

Urban Growth Dynamics and LULC Transformation in Bikaner City: A Spatio-Temporal Geo-Spatial Analysis (2000–2024)

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Abstract

The present research investigates the spatio-temporal dynamics of land use/land cover (LULC) in Bikaner district, Rajasthan, a semi-arid region experiencing rapid urban growth and shifting land-use patterns. Multi-temporal satellite datasets for the years 2000, 2014, and 2024 were processed and analyzed through supervised classification using the Maximum Likelihood Classification (MLC) algorithm in QGIS. Five major LULC categories—Built-up, Agricultural Land, Forest, Grazing/Wasteland, and Water Bodies—were delineated and quantified. The classification achieved an overall accuracy of 87.9% (2000), 89.6% (2014), and 91.2% (2024), with Kappa values above 0.85, indicating strong reliability of the results. The transition matrix revealed significant LULC conversions, particularly a sharp increase in Built-up area, which expanded from 2.8% (2000) to 6.5% (2014), and further to 11.2% (2024). This expansion occurred largely at the cost of agricultural land (declined by ~8.7%) and grazing/wasteland (declined by ~5.3%), reflecting both urban sprawl and land degradation processes. The findings underline that urbanization has emerged as the dominant driver of land cover change in Bikaner, where traditional agrarian landscapes are increasingly being replaced by built-up infrastructure and services. The orientation of urban expansion is concentrated along transport corridors, peri-urban fringes, and industrial clusters, consistent with growth patterns observed in other semi-arid cities of Rajasthan. These insights are crucial for sustainable urban planning, water resource management, and policy formulation in fragile arid and semi-arid environments, where unregulated expansion may exacerbate ecological stress and resource scarcity.

Keywords: LULC, Landsat data, QGIS, Accuracy assessment

Rationale of the Study:

The rapid growth of the global population, when contrasted with the finite land resources of the Earth, has placed unprecedented pressure on nations worldwide. With land comprising only a limited share of the Earth's surface, competition for its use has intensified—particularly under the combined forces of accelerating urbanization and shifting land use patterns. Over the last few decades, Land Use and Land Cover (LULC) studies have become a focal point of geographical and environmental research, as they provide crucial insights into the relationship between human settlements and natural systems (Lambin, Geist, & Lepers, 2003).

Among the many processes driving land transformation, urban expansion has emerged as one of the most profound. Projections indicate that within a few decades, nearly half of the global population will be concentrated in urban areas (United Nations, 2019). The most dynamic changes are evident at the urban peripheries, where unregulated growth reshapes landscapes at a rapid pace. Such expansion often occurs at the expense of productive agricultural land, threatening food security, undermining local economies, and altering ecological balances (Seto, Güneralp, & Hutyra, 2012). Consequently, analyzing the spatial and temporal dimensions of LULC change in peri-urban regions has become critical for sustainable urban planning, ecological conservation, and informed policymaking (Sudhira, Ramachandra, & Jagadish, 2004).

India, a rapidly urbanizing nation, faces these challenges acutely. In the arid state of Rajasthan, pressures are compounded by scarce water resources, fragile ecosystems, and the traditional dependence on agriculture. Studies on Indian cities have highlighted the growing extent of urban sprawl, particularly its expansion into peri-urban landscapes (Jat, Garg, & Khare, 2008). Bikaner district, located in the heart of the Thar Desert, provides a representative case of these transformations. As one of Rajasthan's major urban centers, Bikaner has witnessed

significant urban expansion over the past three decades, leading to the conversion of agricultural and grazing lands into built-up areas. Similar patterns of urban growth and land conversion have also been documented in other semi-arid cities of Rajasthan, such as Jaipur (Sharma & Mehta, 2012; Nathawat & Painuli, 2015). This trend reflects the growing demand for urban infrastructure and services, while simultaneously increasing pressure on already limited natural resources (Nag & Kudrat, 1998).

The present study explores the spatio-temporal dynamics of LULC in Bikaner district between 2000 and 2024, with specific attention to the city and its peri-urban surroundings. By analyzing multi-temporal satellite imagery, the research identifies key patterns of land transformation and quantifies the extent of agricultural and grazing land conversion into urban settlements. The study also highlights the orientation of growth, particularly along transport corridors and peri-urban fringes, where urban sprawl is most pronounced.

Ultimately, this research contributes to the broader understanding of urbanization-driven land use change in semi-arid regions, emphasizing the need for strategies that balance ecological conservation with urban development. By documenting both the magnitude and direction of change, the findings provide valuable insights for sustainable urban design, land resource management, and policy formulation in Bikaner and comparable arid environments.

