



Spatio Temporal Dynamics of Land Use Land Cover Change and Urban Expansion in Multan Tehsil, Pakistan (2000-2020)

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Abstract

Rapid urbanization has emerged as a major driver of land use and land cover (LULC) transformation in medium-sized cities of developing countries. This study analyzes the spatiotemporal dynamics of LULC change and urban expansion in Multan Tehsil, Pakistan, over a twenty-year period (2000-2020) using Remote Sensing (RS) and Geographic Information Systems (GIS). Multi-temporal Landsat imagery for the years 2000, 2005, 2010, 2015 and 2020 was classified using a supervised Maximum Likelihood Classification approach to identify five major LULC classes: built-up area, mango orchards, vegetation cover, barren land and water bodies. Post classification change detection and spatial analysis techniques were employed to quantify land-use transitions, growth rates and expansion patterns.

The results reveal a substantial increase in built-up area from 59.73 km² in 2000 to 207.10 km² in 2020, representing a 246% growth over two decades. In contrast, mango orchards declined significantly from 52% to 27% of the total area, indicating extensive conversion of productive agricultural land into urban land uses. Urban expansion exhibited a corridor-based and peri-urban growth pattern, primarily concentrated along major transportation routes and high-value orchard zones. Change detection analysis highlights a strong inverse relationship between urban growth and orchard loss, with evidence of a two-stage conversion process involving land clearance followed by construction.

The study concludes that Multan Tehsil has undergone a structural transition from an agriculture dominated landscape to an urban-oriented system. The findings provide critical spatial insights for sustainable urban planning, agricultural land protection, and informed land-use management in rapidly urbanizing regions of Pakistan.

Keywords:

LULC Changes; Urban Sprawl; Spatio-Temporal Dynamics; Remote Sensing and GIS; Multan

1. INTRODUCTION

Urbanization is one of the most dominant processes shaping the spatial structure of cities in the twenty-first century. Globally, more than 55 percent of the population now resides in urban areas and this proportion is projected to increase to nearly 68 percent by 2050. Rapid urban growth has transformed

landscapes worldwide, particularly in developing countries where population pressure, economic restructuring and weak land use regulation accelerate unplanned expansion. As cities grow outward beyond their traditional boundaries, significant changes occur in land use and land cover (LULC), influencing environmental sustainability, resource availability and spatial organization.

Land Use Land Cover change is a dynamic process reflecting the interaction between human activities and the natural environment. Urban expansion is one of the most visible forms of LULC change, often occurring at the expense of agricultural land, vegetation and open spaces. Understanding the spatial and temporal dynamics of these changes is essential for sustainable urban planning, environmental management and policy formulation. In recent decades, geospatial technologies such as Geographic Information Systems (GIS) and Remote Sensing (RS) have emerged as powerful tools for monitoring urban growth and quantifying LULC changes with high accuracy and temporal consistency. Urban expansion is not uniform; rather, it exhibits distinct spatial patterns influenced by infrastructure development, accessibility, economic activity and policy frameworks. Spatio-temporal analysis enables researchers to examine how cities expand over time, identify growth corridors and detect patterns such as leapfrog development, edge expansion and infill growth. Such analyses are particularly relevant for medium sized cities in developing countries, where urban growth often proceeds faster than planning and regulatory mechanisms.

