SPATIO-TEMPORAL ANALYSIS OF BUILT-UP AREA EXPANSION IN MATSYA INDUSTRIAL AREA (2001–2024) USING GEOSPATIAL TECHNIQUES

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ABSTRACT

The rapid expansion of built-up areas in industrial regions has profound implications for urban sustainability and land-use planning. The study assesses the spatio-temporal growth of built-up land in the Matsya Industrial Area (MIA), Alwar, India from 2001 to 2024 using geospatial techniques. The Normalized Difference Built-up Index (NDBI) and Modified Normalized Difference Water Index (MNDWI) have been applied to Landsat 5 (2001) and Landsat 8 (2024) imageries for November month to extract built-up and non-built-up areas. The analysis has been conducted using Google Earth Engine (GEE), an advanced cloud-based geospatial platform. Built-up areas include residential, commercial, industrial and roads, while non-built-up areas comprise agriculture, vegetation, and barren areas. The results indicate a significant increase in built-up areas due to rapid industrialization and urban expansion. In 2001, built-up land covered 1.18 sq. km, constituting 4.47% of the total study area (26.35 sq. km). By 2024, the built-up area expanded to 9.90 sq. km, accounting for 37.57% of the total area. This substantial growth highlights the impact of industrialization on land-use patterns in the area.

Keywords: NDBI, MNDWI, Built-up Change, Remote Sensing, Matsya Industrial Area and Alwar.

1.INTRODUCTION

In terms of land use planning, built-up area refers to the portion of land that is covered by buildings and other structures, including residential, commercial, industrial, and institutional developments. It excludes open spaces like parks, agricultural land, forests, and water bodies. Urban land cover has the tendency to change drastically. Rapid changes have been happening in terms of land use/ land cover activities. The built-up usage of land has increased over the last few decades.

It has been the case even in area specifically defined for industrial activities. The industrial area of Alwar district, Matsya Industrial Area (MIA) has seen varied type of land use activities. The area has commercial and residential land cover, agricultural land use as well as land under forest. As pointed out earlier, the land under commercial built-up area has increased drastically over the period of time. There is a considerable increase in built-up area consisting of industries of various types. This change has been recorded with the help of remote sensing imagery.

In the current study, the Normalised Difference Built-up Index (NDBI) method has been used to assess the change in built-up area in MIA region. The NDBI method helps differentiate built-up regions from natural land covers like vegetation and water bodies. The NDBI uses building materials' distinctive reflectance qualities to identify built-up regions, making it more effective than vegetation and soil (Q. Zhang,2011). Built-up growth may be detected more quickly and effectively when NDBI is used in land change analysis. Enhancing the precision of land use categorisation can be achieved by combining NDBI with other indices (H. XU, 2007). In tropical areas that regularly see fast growth, the NDBI approach is quite successful in detecting changes in built-up land. It is also inexpensive yet reliable. The Modified normalized difference water index (MNDWI) is used to reduces noise from built-up areas and detect surface water in vegetation and built-up areas (H. XU,2008). Google Earth Engine (GEE) is a cloud based geospatial analysis tool. This tool used for visualization and analysis of satellite imagery and geospatial datasets (Sidhu et al.,2018). Earth engine gives an assortment of geospatial analysis features such as trend analysis, change detection and land cover classification. The main objective of this present study is as to identify the growth in built-up area in MIA from 2001 to 2024.