Materials and Methods

Study Area

This research examines the urban and peri-urban landscapes of Bikaner city, with a particular emphasis on land use and land cover (LULC) transformations. Geographically, Bikaner is positioned at approximately 28.02° N latitude and 73.31° E longitude in the northwestern arid zone of Rajasthan, forming a prominent node of the Thar Desert's Golden Triangle. It functions as the administrative headquarters of both Bikaner district and Bikaner division, thereby serving as a regional hub of governance, trade, and culture.

The city extends over an estimated 270 km² at an elevation of about 242 m above mean sea level. According to the 2011 Census of India, Bikaner recorded a population of 644,406, marking it as one of the largest urban centers in the arid belt of Rajasthan. Historically a fortified desert town established in the late 15th century, Bikaner has evolved into a dynamic urban agglomeration, witnessing rapid growth driven by trade, agro-based industries, handicrafts, and more recently, infrastructural investments under urban development programs.

Climatically, Bikaner falls under the hot desert (BWh) category of the Köppen classification, characterized by extremes of temperature and scarce rainfall. Summers are harsh, with maximum temperatures soaring to 47–48 °C, while winters are comparatively cold, with minimum temperatures often falling to 0 °C. The region receives an average annual rainfall of about 290 mm, concentrated during the southwest monsoon (late June to September). However, rainfall distribution is erratic, with frequent droughts and water scarcity shaping the city's ecological and socio-economic conditions. These climatic challenges directly influence land use practices, making water-efficient agriculture, grazing land management, and urban water supply critical issues for the city's sustainability.

Unlike conventional urban studies that are limited to the Bikaner Municipal Corporation (BMC) boundary, the present research adopts a broader perspective by using the Notified Urban Area Limit – 2043, delineated in the Bikaner Development Authority (BDA) Master Plan. The Bikaner Master Plan 2043 draft encompasses an extensive area of 108,749 hectares, incorporating not only the core city but also 90 surrounding villages. This expanded boundary has been chosen because the urban footprint of Bikaner has extended well beyond the traditional municipal limits, with major land transformations now occurring in peri-urban and fringe zones. These outer areas are witnessing intense conversion of agricultural and grazing lands into residential, industrial, and infrastructural uses, reflecting the broader patterns of urban sprawl in arid and semi-arid regions of India.

By situating the study within this larger planning framework, the research acknowledges the realistic scale of Bikaner's urban expansion while aligning its analysis with the official urban development trajectory envisioned for 2043. This approach enables a comprehensive assessment of both past and ongoing land transformations and provides a spatially relevant basis for forecasting future urban growth and its implications for sustainable land management.

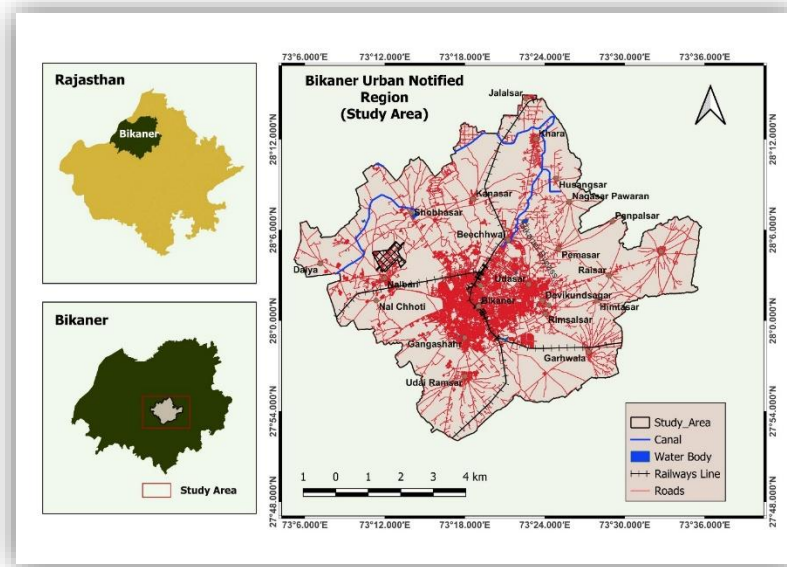


Figure 1. Location Map of Bikaner Urban Notified Area (Study Area).