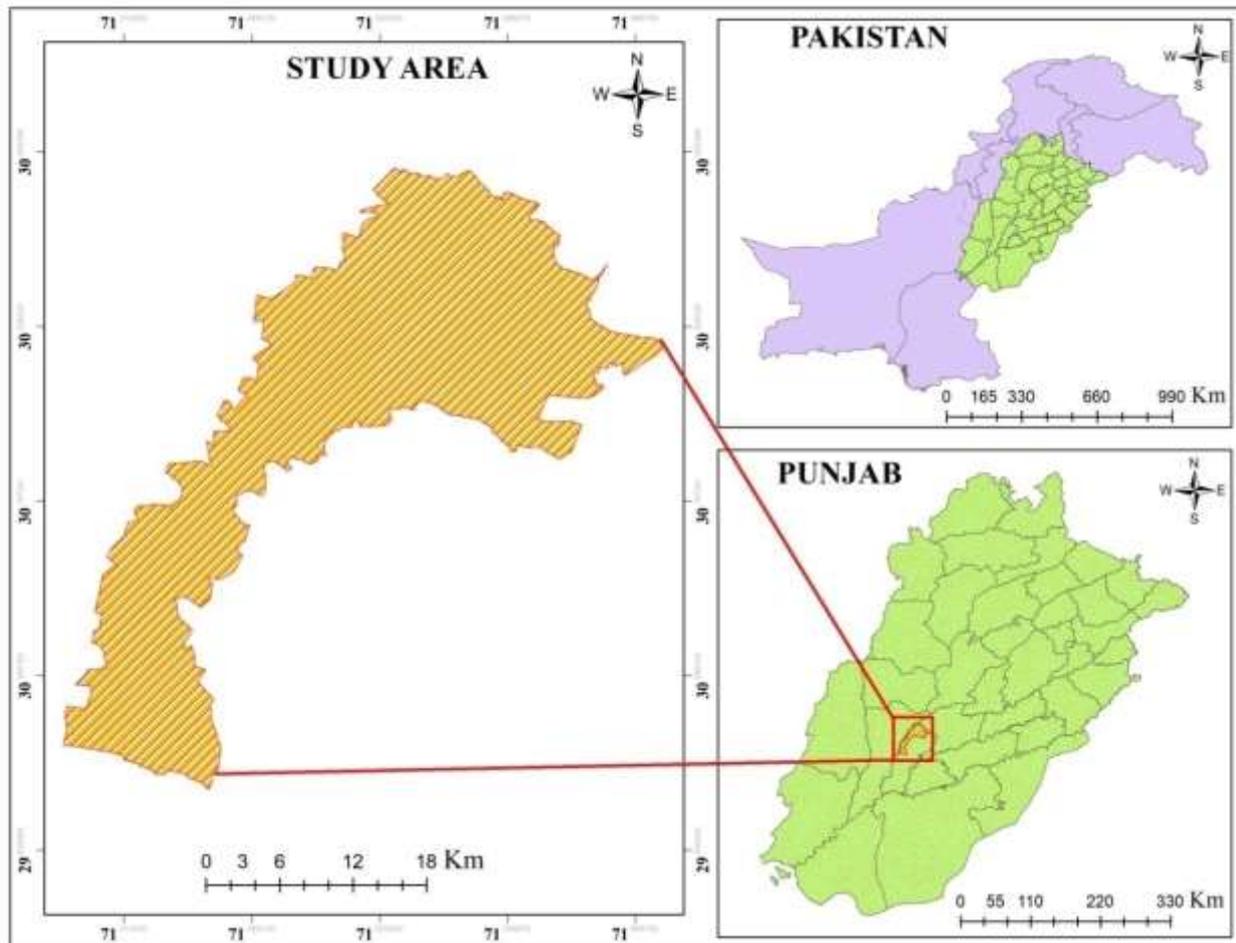
Pakistan is among the most rapidly urbanizing countries in South Asia. According to the Population Census 2023, more than 38 percent of the population resides in urban areas, a figure expected to rise substantially in the coming decades. Urban growth in Pakistan has been largely unplanned, resulting in the conversion of productive land into built-up areas. Despite the scale of this transformation, systematic spatio-temporal assessments of LULC change remain limited, especially at the tehsil level, where local planning decisions are implemented. One of the most fast growing cities of Sindh, Khairpur is also facing an issue of Urbanization specially after flood 2010. During the flood a large number affected population moved toward the Khairpur, specially from surround areas and neighbor districts, Chandio, N. H., & Shirazi, S. A. (2022). The urbanization has created various social and environmental issues, similarly Larkana is fourth largest city, where by the urbanization has created climatic issues. In the last three decades (1990-2020), the built-up area of the city increased from 12.31 km² to 43.83 km² Rahman, which causes of increasing land surface temperature and affecting the urban thermal environment., Chandio, N. H., Moazzam, M. F. U., & Al Ansari, N. (2023).

Multan Tehsil, located in southern Punjab, represents a significant case for studying urban expansion. As one of the oldest cities in the subcontinent and a major cultural, commercial and administrative center, Multan has experienced rapid population growth and infrastructural development over the past two decades. Improved road networks, housing schemes, commercial centers and public facilities have contributed to the outward expansion of the city. This expansion has altered the spatial configuration of land use, replacing agricultural and vegetated areas with residential and commercial developments. Previous studies on urban growth in Pakistan have largely focused on major metropolitan cities such as Karachi, Lahore and Islamabad. However, medium-sized cities like Multan are increasingly becoming growth poles, attracting migration and investment while facing significant land transformation challenges. A detailed spatio-temporal analysis of LULC change in Multan Tehsil is therefore necessary to document the extent, direction and rate of urban expansion over time.