2. STUDY AREA

Located in the north-eastern part of Rajasthan, the Matsya Industrial area lies between 27°29´ N to 27°33´ N latitude and 76°40´ E to 76°43´ E longitude (figure 1). It is a well-known industrial hub. The largest industrial zone of the district is Matsya Industrial Area (MIA), spanning across approximately 2340 acres to the south-east of Alwar city and housing around 545 industries (Factsheet of industrial emissions in Alwar). MIA mainly comprises of industries such as mineral grinding, chemical based and food processing. The region includes residential, agriculture and forest land. The area has undergone rapid change in land-use activities over the last 10 to 20 years. A large number of industrial units sprung up and agricultural area has shrunken.
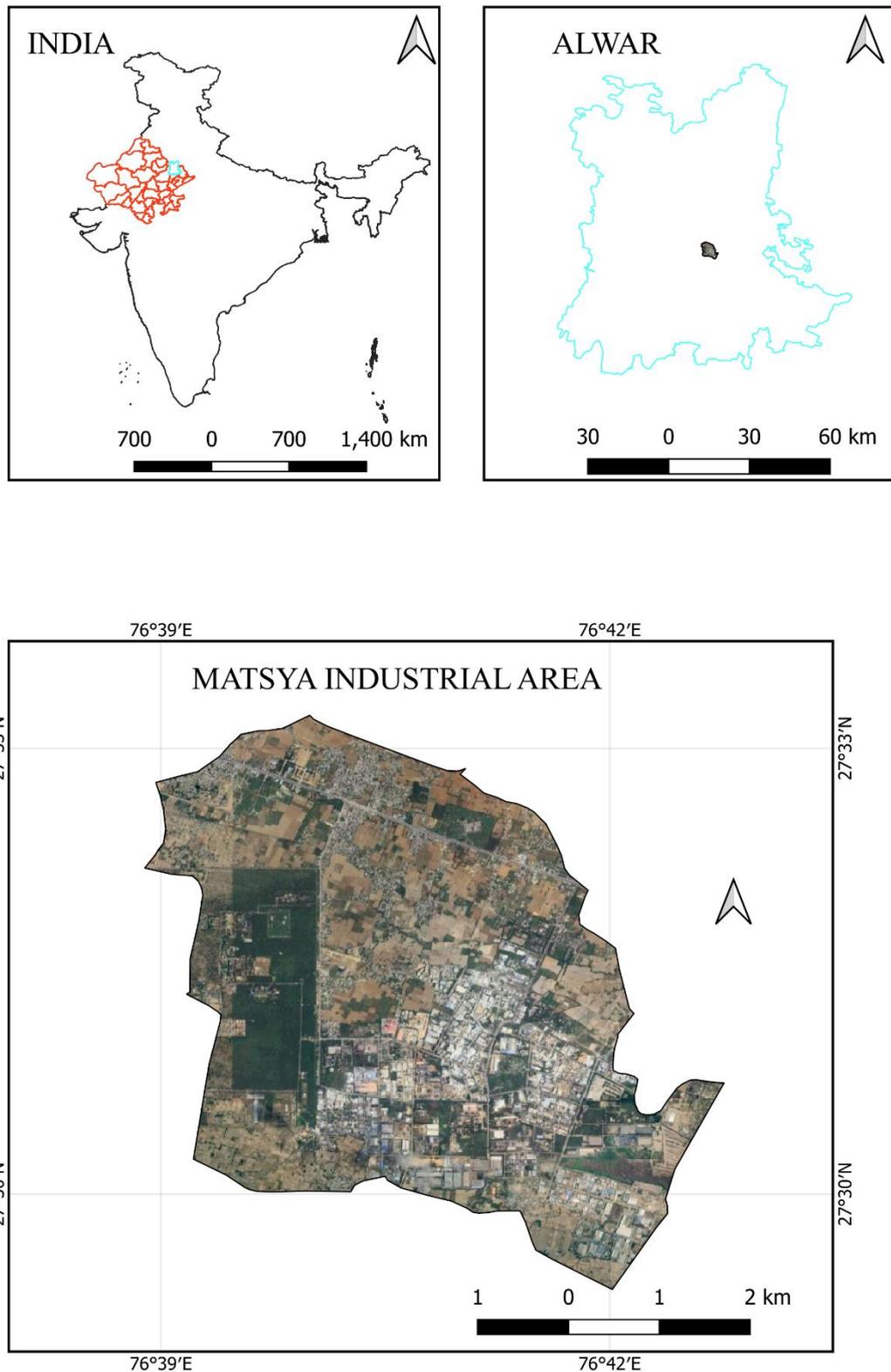
Figure 1: The Location map of Matsya Industrial area (source: Google Earth image)