Materials and Methodology

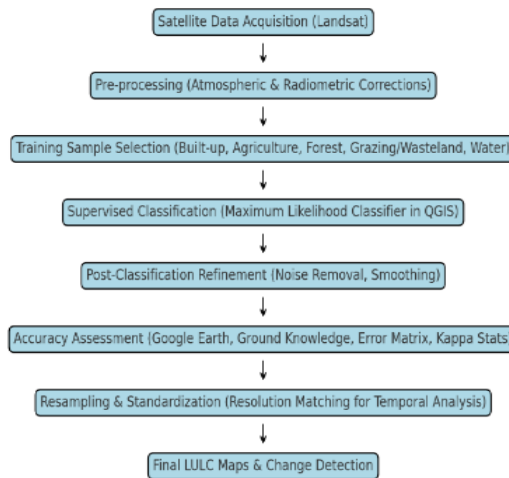
Data acquisition and image pre processing

In the context of LULC change analysis for Bikaner city, Satellite images were selected with due consideration to phenological variations, seasonal consistency, and minimal cloud cover to ensure reliable land cover classification. Landsat TM 5 data for the year 2000 and Landsat 8 OLI data for the years 2014 and 2024 were acquired from the USGS Earth Explorer portal (<https://earthexplorer.usgs.gov/>), each with a spatial resolution of 30×30 meters. These images, corresponding to path/row 149/41 and 149/40 with less than 1% cloud cover, were downloaded from the USGS Earth Explorer portal. The acquired satellite data were pre-processed using QGIS 3.40.7 software through a series of steps. First, the images were reprojected from the World Geodetic System 1984 (WGS84) to the Universal Transverse Mercator (UTM) Zone 44N. This was followed by layer stacking and mosaicking of the images. Subsequently, the study area was extracted from the mosaicked images.

Table 1. List of Landsat satellite images with their specification, used during the study

S. No.	Landsat Scene Identifier	WRS Path/Row	Sensor Identifier	Date Acquired	Image Quality	Scene Cloud Cover
1	LT05_L2SP_149041_20001005_20200906_02_T1	149/41	L5_TM	2000-10-05	9	0.00
2	LC08_L1TP_149041_20141012_20200910_02_T1	149/41	LANDSAT_8OLI_TIRS	2014-10-12	9	0.00
3	LC08_L1TP_149041_20241023_20241109_02_T1	149/41	LANDSAT_8OLI_TIRS	2024-10-23	9	0.00

Workflow for LULC Classification and Validation in QGIS



LULC Classification System Adopted for Study Area

Land Use/Land Cover Classification Framework

The choice of an appropriate land use/land cover (LULC) classification system plays a decisive role in determining the reliability and applicability of spatial data for research. When analyzing temporal changes or integrating datasets from different administrative units, it is essential to ensure consistency with established classification standards. Such harmonization not only enhances comparability across timeframes but also strengthens the accuracy of regional assessments and supports integrated urban planning across jurisdictional boundaries. In the Indian context, the National Urban Information System (NUIS), launched in March 2006 as a Mission Mode Project by the Ministry of Urban Development in collaboration with the Survey of India, introduced a nationally standardized urban land classification framework. The NUIS system was developed primarily for 1:10,000 scale mapping, employing a detailed five-tier hierarchical structure that facilitates precise categorization of urban and peri-urban landscapes using high-resolution satellite data. For the present study of Bikaner city, this national framework provides a useful reference point. However, because the available data is derived from Landsat imagery, which offers medium spatial resolution, it is not feasible to implement the complete five-level hierarchy prescribed by NUIS. To address this limitation, the study employs a simplified two-level classification scheme, designed to align with the resolution capacity of Landsat while maintaining broad compatibility with NUIS categories. This adapted approach strikes a balance between data usability at the regional scale and comparability with standardized national datasets, ensuring that the findings remain both methodologically sound and practically relevant.

Table 2. NUIS LULC Classification System Adopted for Study

Level 1 Category	Level 2 Sub-Categories (Grouped for Landsat-based classification)	Description
Built-up Area	Urban settlements- Rural settlements- Industrial/commercial area- Institutional area	Includes all man-made constructions, such as residential colonies, markets, administrative buildings, and urban/rural settlements.
Agricultural Land	Cropland (irrigated and unirrigated)- Fallow land	Cultivated fields used for agriculture including both seasonal and permanent crops.
Forest/Scrub	Forest cover- Scrubland, Forest Dept. Notified Area	Natural or semi-natural vegetation including sparse shrubs, tree cover, and degraded forest patches.
Grassland/Wasteland	Pastures- Recreational green spaces- Open barren land	Includes community parks, grazing fields, barren wasteland, and undeveloped urban open lands.
Water Bodies	Canals- Reservoirs- Lakes/Ponds	Natural and man-made water features including seasonal and perennial sources.

LULC Classification Methodology

The land use/land cover (LULC) classification for the Bikaner region was undertaken using a supervised classification approach, specifically the Maximum Likelihood Classifier (MLC) implemented in QGIS. This technique, widely regarded for its statistical robustness, assigns pixels to the most probable land cover class based on their spectral signatures and the variance-covariance structure of training data. For this study, representative training samples were carefully delineated for major land cover categories: Built-up, Agricultural Land, Forest, Grazing/Wasteland, and Water Bodies.