This study aims to analyze the spatio-temporal dynamics of land use land cover change and urban expansion in Multan Tehsil between 2000 and 2020 using GIS and Remote Sensing techniques. Multi-temporal satellite imagery is employed to classify major land cover categories and quantify changes across five-time intervals. The study examines patterns of built-up area expansion, transitions among

land use classes and the spatial distribution of urban growth. By identifying the dominant trends and trajectories of urban expansion, this research provides empirical evidence for understanding how urbanization is reshaping the landscape of Multan. The findings of this study are expected to contribute to urban geography and spatial planning literature by offering a comprehensive assessment of LULC dynamics at the local scale. Moreover, the results can support policymakers and urban planners in developing strategies to manage future urban growth, protect valuable land resources, and promote sustainable land-use planning in rapidly urbanizing regions of Pakistan.

Figure 1 Location Map of Study Area



Aims and Objectives

To analyze the spatio-temporal dynamics of land use land cover change and urban expansion in Multan Tehsil from 2000 to 2020 using GIS and Remote Sensing techniques.

1. To classify major land use land cover changes in Multan Tehsil for the years 2000, 2005, 2010, 2015 and 2020 using multi-temporal satellite imagery.
2. To examine the spatial patterns and directional trends of urban expansion in Multan Tehsil.
3. To assess the rate and intensity of built-up area growth during different time intervals.
4. To provide spatially explicit information that can support sustainable urban planning and land management.

2. LITERATURE REVIEW

Urbanization is one of the most significant spatial transformations occurring globally, particularly in developing countries. Urban sprawl defined as the rapid, often unplanned outward expansion of cities

into surrounding rural land has become a dominant feature of contemporary urban growth. According to Rafferty (2021), urban sprawl is characterized by low density development, single use zoning, automobile dependency and fragmented land-use patterns. These characteristics distinguish sprawl from compact urban growth and make it a major concern for planners and geographers. Several scholars conceptualize urban sprawl as excessive or inefficient spatial growth. Brueckner (2000) defines it as disproportionate spatial expansion relative to population growth, while Couch et al. (2007) describe sprawl through declining urban density gradients, dispersed development and increased transportation demand. Downs (2008) further emphasizes the lack of coordinated land use planning, leapfrog development and dependence on private automobiles as core attributes of urban sprawl. These conceptual definitions provide a theoretical basis for analyzing spatial patterns of urban expansion. Urban sprawl is driven by a combination of demographic, economic and institutional factors. Population growth, rising incomes, cheaper peri-urban land and improved transportation infrastructure have been widely identified as key drivers (Ewing et al., 2008; Nechyba & Walsh, 2004). In many developing countries, weak land-use regulations and fragmented governance structures further accelerate uncontrolled urban expansion. Market liberalization and economic restructuring have also contributed to rapid land conversion in metropolitan regions (Neve et al., 2015).

Globally, urbanization trends indicate a steady increase in the urban population. According to UN-DESA (2018), approximately 55% of the world's population lived in urban areas in 2018, a figure projected to reach 68% by 2050. The number of large cities has also increased substantially, with megacities becoming more common. This expansion has intensified land-use transformation, particularly at the urban fringe, where agricultural and natural lands are most vulnerable. In South Asia, urban expansion has been especially rapid due to high population growth and rural-to-urban migration. Sudhira et al. (2004) argue that understanding urban sprawl requires a detailed examination of land-use transitions from natural or rural surfaces to built-up areas. These transitions often result in fragmented landscapes, inefficient infrastructure provision, and increased environmental stress.

Remote sensing and Geographic Information Systems (GIS) have become indispensable tools for analyzing spatio-temporal land use land cover (LULC) change. Multi-temporal satellite imagery enables researchers to detect, quantify and map changes in land cover over time with high spatial accuracy. Numerous studies have used classified satellite data to assess urban expansion patterns, growth rates and directional trends (Ban et al., 2012; Netzband et al., 2015). These methods allow for objective, reproducible analysis across different temporal intervals. Several studies highlight the effectiveness of spatio-temporal analysis in capturing urban growth dynamics. Ibrahim et al. (2011), for example, used historical satellite data to analyze urban sprawl in Shiraz, Iran, demonstrating how urban growth patterns evolve over decades. Similarly, studies conducted in India and China have shown that urban expansion often occurs along transportation corridors and toward areas with fewer physical constraints (Du, 2014; Van, 2017).

