Synergy: International Journal of Multidisciplinary Studies
Vol. 3. **Issue** 1, 2026. Pp. 101-118
ISSN: 3048-7005

Journal homepage: https://sijmds.com/index.php/pub

Article

Urban Morphology and Its Master Plan of Jaipur City

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Article History

Received: 22-12-2025
Revised: 25-01-2026
Accepted: 26-02-2026
Published: 01-03-2026

DOI: 10.63960/sp.2026.sijmds.3.1.87

Abstract:

An examination of Jaipur's urban form reveals how the city's geography, history, and planning philosophies have collectively shaped its unique spatial and cultural identity. Strategically located along the Aravalli hills and Banas River valley, Jaipur benefited from natural defenses, fertile soil, and water resources, influencing both its early settlement and ongoing urban development. The city's evolution unfolded in three major phases: its founding in 1727 by Sawai Jai Singh II, characterized by prominent public structures like Jantar Mantar and a gridiron street plan; the 19th-century expansion under Sawai Pratap Singh and Maharaja Ram Singh II, when development extended beyond walled limits with significant architectural projects; and a more recent phase marked by growth amid challenges. While initial planning emphasized environmental harmony, social hierarchy, and aesthetic considerations, modern issues such as urban sprawl, unregulated land use, and infrastructure deficits threaten its historic fabric. Addressing these concerns necessitates integrated urban management strategies that promote sustainable densification, heritage conservation, and inclusive governance. Leveraging advanced spatial technologies and socio-economic research will be vital in balancing rapid urbanization with heritage preservation. Jaipur exemplifies a deliberate, harmonious approach to urban planning that marries traditional wisdom with contemporary needs, offering valuable insights for similar historic cities worldwide.

Keywords: Jaipur, Urban morphology, Historical urban growth, Urban sprawl, Land use change, Population growth

1. INTRODUCTION

The study of urban morphology is a necessity for comprehending how geographical and environmental factors affect the development and planning of human settlements. The capital city of Rajasthan, Jaipur, or the so-called Pink City, is an excellent demonstration of how the natural environment, defence measures, and the environment affected traditional Rajput settlements on the hills. A look into the physiography of Jaipur and its geographical location, as well as soil conditions, illustrates the complex interdependence between the urban physical built-up and the natural landscape.

Jaipur is geographically positioned in the Aravalli hill ranges about 200 miles due north of the capital, Delhi; 150 miles due north of Agra, the former Mughal capital; and 84 miles due west of Ajmer. The city is located at 26°55' N and 75°50' E at the Banas River basin in the well-drained eastern plains of Rajasthan. Several seasonal rivers lend support to this basin, with the notable ones being Banganga, Dhundh, and Bandi. The existence of these

rivers did not only make the region more fruitful but also made early settlements of humans possible and, later, the city planning.

Geologically, Jaipur lies on the eastern plains of Rajasthan, extending over the northeast, east, and southeast of the Aravalli range. This area is usually known as the Eastern Plain and lies in the southeast of the Vindhya Plateau and in the west of the eastern edge of the Aravalli, north of Udaipur. The plain is further subdivided into two physiographic units, which include the Banas Basin and the Chappan Plains. Jaipur is situated in the Banas Basin, which is characterised by erosional features that are cut out of granite and gneiss rocks. The topography of this basin has a gradual northeast slope with a natural gradient that facilitated the city's growth.

The composition of the soil in Jaipur also allows pointing out the uniqueness of the environment. Alluvial soils prevail in the region, which, despite the lack of lime, phosphoric acid, and humus, allow a wide range of agricultural operations. The texture of the soil is clayey to sandy loam and frequently is intermixed with kankar (calcareous nodules) that rests on sandy clays or sands. In spite of these shortcomings, the land has traditionally been fertile enough to accommodate a broad range of crops, such as wheat, rice, cotton, and tobacco. The geological sequence on which the region is based is basaltic lava flows, sandstone, limestone, shale, schist, gneiss, silt, clay, and sand, and all this affects the soil fertility and land use.

In summary, the urban form of Jaipur cannot be considered out of the context of its geography and geology. It is set up in the Aravalli Hills, in the Banas Basin, and along seasonal rivers that offer natural defences and agricultural potential. In the meantime, the land and geological structures also determined not only the agrarian foundation but also the settlement system. These environmental factors, combined with the old Rajput methods of defence, were important determinants of the city and its unusual urban form; thus, Jaipur is an outstanding example of environmentally responsive urban planning in Rajasthan.

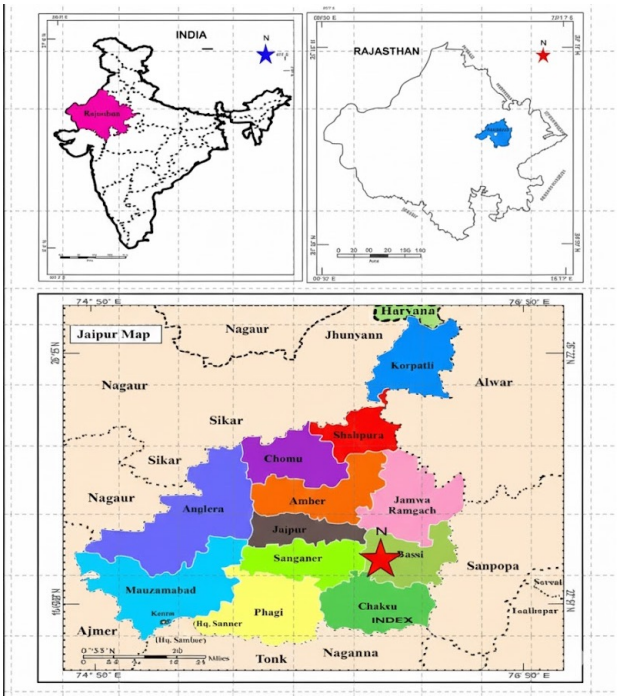


Figure 1: *Jaipur Map*

2. REVIEW OF LITERATURE

Fazl (2017) made an English translation of the Ain-i-Akbari that was originally written during the reign of Akbar, with the aim of recording the administrative, social, and economic structure of the Mughal Empire. The approach used was a descriptive account of statecraft, systems of Taxation, the land revenue system, army organisation, and cultural practices are documented in the imperial gazetteer. The results emphasised the highly organised system of governance of the empire, the effectiveness of the collection of the revenue, and the way different cultural and social practices were incorporated into the administration systems. The conclusion proved that the Ain-i-Akbari is an irreplaceable source of knowledge on the Mughal administration and an unequalled

 https://doi.org/10.63960/sp.2026.sijmds.3.1.87

source of historical knowledge on the socio-economic and political structure of early modern India.

The research by Dadhich and Hanaoka (2011) was on the spatio-temporal modelling of urban growth in Jaipur, India, with the perspective of determining the trends of urban growth through geospatial analysis. This study has used a research approach involving satellite imagery and GIS-based modelling to track changes in the land cover over the years. Findings showed that there was high-value urban sprawling at the cost of agricultural and open spaces and developments in transport corridors and city fringes. It was inferred that urban growth models that rely on spatio-temporal analysis are significant in determining unsustainable trends in the expansion and long-term planning to guide development of the city of Jaipur.