Post-classification accuracy was assessed through visual interpretation of high-resolution imagery from Google Earth, ensuring reliability of the classification outputs. In addition, ground knowledge of the study area, where available, was used to enhance the validation process. Accuracy assessment through error matrices and overall Kappa statistics was also incorporated, as these provide quantitative measures of classification performance and help identify potential class confusions, especially between spectrally similar categories such as grazing land and wasteland.

To facilitate subsequent transition potential modeling and change detection analyses, the classified raster outputs were further processed. Standardization of spatial resolution across all LULC layers and auxiliary spatial variables was achieved through resampling techniques in QGIS. This step was essential for ensuring compatibility in pixel-by-pixel comparisons across multiple temporal datasets, thereby improving the precision of change analysis.

The adoption of MLC, combined with multi-source validation and rigorous preprocessing, enhances the credibility of LULC maps and provides a reliable foundation for examining the dynamics of urban expansion and land cover transformation in the rapidly evolving desert city of Bikaner.

Accuracy Assessment

Accuracy assessment of the post-classified LULC maps was carried out to evaluate the performance and reliability of the classification outputs for the years 2000, 2014, and 2024 in the study area. This process is essential to determine the proportion of pixels correctly classified, misclassified, or excluded from the classification scheme (Congalton & Green, 2019). To ensure an unbiased representation of all land cover categories, a stratified random sampling technique was employed for the selection of reference points. These reference datasets were compiled from multiple sources, including high-resolution satellite imagery, Google Earth, and field-based ground truthing wherever available.

The accuracy evaluation was performed using a confusion matrix, from which overall accuracy and Kappa statistics were derived. The results indicate that the classifications for 2000 and 2014 achieved overall accuracies of 82.10% and 82.78%, with corresponding Kappa values of 0.6943 and 0.7195, respectively, reflecting substantial agreement between classified categories and reference data. In contrast, the classification for 2024 yielded a markedly higher overall accuracy of 88.88% and a Kappa value of 0.8162, which falls within the range of “almost perfect agreement” according to the interpretation guidelines of Congalton and Green (2009). This improvement highlights the enhanced reliability of the 2024 classification compared to earlier years, possibly due to better data availability, improved image quality, and refined classification techniques.

Overall, all three datasets demonstrate acceptable levels of classification accuracy for medium-resolution satellite data, validating their suitability for assessing spatio-temporal dynamics and urban expansion in Bikaner over the past three decades.

Table 3: Accuracy results of different study time periods.

Year	Overall Accuracy (%)	Kappa Statistic
2000	82.10	0.6943
2014	82.78	0.7195
2024	88.88	0.8162

The results indicate that the LULC classifications for 2000 and 2014 achieved accuracies above 82% with Kappa values within the “substantial agreement” range (0.61–0.80), validating their reliability. The classification for 2024 demonstrates the highest performance, with an overall accuracy of 88.88% and a Kappa value of 0.8162, which corresponds to the “almost perfect agreement” category. This suggests that the 2024 classification is highly

reliable, likely due to advancements in satellite imagery quality, refined classification methods, and improved data availability. Together, these results confirm that the LULC maps provide a robust foundation for analyzing spatio-temporal land cover dynamics and urban growth trends in Bikaner.

Results And Discussion

LULC classification and change analysis of land use/cover from 2000 to 2024

The Land Use/Land Cover (LULC) classification of the Bikaner urbanizable area is distributed across five primary categories: Built-up area, Agricultural land, Forest, Grazing/Wasteland, and Water bodies. The total geographical area under analysis remains nearly constant across all three years, approximately 1075 square kilometers.

In the year 2000, Agricultural land occupied the largest share with 605.52 sq. km, covering 56.33% of the total area. This was followed by Grazing/Wasteland at 285.61 sq. km (26.57%), Forest areas covering 126.54 sq. km (11.77%) (Note: - There is no reserved forest area in Bikaner district only protected and Un -classed forest area is in legal status according to Forest department of Rajasthan statistics 2021 so considering this in study area the area of forest is demarcated from Forest department Statistics), Built-up areas at 56.07 sq. km (5.22%), and Water bodies accounting for the smallest area at 1.28 sq. km (0.12%).By 2014, the land cover distribution shows Agricultural land still as the dominant class with 558.29 sq. km (51.93%), followed by Grazing/Wasteland at 324.93 sq. km (30.23%), Forest at 92.04 sq. km (8.56%), Built-up area at 97.96 sq. km (9.11%), and Water bodies at 1.80 sq. km (0.17%).