In Pakistan, urbanization has accelerated rapidly over the past few decades. According to the Pakistan Bureau of Statistics (2017), the urban population increased from 32.5% in 1998 to over 36% in 2017 and 38% in 2023. Major cities such as Lahore, Karachi, Faisalabad, Gujranwala and Multan have experienced substantial spatial expansion. Akram et al. (2018) documented a significant increase in Multan's urban area between 1987 and 2013, largely driven by population growth and infrastructural development. Despite growing research on urbanization in Pakistan, many studies focus primarily on population statistics or socioeconomic aspects, with limited attention to long-term spatio-temporal land-use dynamics. There remains a need for systematic, GIS-based analyses that quantify LULC transitions and

urban expansion patterns over extended time periods. Understanding these dynamics is essential for sustainable urban planning, infrastructure development, and land management.

This study contributes to the existing literature by providing a detailed spatio-temporal analysis of LULC change and urban expansion in Multan Tehsil from 2000 to 2020. By employing multitemporal satellite imagery and GIS techniques, the research offers insights into urban growth patterns, rates of expansion, and dominant land-use transitions, thereby filling an important research gap in urban geography and spatial planning studies in Pakistan.

RESEARCH METHODOLOGY

3.1 Research Design

This study adopts a geospatial and quantitative analytical research design to examine spatiotemporal changes in land use land cover (LULC) and urban expansion in Multan Tehsil over a 20 year period (2000-2020). The research relies primarily on secondary geospatial data, analyzed using Remote Sensing (RS) and Geographic Information Systems (GIS) techniques to identify patterns, rates and directions of urban growth.

3.2 Study Area

Multan Tehsil, located in southern Punjab, Pakistan, was selected due to its rapid urban growth, strategic economic importance, and increasing pressure on surrounding land resources. The tehsil covers approximately 218 km² and exhibits mixed land-use characteristics including built-up areas, agricultural land, orchards, vegetation cover and water bodies.

3.3 Data Sources

3.3.1 Satellite Data

Multi-temporal satellite imagery was obtained from the United States Geological Survey (USGS). Landsat images with a five-year interval were selected to ensure consistency and long-term trend analysis.

Satellite	Year	Spatial Resolution	Bands
Landsat 5	2000	30 m	7
Landsat 5	2005	30 m	7
Landsat 5	2010	30 m	8
Landsat 8	2015	30 m	8
Landsat 8	2020	30 m	11

3.3.2 Ancillary Data

Supporting data were collected from:

- Pakistan Bureau of Statistics
- Multan Development Authority (MDA)
- District Census Reports
- Published research articles and planning documents

3.4 Image Pre-processing

To ensure data accuracy and comparability, satellite images were pre-processed using ERDAS IMAGINE. Atmospheric and radiometric corrections were applied using the ATCOR module to remove haze, noise, and illumination effects. Layer stacking was performed in ArcGIS 10.3.1 to combine multiple spectral bands into a single composite image. Images were then subset to the administrative boundary of Multan Tehsil.

3.5 Image Classification

A supervised classification approach was adopted to classify LULC categories. Training samples were selected based on spectral signatures and visual interpretation. Five major LULC classes were identified:

1. Built-up area
2. Agricultural land
3. Vegetation cover
4. Barren land
5. Water bodies

The Maximum Likelihood Classification (MLC) technique was applied due to its widespread use and reliability in urban studies.

3.6 Change Detection and Spatial Analysis

Post-classification comparison was used to detect LULC changes across different years. Area statistics for each land-use class were calculated in ArcGIS, enabling the quantification of changes over time. Spatial metrics were employed to analyze:

- a) Rate of urban expansion
- b) Directional growth trends
- c) Land-use conversion patterns

3.7 Software Used

- a) ERDAS IMAGINE (image processing & classification)
- b) ArcGIS 10.3.1 (mapping & spatial analysis)
- c) Google Earth Pro (visual validation)

4. RESULTS

4.1 Spatio-Temporal Land Use Land Cover Changes (2000-2020)

The supervised classification of multi-temporal Landsat imagery for the years 2000, 2005, 2010, 2015 and 2020 revealed substantial spatio-temporal changes in land use and land cover (LULC) in Multan Tehsil. Five major LULC classes were identified: built-up area, mango orchards, vegetation cover, barren land, and water bodies. The classification results show a marked shift in land-use composition over the twenty-year study period.

In 2000, mango orchards dominated the landscape, covering approximately 301.68 km² (52% of the total area). Built-up land occupied only 59.73 km² (10%), while barren land accounted for 129.40 km² (22%). Vegetation cover and water bodies occupied relatively smaller proportions of 7% and 8%, respectively. By 2005, built-up area increased to 93.10 km² (16%), while mango orchards declined slightly to 289.81 km² (49.9%). During this period, barren land expanded to 144.68 km², indicating initial land conversion activity.