Zhang et al. (2011) researched the development of urban areas in the Greater Shanghai Area and tried to model the possible development trends in different policy frameworks. The approach taken has been remote sensing, GIS, and urban simulation models to develop alternative growth scenarios. The findings indicated that the planning regulations, population density, and infrastructural development contributed significantly to the urban sprawl of Shanghai, and the compact city model would be better at minimising environmental depreciation as compared to the free-spread model. The conclusion stated that scenario simulation analysis can provide evidence to decision-makers in striking a balance between speedy economic growth and land use planning sustainability.

In a study by Taubenbock et al. (2009), the urbanisation in India was analysed through the use of spatiotemporal analysis of remote sensing data with the objective of mapping the extent and the magnitude of urbanisation. The strategy mixed satellite imagery with geospatial analytics to measure shifts in land cover in rapidly urbanising regions. The findings revealed that India had experienced enormous urbanisation characterised by uneven urban growth and sprawling of urban areas on natural assets, especially in the metropolitan cities. The conclusion was that spatiotemporal monitoring through the use of remote sensing is necessary in managing the issue of urban sprawl in India as well as in facilitating policies that will help in reducing environmental degradation and uncontrolled development.

The Bhatta et al. (2009) research paper on urban sprawl aimed to give a numerical measure of how much urban development has occurred, using remote sensing data to assess the level of freedom, sprawl, and quality of development. The research design employed the use of geospatial analysis of satellite images coupled with statistical measures of sprawl. The findings showed that the framework may be helpful in distinguishing between compact and dispersed structures of urban growth, where larger sprawl indicators reflect ineffective land use. The conclusion indicates that the proposed measures are highly effective for urban planners to assess urban form and develop policies that support sustainable urban development.

Kasimu et al. (2008) compared how cities around the world changed over 40 years by using low-resolution satellite images and GIS to find patterns in urban development. The study was conducted using a blend of satellite data sets and spatial analysis with the help of GIS to study different regions and continents. The findings revealed that urban growth was a global phenomenon and had various regional characteristics because developing nations exhibited a higher rate of growth compared to stable growth in the developed nations. The conclusion renewed the significance of compare-and-contrast research at the global scale in the understanding of the range in the urbanisation process and planning interventions in a specific region.

Lu and Weng (2006) examined the role of impervious surfaces in classifying land use within an urban land-use classification to improve the accuracy of land cover mapping in urban areas. The method applied was the high-resolution satellite image analysis and extraction of the impervious surface data and inclusion in the classification models. The findings showed that the addition of impervious surface had a significant impact on the enhancement of the classification accuracies, particularly between the land use of urban and non-urban. The conclusion was that impervious surfaces make a good proxy of urbanisation and should be adopted in land use classification systems.

Xiao et al. (2006) studied the growth and land use change in Shijiazhuang City, China, and the objective was to study the spatial growth patterns. The method employed multi-temporal satellite images and spatial analysis in GIS to identify the change in land use types over time. The findings indicated high rates of urban expansion that led to the decline of agricultural land and conversion of peri-urban spaces, and the GIS techniques proved to be useful in recording the spatial and temporal processes. It was concluded that GIS and remote sensing have become very useful research tools in urban development and policy formulation, which minimises the vices of uncontrolled urbanisation.

The book by Roy (2006) is a descriptive account of Jaipur's urbanisation, political environment, and sociocultural evolution. The study focused on researching archives, historical documents, and accounts to develop the historical background of Jaipur from its formation to the present. The report describes Jaipur as a planned city established by Sawai Jai Singh, highlighting how tradition and modernisation have shaped its identity. It was inferred that the history of Jaipur is key to understanding the development of the urban form in princely states of Rajasthan and the cultural and political significance of the form.

Hooja (2006) presented a history of Rajasthan in an attempt to give a detailed history of its political, social, and cultural development. The methodology of archival sources, historical records and interpretative analysis of dynastic and regional histories was used as the source of information. The outcome showed that Rajput politics, Mughal and colonial influences, rich culture, and social stratification shaped Rajasthan's multidimensional history. The conclusion also highlighted the significance of history, emphasising that the work has substantial background in the political and cultural history of contemporary Rajasthan.

Li et al. (2005) conducted a forecast of degraded grassland in the Southwest Songnen Plain using RS and GIS with a Markov model to predict land cover variations. The approach utilised remote sensing data, GIS spatial analysis, and stochastic Markov models to simulate degradation trends. The results showed that there was serious grassland degradation due to human impacts and stress factors, and the Markov model was able to predict the probability of a transition in land cover. The conclusion was that this kind of modelling will be essential in ecological monitoring and policies that are supposed to be put in place to conserve delicate environments.

Jain (2005) conducted a study that delved into the historical geography of Amber, Jaipur, and Shekhawati, with the aim of investigating princely terrain and urban change. The methodology comprised historical text analysis, architecture, and local cultures. The results highlighted the political role of Amber, the design of Jaipur, and the unique artistic and architectural history of Shekhawati. The conclusion indicated that these regions can be regarded as significant stages in the history of Rajasthan and demonstrate the interconnection between geography, politics, and cultural expression.

Deal and Schunk (2004) examined a spatial dynamic modelling of the land use change in cities with the aim of examining the expenditures on urban sprawl. The methodology used simulation models that built on spatial dynamics with economic appraisal systems. The results revealed that sprawling is costly to the environment and infrastructure, while compact urban forms are more efficient and sustainable. The conclusion was that simulation-based spatial modelling was able to give vital information about the long-term effects of urban sprawl and could help provide future planning information.

Sudhira et al. (2004) studied urban sprawl with the aim of coming up with measures and models to explain spatial dynamics based on GIS. The research methodology was based on remote sensing data combined with GIS spatial modelling to examine trends in sprawl at various scales of time. The results indicated fast, uncontrolled growth on the fringe of the city, which evinces inefficient use of land and environmental impact. The conclusion has been reached that GIS-based measurements of sprawl are important in monitoring sprawl and in formulating policies that foster planned and sustainable development.

Herold et al. (2003) investigated the urban growth process with the objective of quantifying the spatiotemporal changes in the urban structure. The methodology was composed of a hybrid of remote sensing via satellite and landscape metrics for gauging urban sprawl and urban form. The findings showed that the city development followed patterns that are identifiable and spatial measures were powerful predictors of the form and intensity of development. The conclusion demonstrated that remote sensing along with spatial analysis can lead to the higher level of knowledge concerning the process of urban growth and enables the formation of strategies for sustainable urban management.