In 2024, Agricultural land continues to cover the largest area, amounting to 601.47 sq. km (55.95%). Grazing/Wasteland occupies 273.97 sq. km (25.48%), Forest area stands at 68.21 sq. km (6.34%), while Built-up areas have reached 127.7 sq. km (11.88%). Water bodies cover 3.68 sq. km (0.34%) of the total area.

Table 4. LULC Classes Distribution over time from 2000 ,2014 and 2024

LULC Classes	2000		2014		2024	
	Area in Sq km	% of Area Covered	Area in Sq km	% of Area Covered	Area in Sq km	% of Area Covered
1 - Built UP	56.07	5.22	97.96	9.11	127.7	11.88
2 - Agricultural Land	605.52	56.33	558.29	51.93	601.47	55.95
3 - Forest	126.54	11.77	92.04	8.56	68.21	6.34
4 - Grazing/Wasteland	285.61	26.57	324.93	30.23	273.97	25.48
5 - Water Bodies	1.28	0.12	1.8	0.17	3.68	0.34
Total	1075.02	100.00	1075.02	100.00	1075.02	100.00

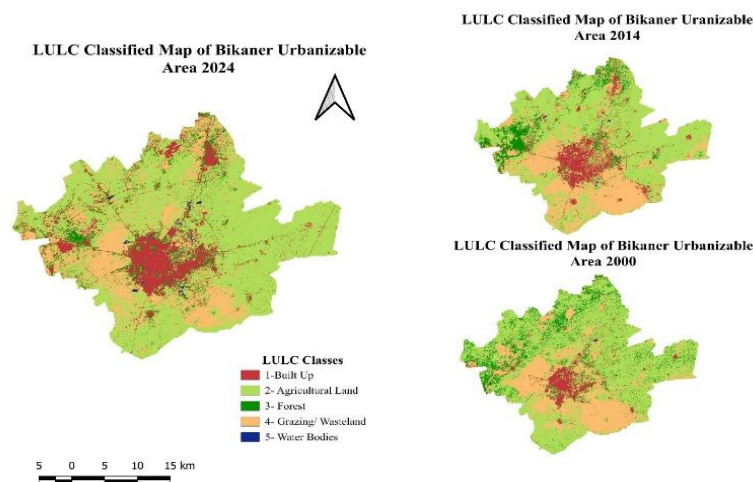


Figure 5. Classified LULC map of Bikaner Urbanizable area showing spatial distribution of various LULC classes in 2000,2014 &2024

Spatio-temporal changes in LULC classes

The analysis of Land Use/Land Cover (LULC) changes in Bikaner’s urban area over the past three decades highlights a steady expansion of the built-up area, reflecting the broader trend of increasing urbanization worldwide.

In 2000, agricultural land occupied the largest share of the urban landscape, followed by grazing or non-cultivable wasteland, forested areas, built-up land, and water bodies. By 2014, agricultural land had declined by approximately 47.23 square kilometers, while built-up areas, grazing land, and wastelands showed moderate growth.

From 2014 to 2024, agricultural land surprisingly showed the highest increase, likely driven by the rising number of tube wells in peripheral areas. Meanwhile, grazing and wasteland areas continued to shrink. The growth rate of built-up land during this period was 2.7%, slightly lower than the 3.9% increase recorded in the previous decade.

In forest LULC class is shows decreasing trends in three decades in study area, due to change in urban notified limit overall there is continuous increase rate in forest cover is visible.

Water bodies expanded from 1.28 square kilometers in 2000 to 1.80 square kilometers in 2014, primarily due to the construction of the Shobhasar reservoir. Between 2014 and 2024, further expansion was observed, attributed to new water storage tanks construction for fulfil the demand of increasing urban population, wastewater accumulation in the Karni Industrial Area and sewage collection near Vallabh Garden and various other places in city.

Overall, the LULC dynamics of Bikaner reflect shifting land priorities influenced by urban expansion, changing agricultural practices, and infrastructure development.

Table 5. Spatio-Temporal changes in LULC classes in 2000,2014 &2024

LULC Classes	2000-2014		2014-2024	
	Change	Change in %	Change	Change in %
1 - Built UP	41.89 sq. km.	3.90	29.75 sq. km.	2.77
2 - Agricultural Land	-47.23 sq. km.	-4.39	43.18 sq. km.	4.02
3 - Forest	-34.50 sq. km.	-3.21	-23.83 sq. km.	-2.22
4 - Grazing/ Wasteland	39.32 sq. km.	3.66	-50.96 sq. km.	-4.74
5 - Water Bodies	0.52 sq. km.	0.05	1.87 sq. km.	0.17

The transition matrix shows the probability values of land use/land cover (LULC) changes from 2000 to 2014 and 2014 to 2024. Each row represents the initial (2000 & 2014) LULC class, while each column indicates the final (2014 & 2024) LULC class. The values are probabilities (ranging from 0 to 1) of transition between the two time points. Here is the analysis of inter LULC class change during last two decades in Bikaner urbanizable area.