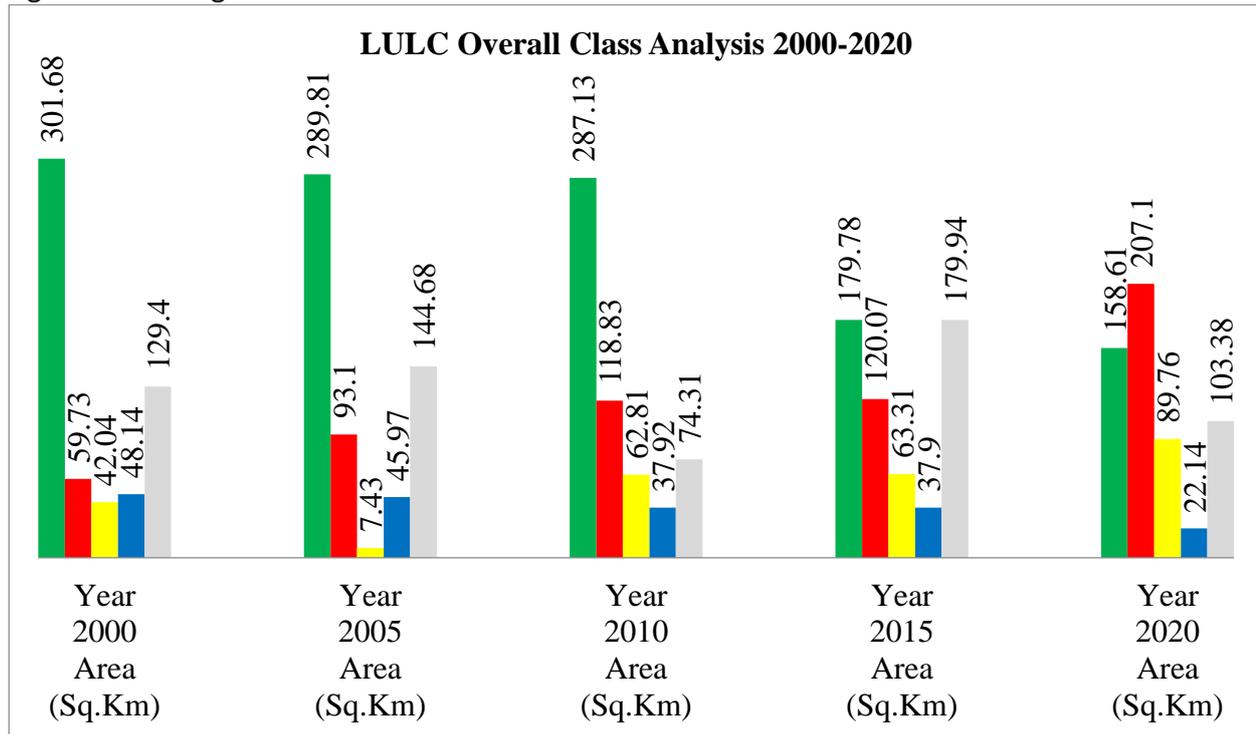
Between 2005 and 2010, urban growth accelerated, with built-up land increasing to 118.83 km² (20.5%). Vegetation cover showed a notable increase to 62.81 km² (10.8%), while barren land decreased significantly to 74.31 km², reflecting ongoing land transformation. A major shift occurred between 2010 and 2015, when mango orchards declined sharply to 179.78 km² (30.9%), and barren land increased to 179.94 km² (31%), indicating widespread orchard clearance.

By 2020, built-up land became the dominant land-use class, expanding to 207.10 km² (35.5%), representing a 246% increase compared to 2000. Mango orchards declined further to 158.61 km² (27.3%). Vegetation cover increased to 89.76 km² (15.5%), while water bodies decreased to 22.14 km² (3.8%). Barren land declined to 103.38 km², suggesting its conversion into built-up areas.

