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Monitoring Urban Sprawl: A Case of Jalandhar City, Punjab, India

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Abstract **Original Research Article**

Urbanisation significantly impacts both the sustainability of urban development and the quality of urban living today. Land, water, and the environment are under more pressure today, especially in large urban centres. It is due to rising urbanisation and industrialisation. As a result, the proportion of India's population living in urban areas has increased as well, from 79 million in 1961, or around 17.92 per cent of the country's total population, to 388 million in 2011, or 31.30 per cent, increasing the pressure on the existing city infrastructure and causing it to expand to its surroundings. Urban sprawl has led to the loss of surface water bodies, open green spaces, and fertile agricultural fields. Therefore, it is imperative to investigate, comprehend, and quantify urban sprawl. In order to take action towards the planned and healthy growth of urban areas, it is necessary to monitor such changes continuously and understand the procedures involved. Recent years have seen an increase in the use of remote sensing data for mapping and tracking urban sprawl. Together with traditional ground data, satellite data can be used to systematically map, track, and evaluate the spatial patterns of urban sprawl across time. To improve decision-making and promote sustainable urban growth, this study has made an effort to monitor Jalandhar City's built-up change over two time periods, from 1991 to 2021, to assess urban sprawl using Landsat series data.

Keywords: Urban Sprawl, City limits, Agricultural conversion.

INTRODUCTION

Urbanisation is essentially the process of land transformation, primarily brought on by urban drivers. The idea of this process evolving began with the creation of towns and cities, which eventually increased in size to become metropolitan and urban agglomerations. Urbanisation is a dynamic and complex process. It involves modifications to the structural and operational elements of built environments, hastening the infrastructural move from the city core to its suburbs. Changes brought by the urban milieu are dynamically fueled by various geographic, political, and environmental factors (Nourqolipour *et al*., 2016; Mondal *et al*., 2017; Sahana *et al*., 2018). Despite making up a tiny percentage of the earth's land area, metropolitan areas have profoundly impacted the environment, ecosystems, and society due to their fast expansion. As a result of this process, towns and cities will inevitably expand into their surrounding areas and beyond their legal boundaries to accommodate the expanding urban population (Mundia & Murayama, 2010; Bhat *et al*., 2017; Mosammam *et al*., 2017).

Numerous attempts have been made to quantify urban sprawl using various scientific techniques. Urban sprawl is a broad and ill-defined notion, making it challenging to measure. Measuring sprawl in urban areas rather than surrounding rural areas was common in earlier empirical research. In order to comprehend a dynamic issue like urban sprawl that necessitates assessments of land use change, the spatial approach has been widely appreciated and consequently applied. Additionally, the resultant thematic layers of sprawl from satellite images have been adequately created using GIS (Ismael, 2021).

India is not far behind in this unprecedented urbanisation development. By 2050, India is expected to have gained 416 million urban residents, the most extensive number of any nation (UN, 2018). India's population has doubled during the past 50 years, but urban populations have grown by a factor of five (Bhagat & Mohanty, 2009; Saini & Tiwari, 2020). Significant factors contributing to urban sprawl in Indian cities include the disproportionate conversion of farmland to urban uses, scattered and mixed land use,

commercial building development at the edge of cities, slums and squatter settlements, built-up housing without a proper plan, agricultural production areas usurped by urban units, dispersed location of settlements suffering from urban amenities, traffic congestion, etc. (Kalota, 2015)

With a total area of 50,362 km^2 or 1.53 per cent of the country's overall geographic area, the state of Punjab is situated in the country's north-western region. Punjab's agro-processing businesses were boosted by the green revolution in 1960. Investment in agriculture and related agro-based sectors expanded following the green revolution. Only 21.72 per cent of Punjab's population was urban in 1951. Punjab, in 2011, had a 33.95 per cent urban population compared to a national urban population of 27.78 per cent (Census of India, 2011). Punjab is India's fourth-most urbanised state after Tamil Nadu, Maharastra and Gujarat. The land of present-day Punjab is carved out by River Beas and Satluj, which divided the state into three geographically distinct regions viz. Majha, Malwa and Doaba. Its geographical setting blesses the state to acquire high agricultural productivity. And because of its fertile land, Punjab has gained the moniker "Food Basket of India" or "Grainary of India." About 12% of India's cereals are from Punjab (Statistical Abstract of Punjab, 2020). The present study takes the largest city of Doaba region, namely Jalandhar City, to evaluate the urban sprawl in the light of conversion of rural land, primarily agricultural occupancy.