Table 6.From to Change 2000-2014

2000	2014						
	LULC Classes	Built UP	Agricultural Land	Forest	Grazing/ Wasteland	Water Bodies	Total
Built UP	0.72	0.17	0.03	0.07	0.00	0.00	1
Agricultural Land	0.05	0.69	0.06	0.19	0.00	0.00	1
Forest	0.05	0.56	0.19	0.20	0.00	0.00	1
Grazing/ Wasteland	0.07	0.21	0.10	0.62	0.00	0.00	1
Water Bodies	0.22	0.27	0.00	0.05	0.46	0.00	1
Total	1.12	1.90	0.38	1.14	0.47	0.00	5

Between 2000 and 2014, Land Use/Land Cover transitions in Bikaner reveal dynamic changes across all classes. About 72% of the built-up area remained unchanged, while significant expansion occurred through conversions from agricultural land (17%), grazing/wasteland (7%), and forest (3%), indicating urban sprawl. Agricultural land showed 69% stability, but experienced notable conversions into grazing/wasteland (19%), forest (6%), and built-up areas (5%), reflecting both land degradation and urban pressure. Forest areas were highly affected, with only 19% retention; the majority was transformed into agricultural land (56%) and grazing areas (20%), pointing to deforestation. Grazing/wasteland maintained 62% of its area, while the rest transitioned into agricultural (21%),

forest (10%), and built-up land (7%), indicating mixed land-use pressures. Water bodies were the most vulnerable, with only 46% remaining intact, while the rest was lost to agricultural use (27%), built-up expansion (22%), and wasteland (5%), highlighting the encroachment and depletion of natural water resources.

Between 2014 and 2024, the Land Use/Land Cover (LULC) transition matrix for Bikaner highlights continued land transformation across various categories. About 65% of the built-up area remained stable, while it expanded through conversions from agricultural land (16%), forest (10%), and grazing/wasteland (8%), indicating ongoing urban development. Agricultural land showed 76% retention, yet experienced changes to grazing/wasteland (14%), built-up area (5%), and forest (4%), suggesting moderate pressure from both land degradation and urban influence. Forest areas maintained only 19% of their 2014 extent, with substantial conversion into grazing land (43%) and agriculture (28%), underlining a continuing trend of deforestation. Grazing/wasteland showed 45% stability but underwent significant transformation into agricultural land (41%), as well as minor changes to built-up (8%) and forest (6%) categories, reflecting its flexible nature in land-use shifts. Water bodies displayed 70% persistence; however, 19% was converted into built-up areas, 7% to agriculture, and 4% to forest, pointing to encroachment and functional repurposing of aquatic zones.

Table 7. From to Change 2014-2024

2014	2024					
	LULC Classes	Built UP	Agricultural Land	Forest	Grazing/Wasteland	Water Bodies
Built UP	0.65	0.16	0.10	0.08	0.00	1
Agricultural Land	0.05	0.76	0.04	0.14	0.00	1
Forest	0.10	0.28	0.19	0.43	0.00	1
Grazing/ Wasteland	0.08	0.41	0.06	0.45	0.00	1
Water Bodies	0.19	0.07	0.04	0.00	0.70	1
Total	1.08	1.68	0.43	1.10	0.71	5

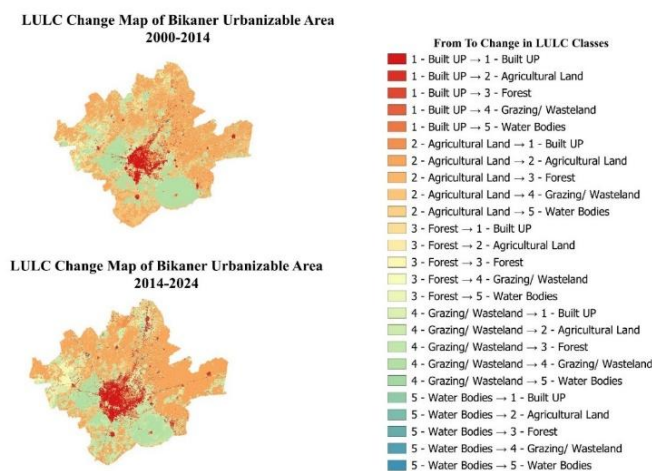


Figure 6. Maps represent change in LULC from 2000-2014 & 2014-2024

LULC Transition Analysis and Potential Modeling for Future

Predicated and projected LULC classification

After achieving satisfactory model validation results, LULC projections were carried out for the years 2034 and 2044. The prediction for 2034 was generated using the temporal LULC datasets of 2014 and 2024, incorporating relevant spatial variables and the corresponding transition probability matrix. The model yielded a Kappa coefficient of 0.99, indicating a perfect level of agreement. Subsequently, the LULC prediction for 2044 was performed using the same temporal inputs (2014 and 2024), supported by updated explanatory variables and transition probability values, resulting in a Kappa value of 0.96