Table 1: LULC Classification and Area (2000–2020)

Year	Mango Orchards (km ²)	Built-up Area (km ²)	Vegetation (km ²)	Water Bodies (km ²)	Barren Land (km ²)
2000	301.68 (52%)	59.73 (10%)	42.04 (7%)	28.14 (8%)	129.40 (22%)
2005	289.81 (49.9%)	93.10 (16.0%)	7.43 (1.3%)	45.97 (7.9%)	144.68 (24.9%)
2010	287.13 (49.4%)	118.83 (20.5%)	62.81 (10.8%)	37.92 (6.5%)	74.31 (12.8%)
2015	179.78 (30.9%)	120.07 (20.7%)	63.31 (10.9%)	37.90 (6.5%)	179.94 (31.0%)
2020	158.61 (27.3%)	207.10 (35.5%)	89.76 (15.5%)	22.14 (3.8%)	103.38 (17.8%)

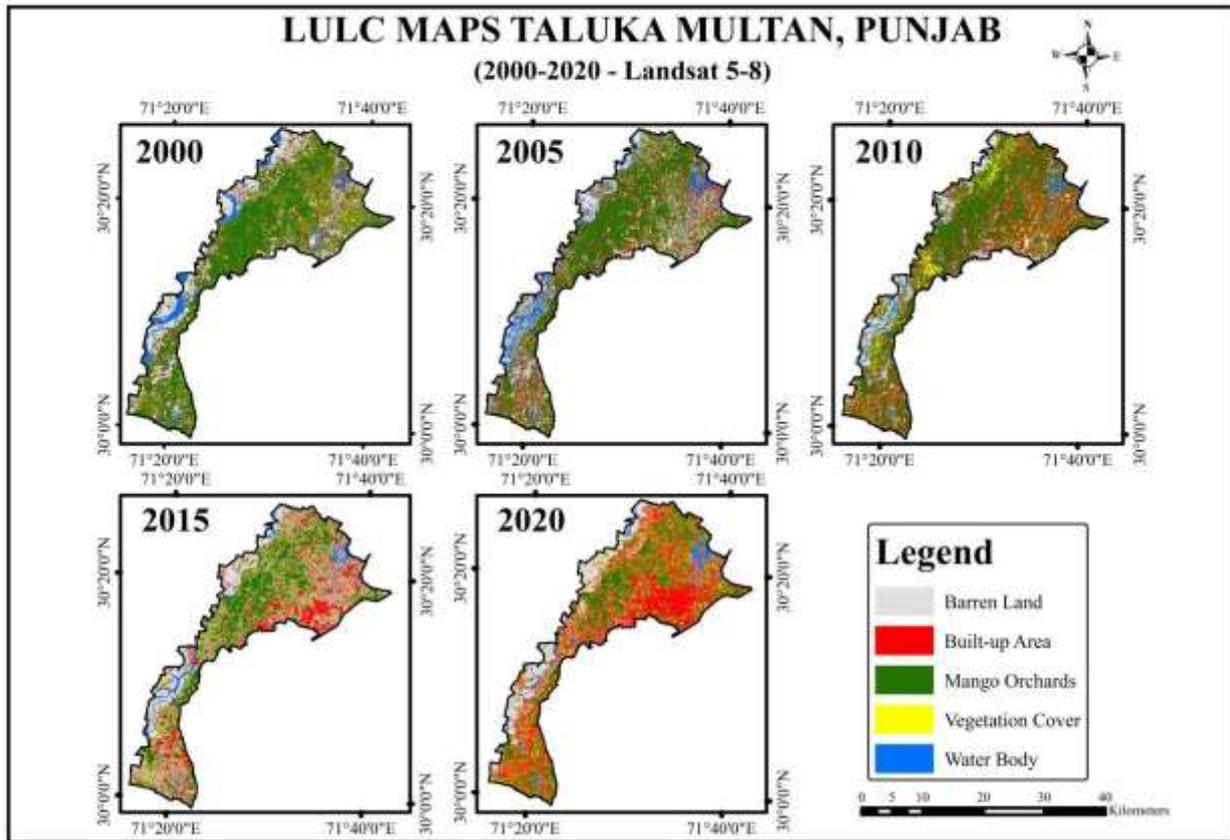
Figure 2 showing LULC Classification



4.2 Urban Expansion Pattern

Spatial analysis of built-up land indicates that urban expansion was not uniform across the tehsil. Growth was concentrated primarily along major road networks and peri-urban zones, particularly in the north-eastern and south-eastern parts of Multan Tehsil. These areas experienced extensive conversion of mango orchards and agricultural land into residential, commercial and infrastructural uses. The built-up area increased dramatically from 59.73 km² in 2000 to 207.10 km² in 2020, representing a 246% increase over two decades.

