

Monitoring Dynamics of Sprawling Bhopal “An Emerging Metropolitan”

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Abstract: Urban growth is a spatial and demographic process. Hasty rate of urban expansion pose endangerment to surrounding natural escape which is termed as sprawl. Data extracted from Landsat 5 TM 1991, Landsat 5 TM 2001, Landsat 7 ETM 2011, Landsat 8 OLI 2020 imageries was utilized to quantify urban expansion of the Bhopal city, with respect to direction and pattern, from 1991-2021. A direct relationship between population and built-up area is established, which reflects urban sprawl. Statistical study and spatio-temporal analysis of the data is done to account for these changes. The research revealed that Bhopal City has majorly spread towards south and south-east directions in an uncontrolled manner, engulfing used productive cropped areas. Sprawling pattern has evolved from radial to leap-frogging, with time.

Keywords: Sprawl, Population, Built-up Area, GIS, Quantification, Bhopal.

1. Introduction

The term urban sprawl is largely used by scholars dealing with urban development and its pattern. Researchers including environmental activists, town planners, demographers and geographers show keen interest in study of sprawl because of its multidisciplinary impacts (Ansari 2000; Franz et al. 2005). Smart cities as identified by Govt. of India, city capitals, cities with historical value and metropolitan cities are major centre of attraction, as they grow faster than other cities. Bhopal being a state capital, smart city and area of historical value has many attributes which makes it a desirable location to be identified for study, but still it credits very limited literature with regard to its sprawling (Aithal et al. 2014; Aithal et al. 2016; Bhattacharya et al. 2017;). Bhopal is the second largest city of the state of Madhya Pradesh (Pandey & Pandey 2016), built on a hilly area, having varied cultural and historical heritage. After Bhopal was made the capital of the state of MP in 1956 a number of central and state govt. offices were established and migration of people started (Census 1991). To make room for the offices and to develop residential accommodation, new constructions began in the area (Dhivya et al. 2015). Geographical expansion and socio-economic development of Bhopal, termed as urban sprawl, turned Bhopal into a vast metropolitan city. Sprawl is a broad topic which emphasizes on the outgrowth of a city on its border regions. This growth (sprawl) is unauthorized, low density, haphazard and auto-dependent (Banai et al. 2014). The area under urban sprawl is characterized by a condition where urban development unfavourably hampers with urban environment which is neither tolerable urban situation nor pertinent for an agricultural rural environment (Chandrasekar et al. 2010; Tiwari et al. 2017). Study of sprawl and its types gives a detailed picture about spatial forms of urban footprint.

Sprawl is observed to obstruct regional sustainable development and thus raise wide social concern (Bruegmann 2005). This topic is very relevant in current scenario as it deals with the development, growth and size of urban centres of Bhopal. The rapid growth of population has given rise to the increasing pace of urbanization, by which there has been a significant migration of population

from rural areas to urban areas in search of better livelihood (Aithal et al. 2016). This phenomenon has completely changed the demographic, social, physical and cultural landscape.

With time, techniques to analyze sprawl have evolved from manual mapping to GIS (Geographical Information system). GIS has developed rapidly, bringing many new capabilities and innovations in spatial planning (Epstein et al. 2002; Bhatta et al. 2012). GIS has literally brought the world in our pockets. GIS is explored for planning and community development (Bhatta et al. 2009). Mapping population density and spatial distribution based on Satellite imagery facilitates in population planning (Batty et al. 2001; Bhatta et al. 2010). These advanced techniques are implied in this work to make accurate analysis about the spatial expansion of Bhopal city in the period of 1991 to 2021. The study further aims to do calculative analysis of sprawl and study the causative factors responsible for urban sprawl. In our previous work, the effect of sprawl on health and environment has been studied, now we have taken the study of the impact of sprawl to some other walks of human life and environment viz demographic, social, cultural and economic characteristics of the city.