Study Area

The study area selected for the current study is Jalandhar city, lying at the centre of Punjab state in the fertile alluvium tract of Bist Jalandhar Doab, referring to the land between Beas and Satluj rivers (Figure 1). The city lies precisely at the 31.32797, 75.57582 centroids. The city caters for a population of 8,62,886 persons within an aerial extent of 101.43 km^2 (Census of India, 2011). The city's hinterland is characterised by census towns, outgrowths and, prominently, villages.

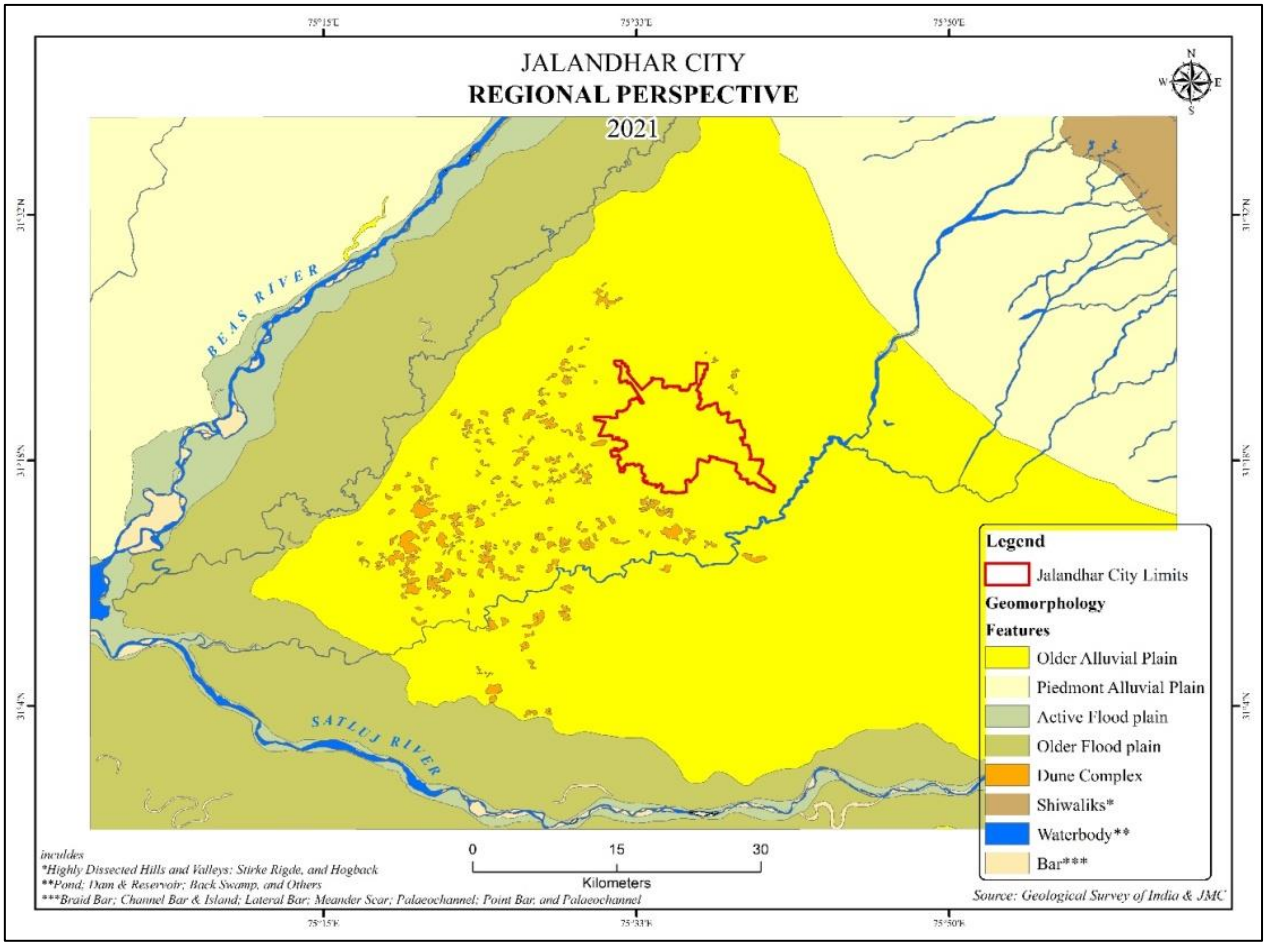

Figure 1: The regional setting of Jalandhar City

METHODS AND MATERIAL

The study involves implementing geospatial data and techniques to determine the nature of the urban sprawl of Jalandhar city. To track the heart of urban sprawl, two time periods are required; thus, the study includes satellite images of 1991 and 2021 years to see the change in the built-up class and form of urban sprawl. The Landsat TM image (1991) with a spatial resolution of 30 meters is incorporated into the process along with the Landsat OLI image (2021) to observe the

changes in the built-up features or the transformation brought by built-up features in the surroundings of the city. Initially, the hard copy maps from the Jalandhar Municipal corporation and Census of India and digital copies of the administrative units from the Survey of India are procured to prepare the basemap. Further, it is utilised to see the changes in the extent of the city in terms of expanding municipal corporation boundary limits and the inclusion of surrounding villages within the city limits. At last, various indices have been applied to quantify the patterns of urban sprawl in the selected study area.

ANALYSIS AND RESULTS

The analysis involves three stages of evaluation. Firstly, the change in the boundary limits of Jalandhar limits is observed, followed by the number of villages included under the city limits and, last, the tracing of the dynamics of urban sprawl.

1. Change in the Municipal Corporation Boundary

The first step in the process tracks the modification in the city limits (Jalandhar Municipal Corporation boundary) of Jalandhar from 1991 to 2021 (Figure 2). Within these 30 years, the municipal corporation boundary of Jalandhar city has extended three-fold. It covered an area of just 26.64 km^2 in 1991, with a percentage increase of 280.743 till 2021. The addition of 74.79 km^2 area in the municipal corporation elucidates the extent of urban expansion in Jalandhar city experienced, making it the most prominent city of the Bist Jalandhar Doab and the third most influential city of the state after Amritsar and Ludhiana (the two million-plus cities from Punjab).