Zhang and Wang (2003) suggested a method that uses rules to classify urban land based on detailed multispectral images, which helps improve the accuracy of land use classification in city studies. The approach was based on determining the rules that used spectral, spatial, and contextual information to interpret urban land parcels more effectively than pixel-based classification. The study found that rule-based systems were better at representing the diverse patterns of cities and were more precise in defining complicated land use types. The conclusion pointed out the success of integrating expert knowledge with computer models so as to optimise remote sensing for urban land management.

 https://doi.org/10.63960/sp.2026.sijmds.3.1.87

Zha, Gao, and Ni (2003) examined the usefulness of the Normalised Difference Built-up Index (NDBI) in the automatic mapping of urban areas in TM imagery to enable better detection of built-up land. They used a method that involved using spectral indices to tell apart urban structures from plants and water, creating an automated mapping tool that relies less on human interpretation. The analysis revealed that NDBI had clear differences in the built-up and non-built-up regions and these characteristics contributed immensely to the classification results in urban mapping. It was concluded that NDBI was efficient, scalable and stable for identifying urban growth through remote sensing.

Van der Sande, de Jong and de Roo (2003) employed a segmentation and classification approach to the IKONOS-2 images to produce high-resolution land cover maps to be used in flood risk and damage assessments. The general objective was to support disaster management through the provision of precise spatial data regarding land use. Object-oriented segmentation and supervised classification techniques were applied to map the urban and rural land covers in terms of hydrological modelling. Our results showed that the introduction of segmentation made the classification more accurate and provided critical information to evaluate flood exposure. The discussion summarises the usefulness of high-resolution remote sensing for disaster preparedness and other risk mitigation measures.

Weng (2002) used remote sensing, GIS, and stochastic modelling to study land use changes in the Zhujiang Delta in China and to gain an insight into the urban growth processes. The methodology combined satellite imagery and spatial modelling to model and forecast land use patterns. The research uncovered a high rate of urbanisation and the increased conversion of agricultural land to built-up land, which transformed the entire regional environment and resource consumption. The conclusion stated the need to integrate remote sensing data and stochastic models to observe and control land changes in rapidly expanding regions.

In their book, Sachdev and Tillotson (2002) tried to uncover historical and cultural processes that created the city of Jaipur with the aim to record the heritage of architecture and planning. They examined how political, social, and cultural dynamics constructed Jaipur as a planned city through archival research, fieldwork, and analysis of urban design. The results accentuated the This is a fusion of traditional Rajput and Mughal architecture with town planning principles that have cosmological and defence orientations. The conclusion stated that Jaipur remains a unique urban form balancing cultural symbolism and functional design and still serves as a source of influence to modern urban studies.

Bauer and Steinnocher (2001) presented a per-parcel land use classification method of urban areas based on a rule-based approach and sought to achieve higher accuracy than pixel-based methods of classification. Their approach was based on parcel boundaries as mapping units plus spectral and contextual rules of classification. It was also found that parcel-based classification was more reliable, especially in heterogeneous urban areas where land parcels are more appropriate in reflecting the actual land use patterns. The conclusion supported the usefulness of rules-based, parcel-based approaches to urban land monitoring.

López et al. (2001) examined land cover and land use change in the urban fringe of Morelia City, Mexico, with the aim of projecting city expansion. They used satellite imagery analysis, GIS, and spatial modelling to evaluate agricultural, forested, and urban land transitions. The results demonstrated how demographic and economic forces gradually transform natural and agricultural areas into urban settlements. The conclusion pointed out the need to have predictive models that can be used to plan cities and the planning of policies to reduce environmental degradation as a result of uncontrolled urban sprawl.

The Census of India (2001) gathered detailed demographic and socio-economic statistics of Rajasthan to provide credible data to the decision-making and governance of the state. It was done through large-scale enumeration of population, households, literacy, employment, and settlement structures within the state. The results of this census identified the trends in the population distribution and urban-rural structure as well as the demographic issues characteristic of Rajasthan. The conclusion stressed the usefulness of census data as the basis for policymaking, regional planning, and social-economic development projects.

Li et al. (1999) designed a map overlaying method in GIS to evaluate the environmental impacts of road networks with the aim of incorporating the transport and environmental aspects. They conceptualised their approach as an overlay of spatial data on roads with ecological and land use layers to assess cumulative environmental stress. The results of the study revealed that the overlay approach was useful in bringing out areas of extreme environmental influence because of road expansion. The conclusion proved that the tools based on GIS were useful in transport

planning and environmental harm reduction.

Stuckens et al. (2000) compared the combination of contextual data with per-pixel classification to increase the accuracy of land cover mapping. They used a methodology that consists of contextual data at the neighbourhood level coupled with pixel-level classification derived using remote sensing imagery. The research results showed that adding contextual information improved classification accuracy by reducing confusion between similar colours and better recognising the area's layout. The conclusion mentioned the context-enhanced classification methods as more reliable in providing land cover maps, particularly in complex landscapes.

Jensen (1996) was a more detailed introduction to digital image processing in remote sensing and was meant to provide the researcher and students with theoretical and practical backgrounds. The methodology was provided with systematic explanations of the image preprocessing, enhancement, classification, and interpretation techniques with case studies. The established findings standardised remote sensing practices into a form of a framework that enabled uniformity in the use of remote sensing in various research works. The summary led to the fact that digital image processing is a necessary tool in environmental monitoring and spatial analysis.

The article by Harris and Ventura (1995) looked into the combination of geographic information with remotely sensed imagery to enhance urban classification. They used a combination of GIS-based spatial data with remote sensing classification output in order to improve records of urban mapping. The results of the study showed that integrated methods had superior performance over the conventional image classification in that the results considered the socio-economic and spatial context. The conclusion restated the possibility of a GIS-remote sensing combination to aid urban planning and land management.

Stewart's (1994) work presented numerical techniques for solving Markov chains with the aim of advancing the efficiency of computational stochastic modelling. Iterative and direct algorithms used in large-scale Markov processes have been described in the methodology, and this has given practical methods of solving mathematical problems. The results indicated that such computational methods enhanced the viability of using Markov chains in real-life applications like in queuing systems and reliability models. The conclusion emphasised the importance of numerical methods for generalising Markov chain models in a wide range of areas.

Muller and Middleton (1994) develop a Markov model to capture land-use change dynamics in the Niagara region of Ontario with a particular emphasis on the changing agricultural, urban, and natural land categories. They used probability matrices of transitions obtained through aerial photo interpretation to forecast the land use in the future, which enabled them to estimate both the short-term and long-term dynamics. The findings of the research confirmed that urbanisation was the key influential factor in the conversion of the land in the region, and agricultural lands were the most susceptible to the process of conversion, whereas some natural landscapes were more stable. The conclusion reiterated the usefulness of Markov modelling as a quantitative method of forecasting land use scenarios and as a means of regional planning strategy support.

Congalton (1991) assessed techniques for determining the accuracy of classification in remotely sensed data by reviewing statistical techniques and error matrices. The paper critically evaluated strategies like Kappa statistics, confusion matrices and sampling to establish their effectiveness in making sure that the classification results are reliable. The findings were that land cover maps must be accurately corrected through accuracy assessment in order to render legitimate usage in resources management. The conclusion stressed the need for having standard procedures of accuracy assessment to achieve scientific rigour of remote sensing studies.