Database – Secondary and tertiary (RS data) data have been used for the present study. However, field observations were also undertaken for verification of ground level realities. The following is the list of data sources employed in this study:

- Survey of India Toposheet No. F43/F7, F8, scale 1:50,000
- Census of India, 1991, 2001, 2011.
- Gazetteers of Bhopal District
- Town and Country Office record, Bhopal
- Municipality Corporation Office record, Bhopal
- Department of Statistic record, Bhopal
- Town Directory record, Bhopal
- Master Plan of Bhopal 1991, 2005, 2031 (Draft)
- LANDSAT 5 TM 1991, LANDSAT 5 TM 2001 and LANDSAT 7 ETM 2011, LANDSAT OLI 2020 (USGS portal)
- Google Earth Imagery

2. Methodology

The study is spread over a period of 30 years from 1991 to 2021. An integrated geo-spatial approach i.e. Remote sensing and GIS in conjunction with secondary data has been adopted in the study. The remote sensing and GIS data were handled with the help of ERDAS Imagine (Product developed by Leica Geosystems) and ArcGIS (Product developed by ESRI).

To create the maps of Bhopal for different decades, demarcating sprawling of Bhopal, toposheets were downloaded from website of Survey of India. Landsat Imageries were acquired from USGS portal and Bhopal Master Plan was procured from department of Town and Country Planning, Bhopal. The Survey of India toposheet no. F43/F7 & toposheet no. F43/F8 with scale of 1:50,000 were scanned. Using these toposheets, georeferencing of satellite imageries viz. Landsat 5 TM 1991, Landsat 5 TM 2001, Landsat 7 ETM 2011, Landsat 8 2020 were performed, followed by geometric correction using ERDAS Imagine 9.2 software. Approximately, 40 ground control points were selected in order to register the images to the Universal Transverse Mercator (UTM) coordinate system WGS 84 Datum. The shapefile was then created in ArcGIS. Thus, Geo-database for needed data was created. Images were then pre-processed including Image Rectification, Image Enhancement, Atmospheric Error correction and Image Destriping. Post processing of images they were classified using unsupervised methods creating signature file. Then, supervised classification was carried out using land use and land cover variable. Further ground truth reality was verified by Earth Google and the overall result was drawn. Finally, maps depicting sprawl of Bhopal metropolitan were prepared and decadal changes were studied. The detailed methodology is demonstrated in Figure 1.

3. Study Area

Bhopal is situated along 77° 25' E longitude and 23° 15' N latitude (Bhopal Master Plan, 2005). It is located in Huzur tehsil of Bhopal district. The city consists of old city, Tatya Tope Nagar, Bairagarh, Bharat Heavy Electrical Limited and a large number of nearby villages. Situated at an elevation of 550-600m (Bhopal Master Plan, 2005) above sea level, the city has a beautiful surroundings of low hills and large lakes. Location of Bhopal city is shown in Figure 2. Most of the city is situated on the Malwa plateau and to the south lies the main line of the Vindhyas, with the fertile valley of the Narmada beyond it. Having 85 wards,

covering a gross area of ~285 km² (Bhopal Municipal Corporation) including the lakes and hills, the city is a low-density city of 50 persons per hectare (PPH). Even if the areas of steep hills and the lake area of 38 km² are discounted, the density on habitable land remains low at 80 PPH (Dasgupta et al. 2013).

Bhopal as we see now has seen many phases of development under different rulers beginning from Raja Bhoj (Bhopal-State-Gazetteer-Vol-III.), passing on to Nawabs and the British Rule. King Vikramaditya desired to develop Bhopal around the Om Valley, but the development shifted towards the lake (Bhopal-State-Gazetteer-Vol-III). Old Bhopal as we see now, including Islamnagar, Jahangirabad, Peer Gate etc. was developed in the reign of Nawabs. Post-independence, after Bhopal was carved out as the capital of the state of Madhya Pradesh, TT Nagar, Govindpura, BHEL etc. were developed. This development marks the beginning of expansion of Bhopal, or sprawling of Bhopal. At the time of the preparation of the Bhopal Development Plan 1991, the city had already expanded to the north and the southeast.