Figure 3: LULC Maps of Multan Tehsil (2000-2020)



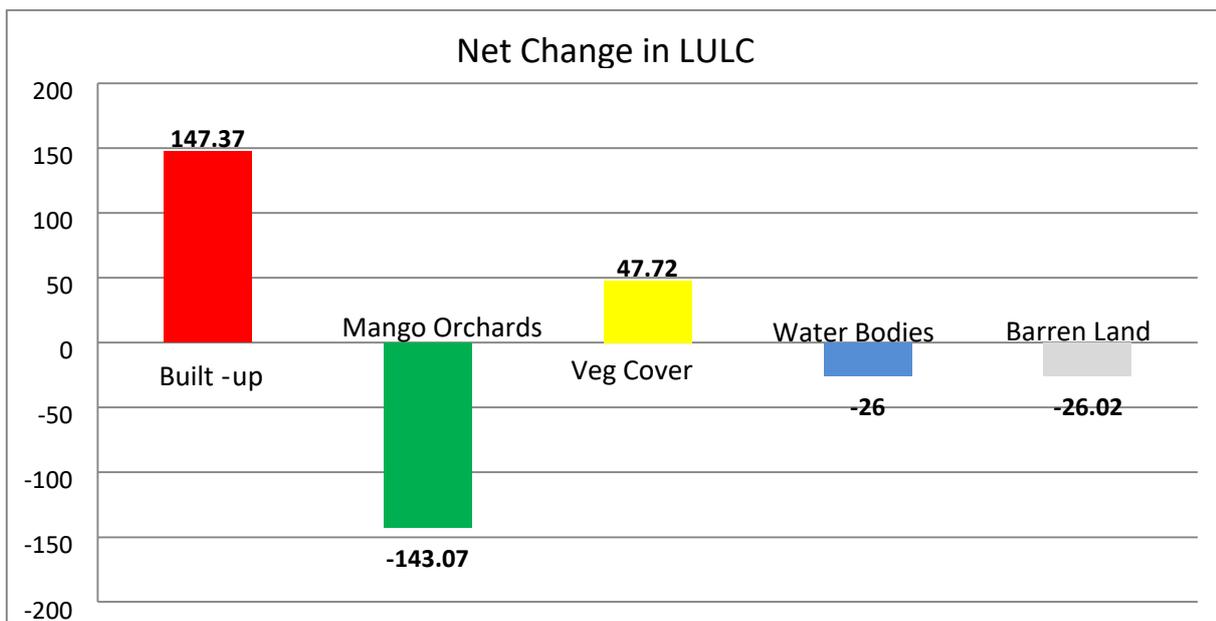
4.3 Change Detection Analysis

Change detection results show a strong inverse relationship between built-up land and mango orchards from 2000 to 2020. Built-up area increased by 147.37 km², while mango orchards declined by 143.07 km². Vegetation cover showed a net increase of 47.72 km², whereas water bodies and barren land decreased by 26.00 km² and 26.02 km², respectively. The results indicate that urban expansion was the dominant driver of LULC change in Multan Tehsil during the study period.

Table 2: Net LULC Change (2000-2020)

LULC Class	Net Change (km ²)
Built-up Area	+147.37
Mango Orchards	-143.07
Vegetation Cover	+47.72
Water Bodies	-26.00
Barren Land	-26.02

Figure 4: Net Change in LULC in Multan Tehsil (2000-2020)



4.4 Discussion

The results of this study reveal significant spatio-temporal changes in land use and land cover (LULC) in Multan Tehsil between 2000 and 2020, with urban expansion emerging as the dominant force reshaping the landscape. The discussion below focuses first on the key empirical findings and then relates them systematically to the study objectives and existing literature.

The most prominent result is the substantial increase in built-up land over the twenty-year period, accompanied by a pronounced decline in agricultural land, particularly mango orchards. In 2000, mango orchards constituted the dominant land-use class, while built-up land was limited to the urban core. By 2020, built-up land had expanded more than threefold and became the dominant class, surpassing orchards for the first time. This clear land-use reversal demonstrates a structural transition from an agriculture-oriented landscape to an urban-oriented system. This finding directly addresses the first objective of classifying and quantifying LULC changes over time and confirms that urbanization is the primary driver of land transformation in Multan Tehsil. Similar agricultural-to-urban transitions have been reported in major Pakistani cities such as Lahore and Faisalabad (Bhalli, 2012; Ghaffar, 2016), but the scale of change in Multan highlights that medium-sized cities are now experiencing equally rapid urban growth, supporting the observations of Akram et al. (2018).

Spatial analysis of the results shows that urban expansion in Multan was not uniform but followed a distinct horizontal and corridor-based pattern. Built-up growth was concentrated along major road networks and peri-urban belts, particularly in the north-eastern and southeastern directions. This spatial behavior indicates outward urban sprawl rather than compact or vertical development. These findings directly correspond to the second objective, which aimed to examine spatial patterns and directional trends of urban expansion. The observed expansion pattern is consistent with classical urban sprawl models described by Sudhira et al. (2004) and Downs (2008), who associate horizontal growth with weak land-use controls and automobile-oriented development. Comparable corridor-based expansion has also been documented in cities across South Asia and China (Du, 2014; Van, 2017), reinforcing the role of transportation infrastructure in shaping urban form.