The Census of India (1991) is an in-depth demographic report of the state of Rajasthan, including all of the vital demographic parameters of size, distribution, density and socio-economic parameters. The methodology used was a complete enumeration process conducted by the office of the Registrar General and Census Commissioner, ensuring that no household or individual was missed in the entire state. These findings were vital in giving details about the trends in urbanisation, literacy levels, and work patterns that shaped the socio-economic nature of Rajasthan at the onset of the 1990s. The relevance of such information in policy, governance, and development planning, both at the state and national level, was supported by the conclusion that was given by the census.

Markov models have also been applied to changes in land cover in the Southern Great Plains grassland region by Coppedge et al. (2007) to study the changes between native grassland, cropland, and woody vegetation. They used multi-temporal remote sensing data and probabilistic transition modelling on land cover patterns that has enabled them to describe temporal and spatial variability in land cover patterns. The results were that there was

 https://doi.org/10.63960/sp.2026.sijmds.3.1.87

significant loss of grassland and its degradation to woody vegetation because of ecological dynamics and land management in the region. The conclusion noted that Markov models are imperative in offering guidance in conservation planning and the ecological management of grassland ecosystems under the pressure of changing land use.

Baker (1989) summarises the past and existing paradigms of landscape change, in which both theoretical and empirical studies were combined to focus on temporal and spatial changes in ecological systems. The paper compared process-based models, stochastic simulations and transition frameworks and their effectiveness in describing landscape dynamics. The results indicated that models have a wide range of performance and cannot be applied in all ecological and geographical settings equally well. The summary highlighted the need to combine various modelling methods to enhance the predictive ability and ecological insight in the studies of landscape change.

Bahura (1979) collected historical information about Sawai Jai Singh in his book Sawai Jai Singh Charit, using historical records maintained in the City Palace, Jaipur. The approach was that of a critical study of historical manuscripts and palace writings to recreate the personal, administrative and political life of the ruler. The findings depicted Jai Singh's contributions to urban planning, scientific research, and governance, which had a big impact on the cultural and political history of Jaipur. It was opined that the biography is a rich historical source that contains the intellectual and administrative traditions of one of the most powerful rulers of Rajasthan.

A thorough discussion on the administrative system of Rajputs has been presented by Sharma (1979), who analyzed the form of government, military administration and the system of finance of the princely states. This work was intended to outline how the Rajput kings could maintain political power through a mixed central/feudal system of administration. The methodology utilised historic texts, royal decrees, and archival sources to study organisational forms and decision-making processes. These findings indicated that the Rajput rule had both heredity and revenue offices, where a system was constituted which provided independence of nobles and subordination to the central government. Finally, in the conclusion, it was argued that the Rajput model of administration was very important in giving the Rajput dynasties stability and in deciding regional politics in pre-colonial Rajasthan.

Sarkar (1984) focused on the history of Jaipur during the period between 1503 and 1938 and gave a chronological account of political, economic, and cultural activities that took place in the state. It was meant to trace Jaipur as it evolved out of its mediaeval roots to its early modern solidification and into its colonial-era changes. The methodology of the research encompassed the critical approach to the reading of the archival record, the state records and secondary accounts of history to reconstruct the course of political power and socio-economic change that Jaipur experienced. The outcomes indicated Jaipur's significance as the prime Rajput state capable of achieving equilibrium among the inner intrigues of power, external pressures from the Mughals and the British invasion, and social and economic adjustments. The conclusion was that the ruling class of Jaipur and their ability to negotiate power made the city live and control the politics of the region throughout the centuries.

Mishra (1985) examined the forts of Rajasthan to present their architecture, defence, and cultural values. The analysis was conducted through archaeological surveys, site visits, and textual analysis of the records available at the time regarding construction methods and military use. The findings revealed that the forts of Rajasthan were not only defensive buildings but also cultural symbols of royal power and pride for their respective royal families. The conclusion stressed the idea that these forts remain as reminders of the Rajput military genius, engineering, architecture, and statecraft and as defensive citadels and memorialisations of local identity.

Gupta (1987) has studied trade and commerce in Rajasthan, particularly in Jaipur, in the 18th century. It was designed to help understand economic systems, trade patterns, and the role of mercantile fraternities in ensuring cities remained prosperous. It relied on historical trade data, archival records, and secondary literature to recreate the business in the city. The results revealed that Jaipur was a very significant trading center with far-reaching ties to local and global trade, facilitated by healthy guilds and merchants' networks. The conclusion stated that trade played a central role in developing the socio-economic life of Jaipur and helped it become culturally rich, prosperous, and urban.

The Maharaja of Jaipur (1967) gave an elaborate report of the state forces of India, and this was intended to trace the formation, organisation, and contributions made by the state forces over different historical backgrounds. The approach used included historical writings, military records and personal experiences to give an insight

into the history of state military forces. The results proved that the army of Jaipur was essential to the region for defence and in ceremonial events as well as in enhancing the pride of the princely state against pre-colonial and colonial influences. The conclusion highlighted that it is essential to learn the history of state forces to assess the political stability of Jaipur and military culture.

3. OBJECTIVES OF THE STUDY

1. To study how Jaipur's geography shaped its urban form.
2. To trace the historical evolution of Jaipur's planning and architecture.
3. To examine the impacts of modernization on the city's heritage and spatial identity.
4. The objective is to evaluate the challenges posed by urban sprawl and land-use changes.
5. The aim is to propose sustainable strategies for the development of urban areas that are sensitive to heritage.

4. RESEARCH METHODOLOGY

The current research employs a descriptive and analytical research design to study the urban morphology and historical development of Jaipur over its nearly three hundred years of existence. The study region is Jaipur, located in the Aravalli hill ranges within the Banas Basin and containing the historic walled city and its suburban and peri-urban extensions until the year 2025. The analysis uses a mix of primary and secondary data: primary data will include mapping, interpreting satellite images, and observing key features like land use, building patterns, transport routes, and heritage areas, while secondary data will consist of census reports from 1881 to 2011, the Master Development Plan 2025, the Clean Air Action Plan (2019), the Comprehensive Traffic and Transportation Study (2019), municipal and JDA records, historical maps, and research on Jaipur and urban sprawl. Remote sensing and GIS techniques are used to conduct spatial-temporal analysis of land-use and land-cover change, built-up area growth, and trends toward compact growth or outward sprawl, while basic statistical tools such as growth rates, density measures, population projections, and land-carrying capacity calculations are employed to associate demographic tendencies with spatial growth. Using the analytical framework, the growth of Jaipur was analysed in three phases (1727-1800, 1801-1900, and 1901-2025), and the dominant morphological and functional features of urbanisation were compared, culminating in an evaluation of the gap between planned and actual urbanisation, particularly regarding land-use conversion, vacant-land capacity, and the implications for sustainable urbanisation and heritage-sensitive development.