The region has mostly flat topography, making it suitable for industrial development. Soil is generally sandy to loamy, which influences local agriculture and development of industries. Generally, the region is characterised by rocky terrain and semi-arid climate. The groundwater level is low; hence water availability is a problem. Agriculture mostly relies on seasonal rainfall. The region has deposits of limestone, quartz and feldspar that support industries like mineral grinding and ceramics (IPS, 2023-24). The nearby seasonal river

is Sahibi river. The region is witnessing high level of air and water pollution due to growing number of industries. It is well-connected by NH 48 and NH 248A.

Table 1: Industrial Area in MIA

S.N.	Name of Industrial Area	Land Acquired
1	M.I.A ALWAR	1804.32
2	M.I.A(Extn.) ALWAR	207.52
3	AGRO FOOD PARK M.I.A.	192.47
4	M.I.A. SOUTHEAST ZONE	51.75
5	M.I.A. SOUTHEAST ZONE (Extn)	84.58
	TOTAL	2340.64

Source: IPS Report (2023-2024), DIC, Alwar

Table 1 shows that industrial area with land acquired in Matsya industrial region.

3. METHODOLOGY

This research utilizes remote sensing and GIS-based techniques to evaluate Built-up sprawl and temporal variations in water bodies using Normalized Difference Built-up Index (NDBI) and Modified Normalized Difference Water Index (MNDWI). Satellite data from Landsat 5 TM (November 2001) and Landsat 8 OLI (November 2024) are utilized in this research. Data processing and analysis were conducted using Google Earth Engine (GEE) and QGIS for spatial data handling efficient computation and space visualization. Figure 2 show flowchart of built change process.
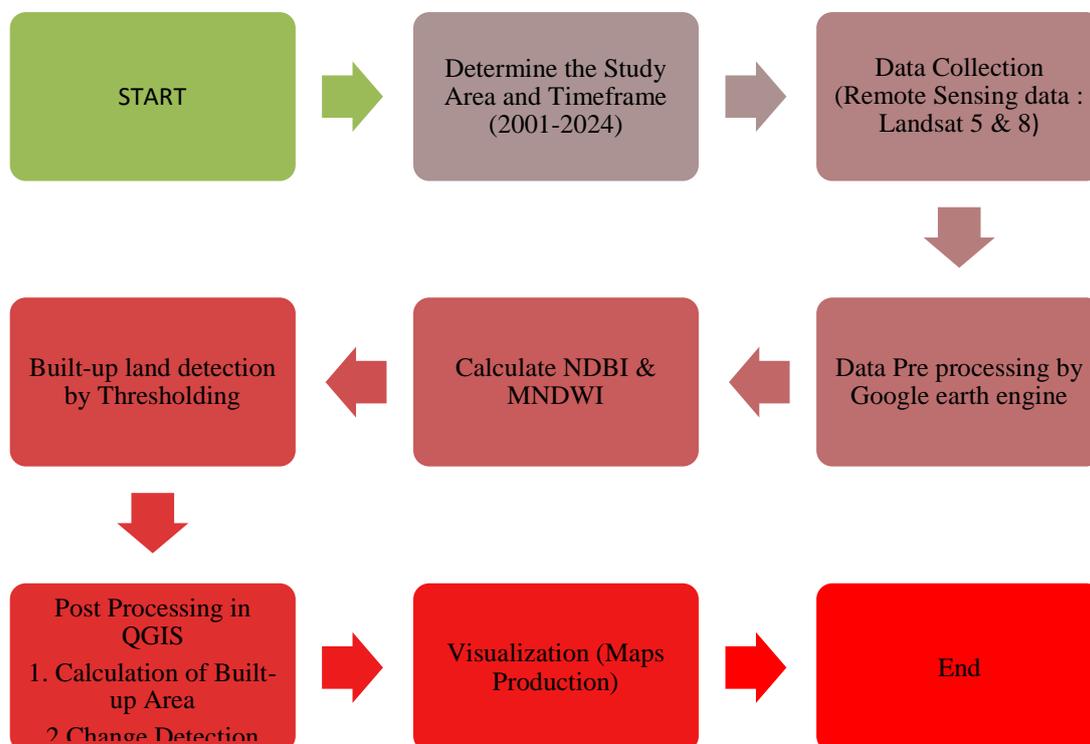