Land Use/Land Cover (LULC) statistics for the years 2024, 2034, and 2044, detailing the spatial distribution (in square kilometers) across five major LULC classes: Built-Up Area, Agricultural Land, Forest, Grazing/Wasteland, and Water Bodies. The total geographical area for all three years remains relatively constant, around 1075 sq. km.

The Built-Up Area exhibits a significant increase from 127.7 sq. km in 2024 to 152.4 sq. km in 2034, reflecting a trend of rapid urban expansion. Interestingly, this value remains unchanged in 2044, suggesting a stabilization or saturation point in urban growth. Agricultural Land demonstrates a gradual decline over the same period, reducing from 601.47 sq. km in 2024 to 598.06 sq. km in 2034, and further to 576.8 sq. km in 2044. This indicates a steady conversion of agricultural zones, possibly into built-up or other land use categories.

The Forest category shows a sharp decline from 68.21 sq. km in 2024 to 46.97 sq. km in 2034, followed by a notable recovery to 68.23 sq. km in 2044. This trend suggests possible degradation due to land pressure in the intermediate period, with subsequent regeneration efforts or afforestation measures contributing to recovery. Grazing/Wasteland remains relatively stable, increasing slightly from 273.97 sq. km in 2024 to 276.4 sq. km in 2034, and then decreasing marginally to 274.76 sq. km in 2044, indicating minimal fluctuations in this category.

Lastly, Water Bodies decline significantly from 3.68 sq. km in 2024 to 1.26 sq. km in 2034, with a slight increase to 2.9 sq. km by 2044. These variations may reflect changing climatic conditions, groundwater table dynamics, or anthropogenic impacts on surface water resources.

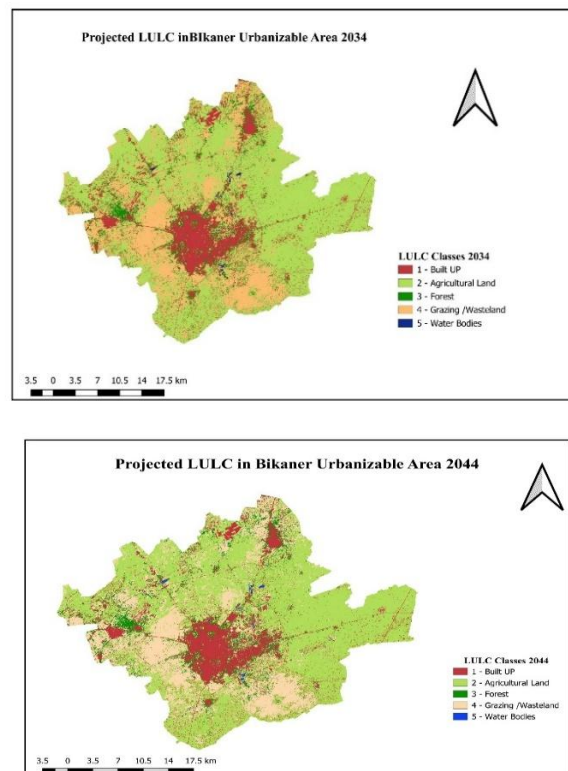


Figure 7. Projected LULC in 2034 and 2044 respectively

Prediction of Change

Land Use/Land Cover (LULC) of 2024 was taken as the base year to compute and forecast spatial and proportionate change in the dominant LULC classes for 2034 and 2044 over the study area of approximately 1075 sq. km. Future change under five dominant land types—Built-Up Area, Agricultural Land, Forest, Grazing/Wasteland, and Water Bodies—were assessed to identify land transformation trend direction and magnitude.

In comparison to the 2024 base, the Built-Up Area is observed to increase from 127.73 sq. km (at 11.88% increase) in 2024 to 152.40 sq. km (at 14.18% increase) in 2034, and no additional increase is projected by 2044, when it

remains 152.40 sq. km (at 14.18% increase). This is a reflection of an ongoing urban expansion followed by a stabilization or regulation phase. Agricultural Land, however, reflects a downward trend in comparison to the 2024 base, from 601.47 sq. km (at 55.95% increase) to 598.06 sq. km (at 55.63% increase) in 2034 and further to 576.80 sq. km (at 53.65% increase) in 2044. This persistent downtrend is reportedly a reflection of ongoing land conversion due to increased urban pressure.