5. HISTORY OF URBAN GROWTH IN JAIPUR CITY

The growth of urban space is different in each city and depends on historical, geographical, administrative, and political factors. Jaipur's spatial growth evolved outwardly, initially confined within the walled city and later expanding to the outskirts. The urbanisation of Jaipur can be divided into three big periods:

5.1 Phase I (1727 A.D. to 1800 A.D.)

Sawai Jai Singh II established the Jantar Mantar observatory, which he completed in 1734, although construction activities continued until 1738. During this period, more than 23 astronomers, along with numerous masons and engravers, were employed on daily wages (Sharma, 1979, p. 28).

The Modikhana Chowkies and Visheshwar Ji were maintained by wealthy Jain and Hindu merchants and businessmen. Merchants, artisans, and workers developed the Johari Bazar section of Chowkri Ghat Darwaza. On the Sireh Deorhi Bazar side, Chowki Ramchandra ji was enclosed by temples and havelis commissioned by the king, his queens, and leading nobles, while the royal staff and craftsmen resided in the eastern and northeastern parts of the city. Topkhana Hazuri, being irregular and sandy in nature, was allotted for factory workers. The Siya-Hazur records of V.S. 1794 (1737 A.D.) also mention the existence of the 'Gangpol' gate in the northern city wall.

To the north of Purani Basti, Brahmapuri colony was developed to house Brahmins from Prayag, who had been invited by Jai Singh II for the Ashwamedha Yagya in 1734. Consequently, Brahmapuri became the settlement of royal priests and other Brahmins. Jai Singh II also introduced trade franchises and granted certain tax concessions to promote commerce. Jai Singh II invited and provided facilities for renowned artists and artisans from Delhi, Agra, and Mathura to settle in Jaipur. Their considerable purchasing power encouraged the

 https://doi.org/10.63960/sp.2026.sijmds.3.1.87

migration of supporting populations such as workers and craftsmen, leading to the settlement of diverse artisans and industrialists. Dastur-Kaumber notes that traders such as Thakarsi, Bulaki, and Beg Mohmad from Agra also moved to Jaipur.

The main roads of the city were constructed with a width of 108 feet, while subsidiary roads were built at half this width. Along Johari, Sireh Deorhi, Kishanpol, and Gangauri Bazars, 162 shops were created on each side, whereas the western side of Kishanpol Bazar had only 144 shops. These shops, uniform in size and structure, occupied 18 and 16 bighas of land, respectively. This standardised shop layout greatly facilitated the commercial growth of the city. The state also issued guidelines for the construction of private residential colonies.

Architectural designs of elite residences incorporated distinctive features such as jharokhas, jalis, chhajjas, and todas, adding significantly to the grandeur and dignity of Jaipur. Jaipur became the center of astronomical activities in the mid-1730s under Sawai Jai Singh II, and it stayed that way until his death in 1743 (Roy, 2006).

5.2 Phase II (1801 A.D. to 1900 A.D.)

This period encompasses the reign of Sawai Pratap Singh (1778–1803) and Maharaja Ram Singh II (1835–1880). During the rule of Sawai Pratap Singh, notable architectural landmarks such as the Anand Bihari Krishna Temple, Hawa Mahal, and Brijnidhi Temple were constructed in 1790 A.D., showcasing remarkable structural designs. However, according to Sharma (1979, p. 29), astronomical activities at the observatory came to an end during Pratap Singh's reign, and the site itself was converted into a gun factory for the manufacture of firearms.

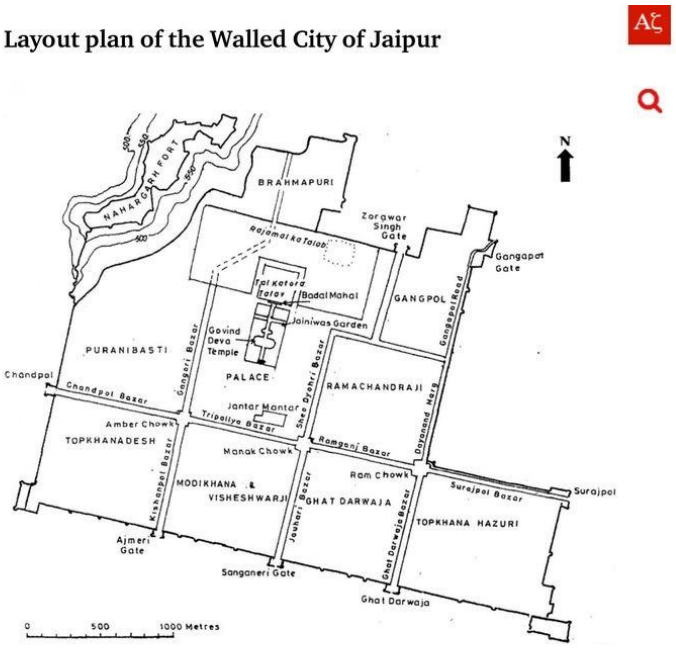
Historically, Raja Man Singh I earned fame as Akbar's distinguished Commander-in-Chief, while Maharaja Jai Singh II held prominence as a general under Aurangzeb. Later, in 1889, the inauguration of the Imperial Service Troops laid the foundation for the modern Jaipur army (H.H. Maharaja of Jaipur, 1967). In earlier times, Nawabpura and Jalupura were constructed in the west for the Meenas and sweepers, while Fateh Tiba was developed to the south, and Badanpura along with Khatik Mandi to the east. Prior to British influence, the suburbs of Jaipur often functioned as theaters of war, discouraging permanent settlement due to the risks involved. Nevertheless, residing near the Royal Palace was considered a matter of honor and prestige.

Significant urban and social developments marked Sawai Ram Singh II's reign (1835–1880). His period witnessed the construction of the Ram Bagh Palace, Ram Niwas Garden, Mayo Hospital, Civil Lines, Railway Colonies, and new roadways. Many of these projects were established outside the walled city, as the old city retained its original planned structure and remained confined within its fortifications. Suburban areas were therefore developed beyond the city walls. Abul Fazl, in the Ain-i-Akbari, had earlier praised the superior quality of ornaments crafted by the goldsmiths and jewelers of Rajasthan, highlighting Jaipur's long-standing artisanal excellence.

This observation aligns with a historic 18th-century map studied by Sachdev and Tillotson, which is associated with the period of Sawai Pratap Singh. Historical accounts provide supporting evidence: Mahadji Sindhia, in his role as the Imperial Regent and Commander-in-Chief of the Mughal Empire, invaded Jaipur in 1786–1787. In 1787, Sawai Pratap Singh retreated within his capital and prepared for a siege (Sarkar, 1984, pp. 271, 273). This volatile political environment likely influenced the decision to establish a gun factory at the Jantar Mantar site.

Although some references attribute the construction of the Laghu Samrat Yantra to Maharaja Ram Singh, the historic map dating to the era of Sawai Pratap Singh (1778–1803) already depicts the instrument. It is therefore plausible that Ram Singh's contribution lay in restoration and repair, rather than its original construction. When first observed in 1882, the instrument was in a dilapidated condition. Later inscriptions confirm that the observatory underwent extensive restoration in 1901, using local masons, materials, and craftsmanship. The instruments were reconstructed with such precision that they appeared newly built.