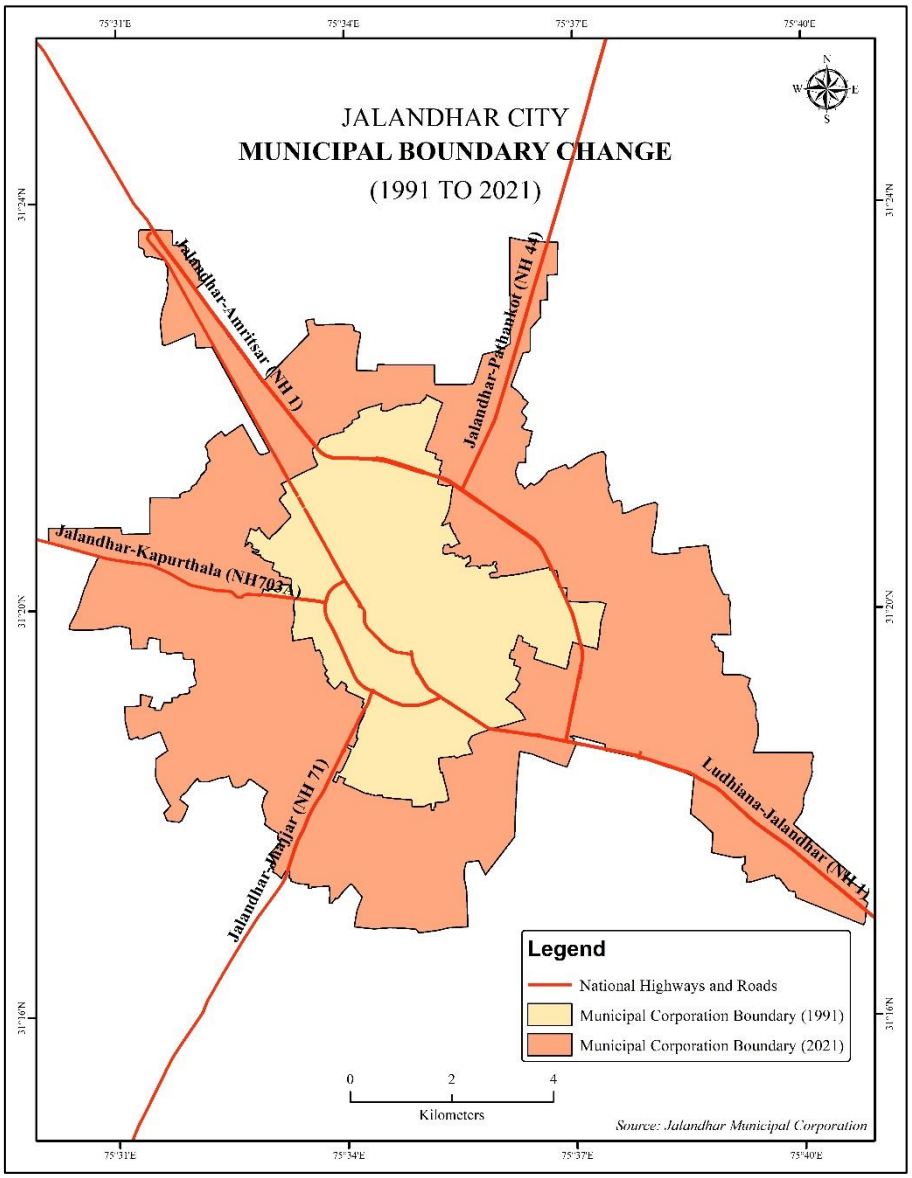

Figure 2: Change in the city limits of Jalandhar from 1991 to 2021

Jalandhar city's connectivity with other major cities across the country can also be noticed through its well-connected network of National Highways. Urban sprawl has historically resulted from several major factors, including population growth and enhanced mobility due to improved transportation linkages made available by new technologies (Shao *et al*., 2021).

2. Engulfing of Neighbouring Rural Land

As mentioned in the first step, the city limits have increased over time, which engulfed the surrounding villages and bastis of Jalandhar city. There was a total of 39 such units, which became part of the municipal corporation boundary by 2021. These villages and Bastis are Bulandpur, Nangal Weeran, Lidhran, Salimpur Musalmana, Gadaipur, Chak Zinda, Nandanpur, Maksudpur, Noorpur, Reru, Kotla, Nagra, Lamba Pind, Suchipind, Basti Bawa Khel, Chohak, Ladhe Wali, Basti Pirdad, Basti Mithu Sahib, Basti Guzan, Basti Nau, Chugitti, Basti Danashmandan, Dhilwan, Basti Shah Kuli, Basti Sheikh Darwesh, Dakoha, Dhenowali, Todar Pur, Kot Sadiq, Bring, Boot, Garha Vahin Da, Kingra, Khurla, Sabowal, Paragpur, Mithapur, and Luhar Nangal (figure 3). Along with the submergence of these villages, their rural land also becomes part of the city limits. In other words, the inclusion of rural land within the city led various actors to transform it into urban occupancy. The land restrictions, like strict land conversion laws, on rural land, will no more applicable once it becomes part of the city, escalating the rate of its transformation. The most significant emerging land-use class is undoubtedly built-up, led by numerous developmental projects supporting the population and making an ideal city. The circumscribing of surrounding village units supports the growing population and need for infrastructure expansion for some years. Then again, a necessity arises for further movement of built-up beyond the city limits. It led to the unopposable urban sprawl. The present scenario of Jalandhar City and the areas along its boundaries face the same pressure to support the ever-growing built-up expansion from the city limits, transforming the very nature of rural entities. During the last census survey, four villages at the edge of Jalandhar city were entitled as Census Towns (2011). These are Dhin, Khambra, Sansarpur and Sufipind. The inclusion of surrounding villages brings together massive transformational changes across the city region. The adjacent villages to the new city limits further get influenced by the urban amenities and aspire for change.

