies, and the transformation of such lands into other land classes. The change detection depicted the change of agricultural land or other classes into built-up areas.

During the study years, it was clearly witnessed that changes in LULC are noticeable in Multan city during the study period: 1993, 2003, 2013 and 2023. Such changes both positively and negatively impact the environment. For example, the conversion of barren land to agricultural land can provide food and income for local communities, and this change is detected in this study from 1993 to 2003. The reduction in agricultural land and enhancement in built-up area, which is highly observed during the study period of 2013 – 2023, shows the pace of LULC changes spatially and temporally in Multan city.

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