The strong presence of bankers and merchants during this time reflects Jaipur's thriving commercial activities. Its strategic location on the trade route from Delhi to Ahmedabad further strengthened its economic significance. The Siyah-Rukka notes that Jaipur was an important marketplace for precious stones such as emeralds, diamonds, and pearls, underscoring the city's stature as a major commercial hub.



Salam, Abdul. Foundation and early history of Jaipur city. Aligarh Muslim University, 2011.

Figure 2: *Layout Plan of The Walled City of Jaipur*

5.3 Phase III – From 1901 A.D. to 2025 A.D.

During this phase, Jaipur emerged as a prominent center for administration, commerce, and trade, supported by the development of irrigation dams and several public buildings. Under the reign of Sawai Madho Singh II, a metre-gauge railway line of 118 km was constructed from Sanganer to Sawai Madhopur, along with the Jaipur–Shekhawati Railway, which extended over approximately 108 miles. The city also witnessed the arrival of its first motorcar during this period, signalling the onset of modern transport. At the same time, Jaipur began expanding beyond the confines of its walled city.

In 1923, the long-standing practice of closing the city gates at 11:00 p.m. was abolished, with Chandpol Gate ordered to remain open throughout the night. The municipality of Jaipur was officially recognised in 1926, followed by the enactment of the Jaipur Municipal Council Act in 1929. The Rebaris, traditionally engaged in camel transportation, continued to play a vital role in trade, as their camels were hired not only by merchants but also by the government, particularly for transporting food grains and salt (Gupta, 1987).

This period also witnessed rapid urbanisation, supported by the expansion of social amenities and industrial developments. Many wealthy nobles, traders, and affluent families moved away from the congested and unhealthy conditions of the walled city to newly emerging suburban areas. Coinciding with the reign of Sawai Man Singh II, Jaipur's municipal area grew significantly, expanding from 4.83 km² to 40.23 km² (Bahura, 1979, pp. 105–106).

The first systematic step toward housing the general population outside the city walls was taken in 1935, with the planning of a residential locality between the walled city and Mirza Ismail Road. Several large-scale development schemes followed, including:

- Fateh Tibba
- Medical College and Gangwal Park area
- Ashok Nagar,
- New Colony
- Jalupura and Bani Park.

Although the initial plan prioritised the 'D' Scheme, Mirza Ismail emphasised the swift execution of the 'C' Scheme. Meanwhile, the Bani Park Scheme was initiated to the northwest of the city (Sarkar, 1984).

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Industrial development also accelerated during this phase. Areas such as Sanganer, Sitapura Industrial Area, and Malviya Industrial Area toward the southeast were established, strategically aligned along the railway lines. Collectively, Jaipur's major industrial hubs developed like "pearls on a string", concentrated mainly in the northwest and southwest of the city. The New Colony locality, developed as part of this expansion, was handed over to the municipality for maintenance in 1946.

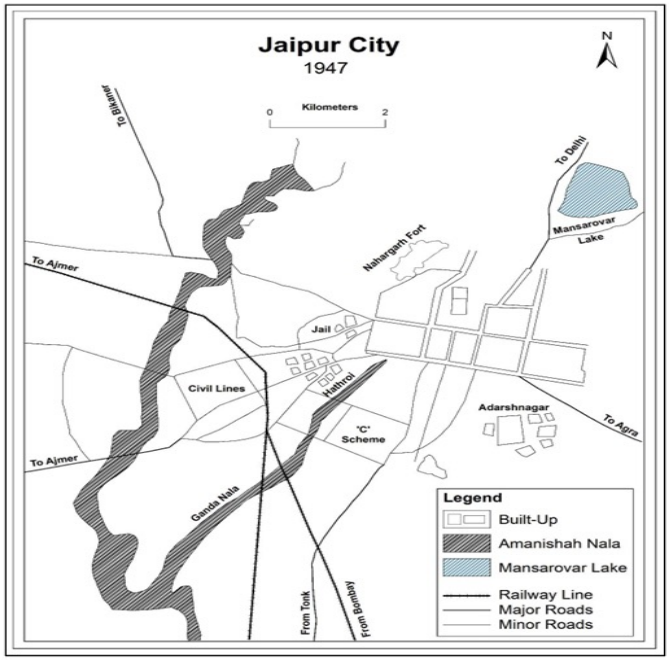

Figure 3*: Jaipur City Map*

6. URBAN SPRAWL

Jaipur is witnessing a problematic pattern of urban growth, characterised by low-density development, rising travel times, excessive dependence on private automobiles, the encroachment of agricultural land, and a consequent increase in greenhouse gas emissions. These issues have been identified by analysing the city's growth dynamics over the past two decades through spatial mapping and by reviewing key planning and policy documents such as the Master Development Plan 2025, the Clean Air Action Plan (2019), Census 2011, and the Comprehensive Traffic and Transportation Study (2019), along with consultations with Jaipur Municipal Corporation (JMC) and Jaipur Development Authority (JDA). As Jaipur aspires towards accelerated economic growth, the urban areas lying outside its UNESCO-protected heritage zones are increasingly exposed to pressures of rapid development, placing the city's cultural and historical identity at risk. An urban sectoral assessment further demonstrates how these challenges are interconnected across multiple development sectors, as detailed in Annexure 6.1. The assessment shows that urban sprawl is a big problem, with poor results: urban layout, public spaces, and safety are rated 'very low'; transportation is 'lower medium'; and the environment and ecology are at a 'medium' level.

Jaipur's 2025 population is now estimated at 4,411,110. In 1950, the population of Jaipur was 294,021. Jaipur has grown by 102,600 in the last year, which represents a 2.38% annual change. These population estimates and projections come from the latest revision of the UN World Urbanization Prospects. These estimates represent the urban agglomeration of Jaipur, which typically includes Jaipur's population in addition to adjacent suburban areas.