Figure 2: The flowchart of how NDBI work in the Research Area

3.1 Data Acquisition

- Satellite images were acquired from the United States Geological Survey (USGS). The Atmospherically corrected datasets were used and Level-2 surface reflectance (SR) products with a cloud cover percentage below 20% to minimize atmospheric distortions. A cloud mask was applied to eliminate residual cloud cover. Table 2 shows Landsat dataset.

Table 2 : Landsat Datasets acquired for NDBI & MNDWI Analysis

Landsat	Acquisition Date	Sensor	Spatial Resolution	NDBI & MNDWI Band
5	Nov. 2001	Thematic Mapper	30m	B4 (NIR), B5 (SWIR)
8	Nov. 2024	Operational land imager	30m	B3 (GREEN), B5(NIR), B6 (SWIR)

3.2 Index Computation

The following formulas were employed to compute the indices:

- **Normalized Difference Built-up Index (NDBI):**

$NDBI = (SWIR - NIR)/(SWIR + NIR)$ ……...   Eq.   (1)

Where: Shortwave Infrared (SWIR) and Near-Infrared (NIR) bands have been obtained from Landsat data. NDBI value range from -1 to +1. Built-up places have greater NDBI values and lesser values shows the non built-up areas (Yasin et al.,2021).

- **Modified Normalized Difference Water Index (MNDWI):**

$MNDWI = (GREEN - SWIR1) / (GREEN + SWIR1)$ ………Eq. (2)

Where: Landsat data were processed using Green and SWIR bands. MNDWI range from -1 to +1. Positive values indicate water body presence (Prasomsup et al., 2020).

3.3 Threshold-Based Classification for Built-up

Threshold values were utilized to separate built-up and water bodies on the basis of index values:

For 2001 (Landsat 5 TM)

 Buil-up areas: $NDBI > -0.1$ & $MNDWI > -0.24$ ……. Eq. (3)

For 2024 (Landsat 8 OLI)

 Built-up areas: $NDBI > -0.9$ & $MNDWI > -0.34$ ……..Eq. (4)

3.4 Spatial Analysis in QGIS

The classified NDBI and MNDWI maps were subsequently extracted from GEE and processed in QGIS. Change detection was carried out to assess Built-up expansion and water body alterations. The final results were depicted in classified maps and comparative time series charts.

3.5 Change Detection and Visualization

Overlapping 2001 and 2024 classification outputs in QGIS allowed for examination of built-up area expansion and water body shrinkage. Spatial changes were analysed for patterns using difference maps, area statistics, and graphs.

4. RESULTS AND DISCUSSION

Built-up area expansion from 2001 to 2024 using NDBI and MNDWI indices demonstrates extensive urbanisation in Alwar, Rajasthan. Categorisation between built-up and non-built-up land using Landsat 5 TM (2001) and Landsat 8 OLI (2024) imagery indicates a significant rise in industrial, residential, and commercial land use.