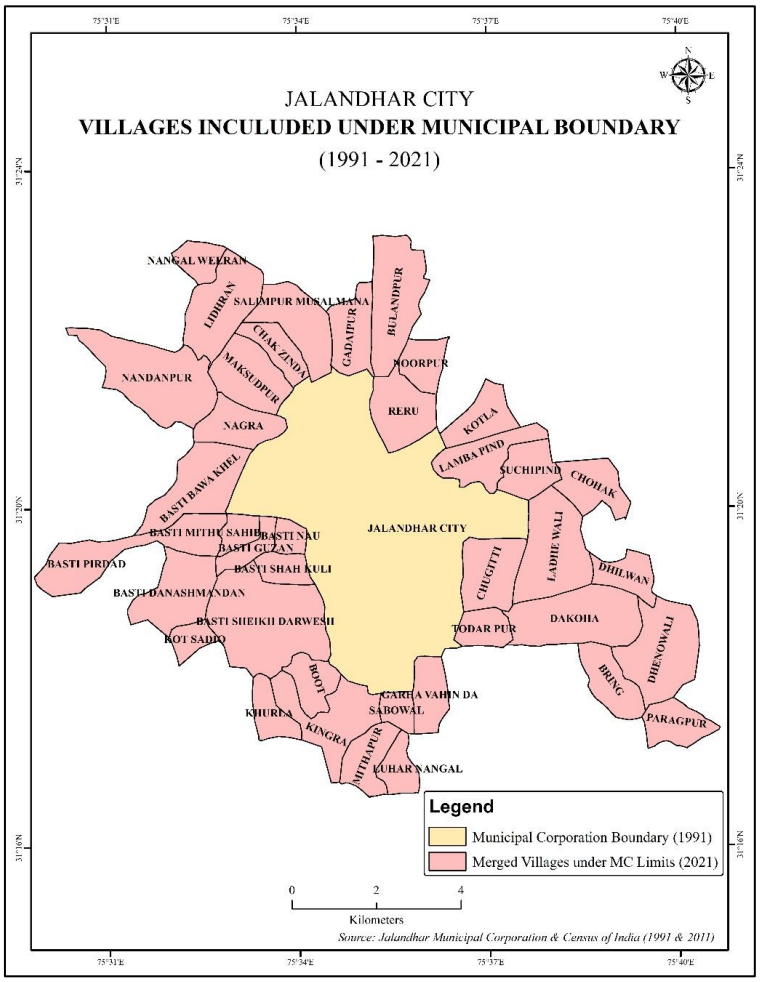

Figure 3: The proportion of rural units converted under city limits by 2021

3. Sprawl Dynamics

A buffer of 3 km from the municipal boundary (2021) is created to review the expansion of built-up around Jalandhar City. The urban sprawl is quantifiable by implementing the Built-up area extraction method (BAEM) (Bhatti & Tripathi, 2014). The suggested method takes into consideration three different indices, namely NDBI (Normalised Difference Built-up Index), NDVI (Normalised Difference Vegetation Index) and MNDWI (Modified Normalised Difference Water Index). Instead of binary values, continuous image values of these indices are analysed. For NDBI, the Principal Component Analysis (PCA) first components are used. The BAEM gives the built-up features while delineating the non-built-up ones in the stud area. The following calculations are incorporated into the process:

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

$$NDVI = (NIR - R) / (NIR + R) \quad .....Eq.2$$

$$NDWI = (G - NIR) / (G + NIR) \quad .....Eq.3$$

$$BAEM = NDBI - NDVI - NDWI \quad .....Eq.4$$

Built-up areas also pose high-temperature values in the thermal bands; therefore, thermal bands are also utilised in the process. As Landsat 8 OLI image (2021) is used for the process, the following bands (Table 1) from the sensor are procured to carry out the above-stated equations.

Table 1: Bands used to delineate built-up

Bands	Wavelength (micrometres)	Resolution (meters)
Band 3 – Green	0.53-0.59	30
Band 4 – Red	0.64-0.67	30
Band 5 – Near Infrared (NIR)	0.85-0.88	30
Band 6 – Shortwave Infrared (SWIR 1)	1.57-1.65	30
Band 7 – Shortwave Infrared (SWIR 2)	2.11-2.29	30
Band 10 – Thermal Infrared (TIRS) 1	10.6-11.19	100
Band 11 – Thermal Infrared (TIRS) 2	11.50-12.51	100

Source: U.S. geological survey. USGS.gov

Equation 1 includes the PCA components of Band 6 & 7 and Band 10 & 11. Both these components constitute SWIR under equation 1 and Band 5 as NIR to calculate NDBI. Similarly, for calculating NDVI (equation 2), Band 5 & 4 and for NDWI (equation 3), Band 3 & 5 are used. The output images from all three indices are brought to Raster Calculator under the GIS environment to calculate BAEM (equation 4). The resultant image gives a raster image of the built-up class, clipped from the boundary area of Jalandhar City in 1991, to assess the proportion of urban sprawl accurately. In the last step, the built-up present beyond the city limits (1991) and the city limits (2021) is also erased from the previous resultant image. The produced image (Figure 4) portrayed the extent of Urban Sprawl from Jalandhar City's boundary in 1991.