Table 1: *Population*

Year	Population (in lakhs)
1950	2.94
1960	4.02
1970	6.06
1980	9.84

1990	15
2000	23
2010	30
2020	39
2025	44
2030 (Projected)	49

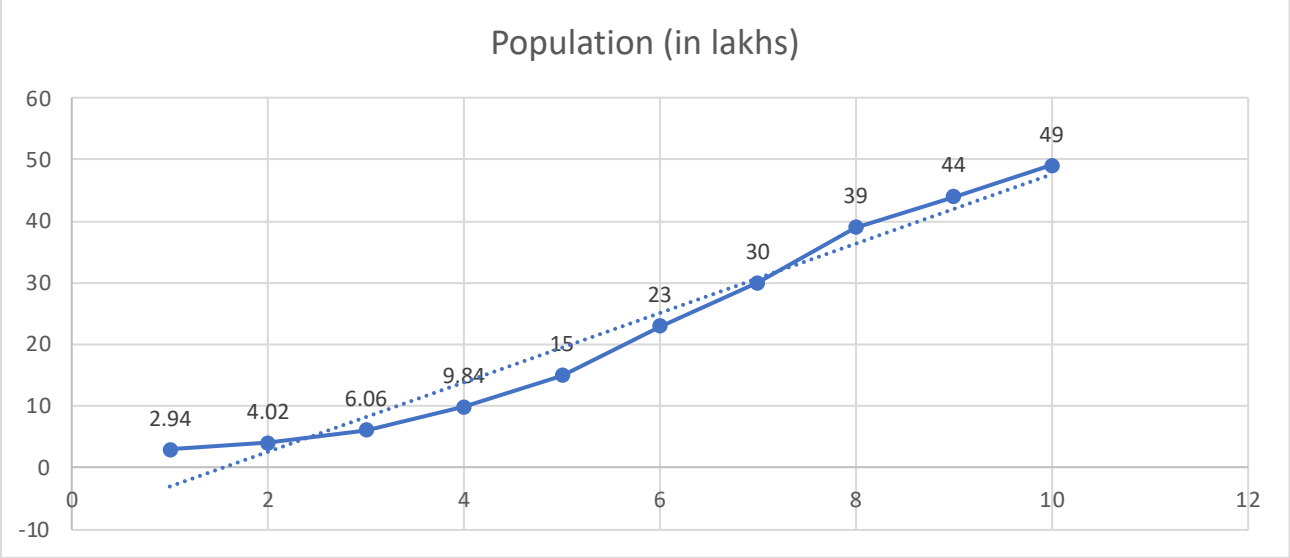

Figure 4: *Population*

Between 2000 and 2014, Jaipur's built-up area expanded significantly, recording a 21% increase—from 139.50 sq. km. to 169.12 sq. km. (see Map 5.1). During the same period, the city's population grew from 23.22 lakh to 30.46 lakh. Although the Jaipur Development Authority (JDA) formulated the Master Development Plan (MDP) 2025 in 2011 to steer urban growth, the city's expansion has remained largely sporadic and inadequately monitored due to the absence of robust implementation strategies.

Spatial mapping of Jaipur's morphological growth reveals a departure from its historically compact and efficient settlement structure toward a more dispersed, outward sprawl. One of the key shortcomings of the MDP 2025 is its reliance on outdated Census 2001 data, prepared during a period when Jaipur recorded its highest-ever urban growth rate of 59.3% in the preceding decade. Based on this exceptional growth, future population estimates were projected using statistical models, with growth rates anticipated at 55% for 2011 and 49.6% for 2025. Consequently, infrastructure planning and demand estimations were aligned with these projections. However, actual census figures from 2011 revealed a much lower growth rate of only 31.2%, exposing a stark mismatch between projections and real demographic trends.

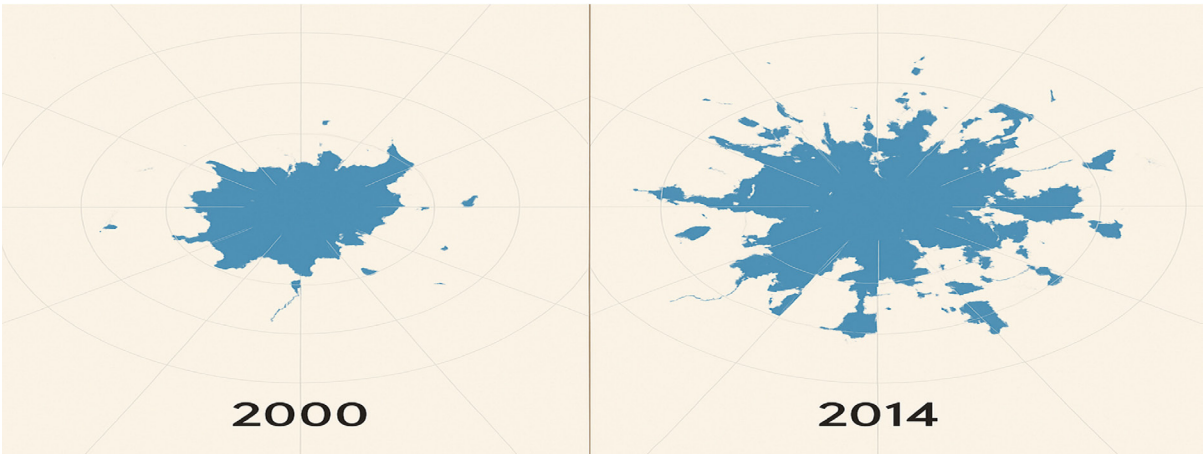

Figure 5: *Change In Layout*

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7. EASE OF CHANGE IN LAND USE PROCESS

The Master Development Plan (MDP) 2025 does not allocate any land within the U1 zone specifically for agricultural purposes. The existing policy for changing land use facilitates the conversion of various land types into residential use with relative ease, promoting unregulated and fragmented development along the city's outskirts. This trend has not only resulted in the loss of agricultural land but has also contributed to ecological degradation in several instances. For a land parcel designated for residential use to be developed as a residential township, only three basic criteria need to be satisfied; notably, these criteria do not consider the land's location, proximity to existing developed clusters, or access to transportation connectivity. By 2020, most of the areas converted to residential use remained largely undeveloped, showing only sporadic construction activity. This situation underscores the urgent need to focus on densifying already developed urban areas, since outward expansion would create additional spatial and financial burdens for delivering essential infrastructure to dispersed, remote developments. Growth along major corridors such as Agra Road have fallen short of projections. Furthermore, the allocation of residential land extends significantly beyond the existing built-up area and surpasses the actual housing demand within the city.

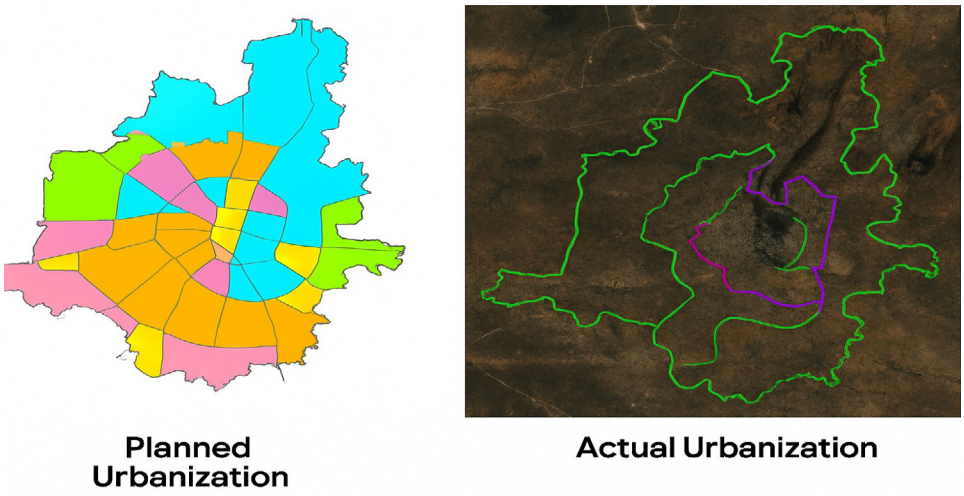

Figure 6: *Planned & Actual Urbanization*

8. LAND CARRYING CAPACITY ANALYSIS

According to UN-Habitat's Five Principles for Sustainable Urban Development, compact cities should target a recommended population density of 150 persons per hectare (PPH). Applying this guideline to Jaipur's current stock of vacant land within the Jaipur Municipal Corporation (JMC) limits, it is estimated that the available vacant land (5,575.27 hectares) could accommodate approximately 8.36 lakh people, which equates to nearly 20% of the city's existing population.