The Forest class exhibits a dramatic fluctuation from 2024 levels. It plummets dramatically from 68.23 sq. km (6.35%) in 2024 to 46.97 sq. km (4.37%) in 2034 only to return to 68.23 sq. km (6.35%) in 2044. This decline and recovery are seen to reflect a temporary decade of deforestation or land degradation, perhaps reversed by afforestation effort or increased conservation policy in the following decade. The Grazing/Wasteland classes are comparatively stable throughout the forecast period, fluctuating only slightly from 273.98 sq. km (25.48%) in 2024 to 276.40 sq. km (25.71%) in 2034 and 274.76 sq. km (25.56%) in 2044, indicating that this class is less affected by anthropogenic disturbance than others.

Water Bodies, relative to 2024, have a significant drop in 2034 from 3.68 sq. km (0.34%) to 1.26 sq. km (0.12%), and a moderate rise to 2.90 sq. km (0.27%) in 2044. All of these could be attributed to seasonality, declining water supply, or human intervention in the hydrological system.

Table 8. Area change Matrix From 2024 to 2034.

LULC Classes	Area in Sq km 2024	Area in Sq km 2034	Change	% of Area Covered	% of Area Covered	Change in %
Built Up	127.73	152.40	24.67	11.88	14.18	2.29
Agricultural Land	601.47	598.06	-3.41	55.95	55.63	-0.32
Forest	68.23	46.97	-21.26	6.35	4.37	-1.98
Grazing /Wasteland	273.98	276.40	2.42	25.48	25.71	0.22
Water Bodies	3.68	1.26	-2.42	0.34	0.12	-0.22

Table 9. Area change Matrix from 2034 to 2044

LULC Classes	Area in Sq km 2034	Area in Sq km 2044	Change	% of Area Covered	% of Area Covered	Change in %
Built UP	152.40	152.40	0.00	14.18	14.18	0.00
Agricultural Land	598.06	576.80	-21.26	55.63	53.65	-1.98
Forest	46.97	68.23	21.26	4.37	6.35	1.98
Grazing /Wasteland	276.40	274.76	-1.64	25.71	25.56	-0.15
Water Bodies	1.26	2.90	1.64	0.12	0.27	0.15

Discussions

This research analyzed the Land Use/Land Cover(LULC) processes of Bikaner district with satellite classified data and model-based projections for base years 2000 2014 and 2024, 2034, and 2044. Five major land categories were recognized: Built-Up Area, Agricultural Land, Forest, Grazing/Wasteland, and Water Bodies. Based on the 2024 LULC dataset as the base, spatial change and future directions were evaluated by using transition probability modeling, which reflected the pressures and changes acting in the landscape of the area.

The trend analysis reveals a consistent and clear increase in urbanized land from 2024 to 2034, from 127.73 sq. km (11.88%) to 152.40 sq. km (14.18%). Surprisingly, this increase stabilizes at 2044, possibly due to urban saturation or regulation of spatial control. Agricultural land, on the other hand, continues to decline throughout the study period, indicating urban encroachment and land-use change. Grazing/Wasteland remains relatively stable, indicating minimal land-use changes in these Water bodies, on the other hand, show unusual fluctuations, with a precipitous decline in 2034 followed by some recovery at 2044, indicating environmental stressors and pressures of sustainable water management. In general, the Land Use Land Cover (LULC) trend of Bikaner district reflects the broader pattern of urbanization and agricultural decline commonly observed across India’s arid and semi-arid regions. These findings highlight the urgent need for a balanced regional development policy that simultaneously promotes ecological sustainability,

infrastructure growth, and economic development. Key strategies should include integrated land use planning, effective urban management, conservation of natural resources, and the implementation of climate-resilient policies to ensure long-term sustainability of Bikaner's landscape.

Ultimately, this research reveals a dynamic shift in the region's land use patterns—marked by increasing urbanization at the cost of agricultural and natural cover areas—emphasizing the critical need for robust environmental management and forward-looking sustainable planning.

Software Used

QGIS 3.40.7

Websites for Study Material

- <https://earthexplorer.usgs.gov/>
- <https://www.surveyofindia.gov.in/>
- <https://forest.rajasthan.gov.in/>
- <https://lsg.rajasthan.gov.in/>
- <https://earth.google.com/>
- <https://www.wikipedia.org/>

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