Figure 3 (a) shows that NDBI classification in 2001 revealed that built-up areas, highlighted in red, accounted for only 1.18 square km (4.47%) of the total area being studied (26.35 square km). Industrial land use, residential areas, and commercial buildings comprised most of the built-up areas, and 25.17 square km was taken up by barren land, agricultural fields, and vegetative cover, highlighted in white in the map.
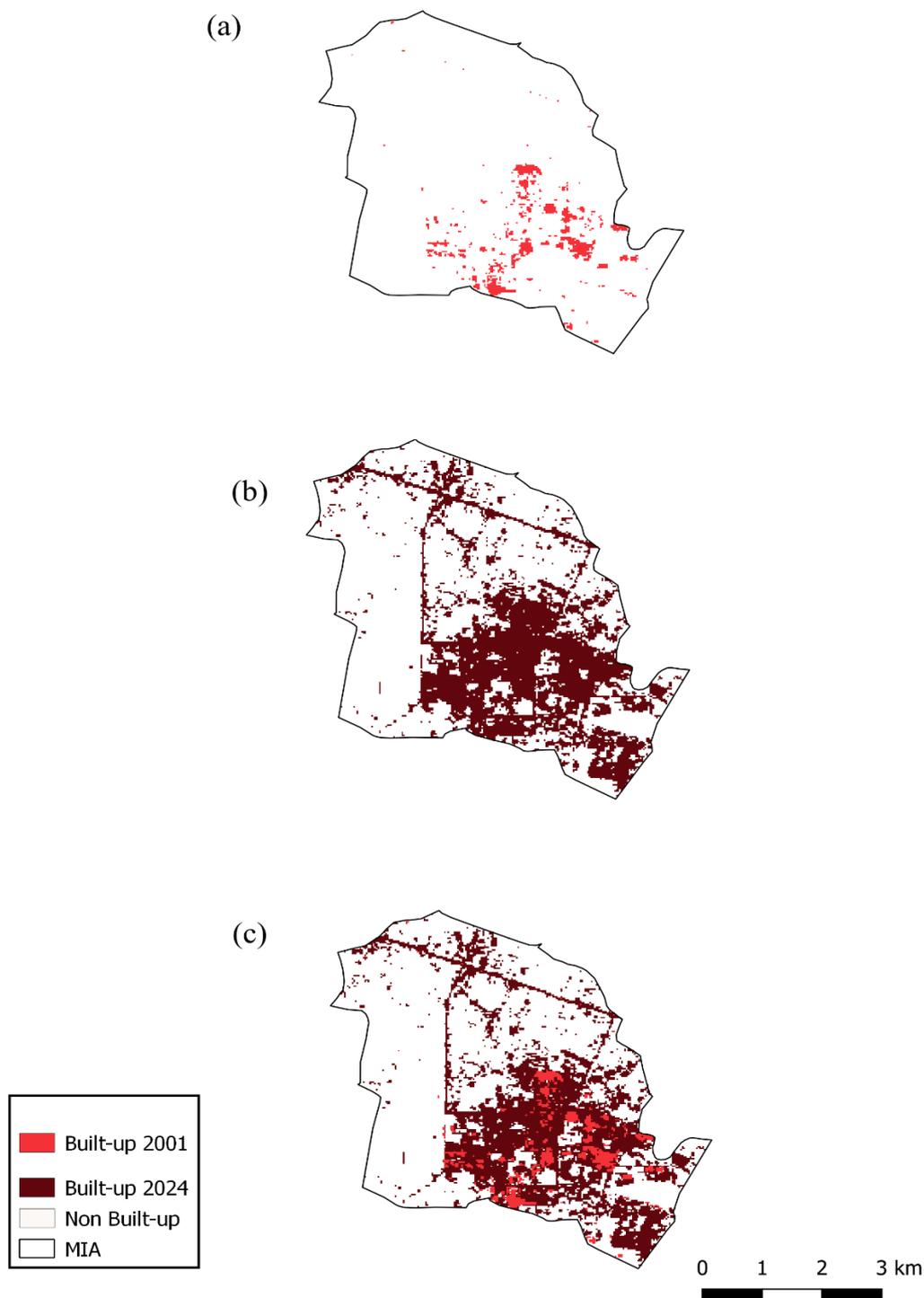

Figure 3: Map of built-up and non built-up of Matsya Industrial Area (a) 2001 (b)2024 (c) Change Map (2001-2024)