Jaipur's current population of 37.07 lakh (Swachh Survekshan, 2019) increases to 45.4 lakh with the addition of this carrying capacity. Significantly, this figure aligns closely with Jaipur's projected population of 44 lakh by 2025.

However, sprawling patterns of urban development present major challenges. Such patterns force residents to travel long distances to access workplaces, services, and amenities. In 2019, more than half of the vehicles in Jaipur comprised two-wheelers and four-wheelers. With sprawl, reliance on individual motor cars will continue to grow, worsening greenhouse gas (GHG) emissions.

To overcome these challenges, Jaipur needs to re-examine its current growth pattern and overhaul its Master Development Plan (MDP). A new strategy must be focused on dense, sensitive development within the already urbanized portions of the city as opposed to unfettered expansion into the countryside. Uncontrolled sprawl may produce disadvantageous social, cultural, economic and environmental impacts in the larger Jaipur area.

Table 2: *Vacant Land Carrying Capacity (Approximation)*

Vacant Land within JMC (Ha)	Recommended Population Density (PPH)	Population that can be Accommodated
5,575.27	150	8,36,290

Source: Vacant Land – JDA

9. CONCLUSION

There is an interesting case study of urban morphology in Jaipur, in which the interrelationship of geography, history, culture, and planning has brought about a unique urban form over almost 300 years. The original plan of the city, created in the early 18th century by Vidyadhar Bhattacharya under Sawai Jai Singh II, was highly structured on the basis of environmental sensitivity as well as the concept of the universe. The geographical position of Jaipur, within the protective range of the Aravalli hills and within the Banas Basin and along some seasonal rivers, was a natural barrier and source of water and agricultural potential which played a role in shaping certain settlement patterns in the city.

The history of urban development in Jaipur, the original walled city, includes its highly systematic streets, markets, and residential areas, the gradual extension of the city beyond the walls in the 19th century, and the blistering transformation into a modern city in the 20th and 21st centuries, all of which bear witness to its adjustment to shifts in political, social, and economic scenarios. Historical events, like the foundation of the Jantar Mantar and the creation of tax benefits for merchants, have identified Jaipur as a cultural and trade center since the beginning. Subsequent developments in infrastructures and growth of the city by progressive rulers further spurred the urbanisation of the city into a modern city.

But then there are modern pressures, like unmanaged urban sprawl, land-use change fragmentation, and poor infrastructure planning, which have started to tax Jaipur in terms of its historic urban form and ecology. The dissimilarity between estimated and actual growth rates, the use of old census data to plan and the low-density outward shift pose threats to the cultural heritage and the environmental sustainability of the city. These emerging challenges underscore the pressing need for renewed policy focus on densification, sustainable land use, and transport-orientated development that respects Jaipur's historic legacy.

Jaipur will need to strike the right balance between preserving its rich heritage, optimally utilising vacant land to meet population growth targets, and mitigating environmental impacts to ensure sustainable urban development. Jaipur can build an inclusive future by blending old-world planning insights with the new urban management and governance tools. After all, the case of Jaipur shows how essential comprehensive studies of the urban morphology can be in leading historic cities through the challenges of the modern urbanisation process without losing their unique character and sense of vibrancy.

10. STUDY IMPLICATIONS

The findings of this research have far-reaching and multidimensional implications for the urban morphology of Jaipur. It, first of all, highlights the fact that traditional ways of environmentally sensitive planning, such as that of Jaipur, its gridiron scheme, and combination with the natural topography, can be used in the contemporary design of a sustainable city. The study points out the urgent necessity of new data-driven urban management policies capable of responding to the demands of fast urbanisation, including uncontrolled sprawl, a lack of infrastructure, and environmental degradation. By demonstrating the socio-spatial structure of the city that balances heritage conservation and modern requirements, the study provides planners and policymakers with a subtle framework through which informed land use, transport, and housing decisions can be made. In addition, knowledge of the social structure and spatial integrity of Jaipur's neighbourhoods supports inclusive urban governance and community-based development. These observations will add value to the general discussion on maintaining the identity and cultural heritage of historic cities in India and managing the pressure for growth, thereby presenting a useful resource to urban scholars, planners, and administrators who need to balance the need to preserve heritage with the demands of sustained development.

11. THE FUTURE SCOPE OF THIS STUDY

The future scope of this study lies in employing advanced spatial technologies such as remote sensing and GIS

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for continuous monitoring of Jaipur's urban sprawl and land use dynamics, allowing for predictive modelling to support adaptive planning. There is also a significant need to integrate socio-economic and cultural analyses to understand the spatial organization of caste-based settlements, economic activities, and their impacts on urban cohesion and inclusivity. Future research should prioritise sustainable and climate-resilient urban development frameworks by exploring green infrastructure, efficient resource use, and renewable energy integration within Jaipur's expanding urban fabric. More detailed land carrying capacity assessments aligned with updated demographics are critical to optimising land use and guiding density management. The delicate balance between heritage conservation and modern urban growth also requires further investigation, focusing on policies that protect Jaipur's historic identity amid rapid expansion. Strengthening governance through studies on policy implementation, institutional effectiveness, and public participation can improve urban management outcomes. Comparative studies with other planned historic cities could provide important lessons for Jaipur's future development. Finally, addressing growing challenges in urban mobility necessitates research in sustainable transportation solutions to reduce sprawl-related congestion and pollution. Together, these future directions underscore the importance of interdisciplinary research in guiding Jaipur's evolution into a sustainable, inclusive, and resilient city.

DECLARATIONS

Author(s) Contribution

All authors contributed equally to the conception, design, analysis, and writing of this manuscript on the urban morphology and master plan of Jaipur City.

Uses of AI Acknowledgement

Portions of this manuscript (including language refinement and organization) were assisted by an AI tool (ChatGPT). The authors reviewed and edited all AI-generated content and take full responsibility for the final version of the paper.

Funding Information

This research was conducted without external financial support. No governmental, commercial, or non-profit funding agency provided funds for this study.

Availability of Data and Materials

The data used and/or analysed in this study (including census data, spatial datasets, and planning documents) are available from the corresponding author on reasonable request.

Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Clinical Trial Registration (if applicable)

Not Applicable

Human Ethics and Consent to Participate

This study is based on secondary data analysis, spatial mapping, and documentary research, and did not involve human participants, clinical interventions, or experiments requiring formal ethical approval or informed consent.

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