A particularly important and new result of this study is the identification of a two-stage land conversion process. The change detection analysis shows that mango orchards were often first cleared and converted into barren land before being transformed into built-up areas in subsequent periods. This process explains the temporary increase in barren land observed between 2010 and 2015 and highlights speculative land practices in peri-urban areas. This finding directly addresses the third and fourth objectives concerning the rate and intensity of built-up area growth and dominant land-use transitions. While land speculation has been discussed conceptually in studies of peri-urbanization and land-use conflict (Magsi et al., 2017), empirical spatial evidence of this sequential conversion process is rarely documented in Pakistan. The present study therefore contributes new empirical insight into the mechanisms driving urban expansion in secondary cities.

Another key result is the strong inverse relationship between built-up land and mango orchards throughout the study period. The near-equivalent magnitude of increase in urban land and decrease in orchard area provides direct spatial evidence that urban expansion is occurring at the expense of high-value perennial agriculture rather than marginal land. This finding supports the fifth objective of identifying dominant land-use transitions associated with urban growth. Similar direct trade-offs between urban expansion and cultivated land have been reported in rapidly urbanizing regions of China (Deng et al., 2015; Zhong et al., 2022), but such relationships remain underexplored in the Pakistani context. Given the long regeneration period and economic importance of mango orchards, their loss represents a significant challenge for agricultural sustainability and local livelihoods.

The results also reveal notable environmental changes associated with urban growth. A continuous decline in water bodies was observed over the study period, while vegetation cover showed minor fluctuations and a modest increase in later years. However, this increase is largely attributable to urban greenery and mixed residential vegetation rather than agricultural recovery. These results align with global studies linking urban expansion to hydrological stress, loss of surface water, and altered ecosystem services (Furberg & Ban, 2012; UN-DESA, 2018). This finding supports the final objective of providing spatially explicit information to guide sustainable urban planning and land management.

Overall, the results demonstrate that urban expansion in Multan Tehsil has been rapid, spatially uneven, and largely unregulated. By focusing on both the magnitude and processes of land conversion, this study extends existing literature by providing empirical evidence from a medium-sized Pakistani city. The strong linkage between results, objectives, and literature underscores the urgent need for integrated land-use planning policies that limit speculative development, protect productive agricultural land, and promote more sustainable urban growth trajectories.

5. CONCLUSION

This study investigated the spatio-temporal dynamics of land use and land cover (LULC) change and urban expansion in Multan Tehsil from 2000 to 2020 using multi-temporal satellite imagery, GIS, and Remote Sensing techniques. The analysis revealed a significant transformation of the regional landscape over the past two decades, driven primarily by rapid and largely unplanned urban growth. By integrating classification and change detection methods, this study provided a detailed understanding of both the magnitude and processes of land-use change in a medium sized Pakistani city.

The results demonstrate a structural shift from an agriculture-dominated system to an urban oriented landscape. Built-up land increased dramatically, while mango orchards the dominant land-use class in 2000—declined substantially. The near-equivalent trade-off between urban expansion and orchard loss highlights that urban growth is occurring at the expense of high-value agricultural land rather than marginal areas. This trend poses challenges for agricultural sustainability, rural livelihoods, and food security, particularly given the economic and ecological importance of mango orchards.

Spatial analysis showed that urban expansion followed a predominantly horizontal, corridor based pattern, concentrated along major roads and peri-urban areas. This reflects classical urban sprawl and demonstrates the influence of accessibility and weak land-use regulation on urban form. A key novel finding is the identification of a two-stage land conversion process: agricultural land was often first cleared and temporarily converted into barren land before being developed. This sequence provides empirical evidence of speculative land practices, a phenomenon rarely documented in Pakistan.

Environmental implications of urban growth were also evident, with reductions in water bodies and limited recovery of vegetation, primarily due to urban landscaping rather than ecological restoration. These changes indicate increasing environmental stress and highlight the need for sustainable urban planning.

Overall, this study underscores the effectiveness of GIS and Remote Sensing in monitoring LULC change and provides spatially explicit information to support urban planning. The findings emphasize the urgent need for integrated land-use policies that regulate speculative development, protect productive agricultural land, and promote sustainable urban expansion in rapidly growing secondary cities like Multan.

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