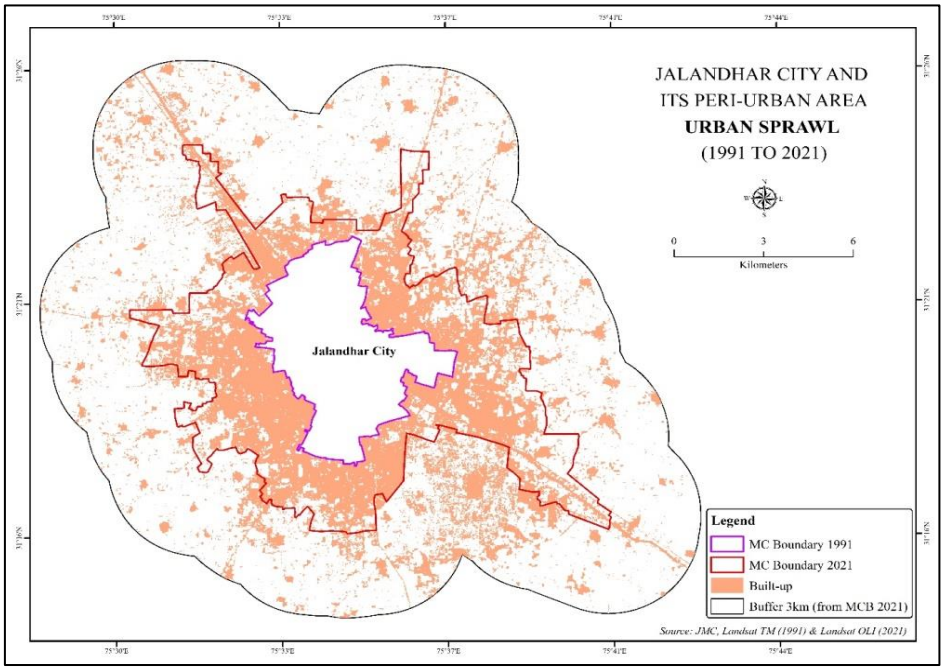

Figure 4: Built-up expansion beyond the Jalandhar City limits (1991 – 2021)

The total area of the buffer is 293.03 km^2, excluding the Jalandhar City area (1991), out of which built-up comes out to be 84.02 km^2. But if the proportion of built-up is observed within the city limits in 2021, then the built-up area comes as 49.54 km^2 of 74.79 km^2 total area. It exemplifies the intensity of sprawl with a coverage of 66.24 per cent in just three decades.

The accuracy assessment of the results is done through GPS points collected from the field at randomly selected locations across the study area. The kappa coefficient comes out to be 0.92, with an overall accuracy of 92 per cent for built-up features.

DISCUSSION

The expansion of built-up occurs mainly on the rural land surrounding the city. The rural land on the fertile alluvium tract supported agricultural practices (classified in the 1991 image). This cropland has transformed over the years along with other rural infrastructure, viz. unmetalled roads to metalled roads, mud/kutcha houses to concrete/pucca houses etc. Jalandhar City has been expanding to its neighbourhood as a natural urban phenomenon. The direction of its sprawl is haphazard, which includes majorly leapfrog type of sprawl across all the directions along with ribbon sprawl, which entails the concentration of built-up (figure 4) along the transportation axes, especially roads in the current research. As most of the roads are National Highway across Jalandhar City, these attract significant infrastructural developments in the present times. These roads bring efficient connectivity to the city with nearby and far-established urban centres propagating the transformational land drive across its periphery. The leapfrogging development pattern on undeveloped land is explicitly visible on the face of the city's surroundings, which have been posing and will continue to pose severe challenges to supporting the city's growing population adequately. The loss and conversion of prime agricultural land will also trigger food insecurity for city dwellers. Though the urban sprawl is unobstructed, to much extent, it can be precisely monitored and managed for the sustainable growth of the city, amicably supporting lives and nature.

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