Figure 3 (b) shows Built-up land, brown in colour in 2024, rose to 9.90 square km (37.57%), lowering the Non built area to 16.45 square km. figure 3 (c) shows 8.72 square km (33.10%) rise in Built-up land in 23 years.
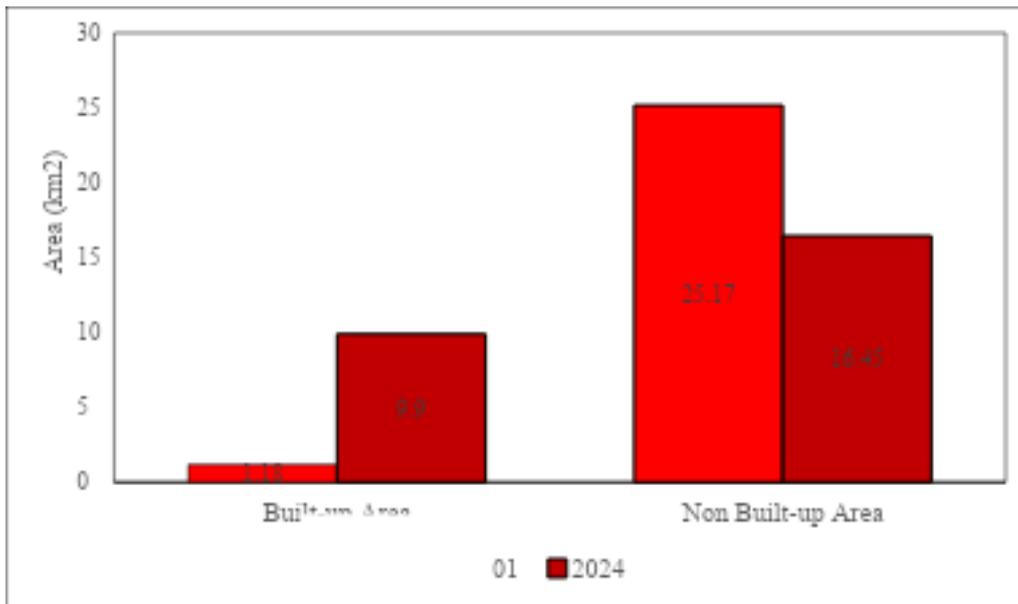

Figure 3: Built-up and Non Built-up of 2001 and 2024

A comparative map overlay for 2001 and 2024 reveals the extensive expansion in industrial and residential land has reduced agricultural land and barren land, which shows a transformation from agrarian land use to urban and industrial expansion.

Table 4: Statistical Analysis of NDBI Values

Year	Mean	Standard deviation
2001	0.02	0.15
2024	0.19	0.39
Changes	0.17	0.24

Table 4 shows that the rise in mean NDBI values and increased standard deviation reflect increased land-use variations due to urbanization.

Drivers of Alwar's Built-up Growth

The prime cause for this growth is industrialisation. There was only one industrial area in 2001, but in 2024, there were industrial areas numbering five. This rapid rise in industrial complexes is most likely to have led to Built-up sprawl driven by industrial workers' need for homes and Conversion of agricultural land to industrial and residential plots.

Besides industrial expansion, other factors that influence urban growth are:

1. **Proximity to Delhi NCR:** Alwar's strategic location between Delhi and Jaipur has led to spillover urbanization from the Delhi-Mumbai Industrial Corridor (DMIC) and Gurgaon's expanding economic influence.

2. **Infrastructure Development:** Enhanced road connectivity and highway expansions (e.g., NH-48) have facilitated real estate and industrial investments.

5. CONCLUSION

The study confirms a 33.10% Built-up growth between 2001 and 2024 in Alwar, driven primarily by industrial growth and infrastructural growth. This Built-up growth has transformed agricultural and semi-arid land into residential, commercial, and industrial space, transforming the face of the area. While this growth has brought economic opportunities and improved infrastructural facilities, it has also driven concerns regarding environmental sustainability, loss of natural resources, and increased pressure on public amenities. Well-designed urban growth strategies should therefore be adopted to promote balanced growth, promoting economic growth while mitigating negative environmental and social impacts. Alwar's future growth demands industrial growth with a thoughtfully designed plan, green space conservation and effective management of water resources to achieve a balance between economic growth and environmental sustainability.

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