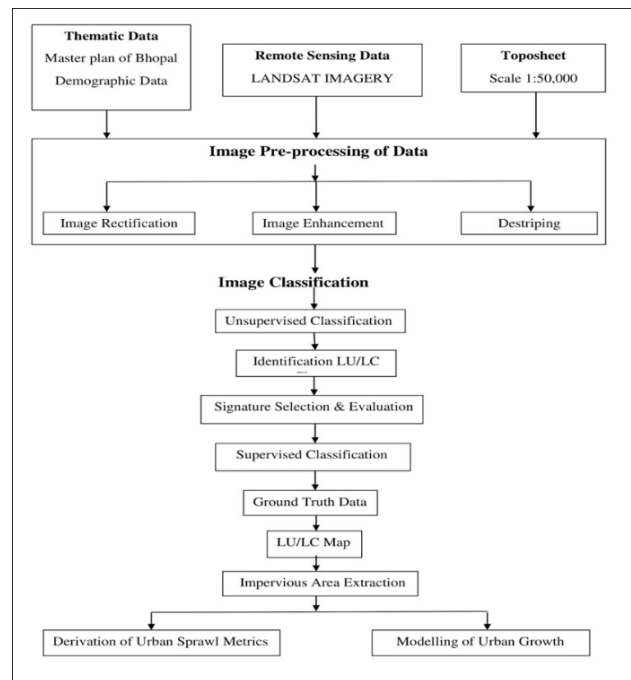


Figure 1. Flowchart explaining the steps followed to construct spawl and landuse map from GIS software

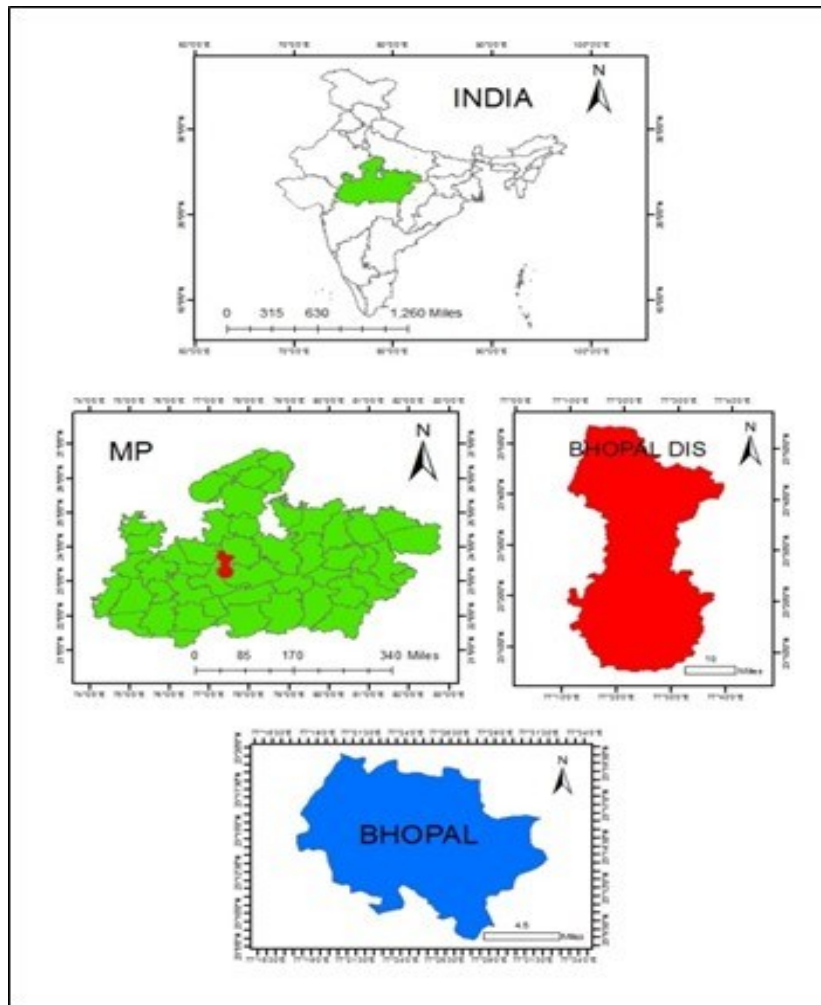


Figure 2. Location map of Bhopal district

4. Result and Discussion

Human built-up environment and natural environment, altogether makes ecosystem. Urban sprawl can be broadly studied by analysis of these two basic parameters over a period of time. Analysis of built-up area along with urban and rural fringe is a potential and a precise parameter that indicates sprawling (Brueckner 2000). This is then influenced by other parameters such as, population growth rate, migration, industrial development (Pareta et al. 2015) etc. Sprawl is influenced by the population in a particular region. To have a better view of how the city grows over time, and to drive a statistical illustration of urbanization, there is need to choose quantitative measures (Deal et al. 2004), which will summarize one or more characteristics that define urban sprawl. Quantification of sprawl is done by calculating the ratio of total population to the total built-up of the area under study, in a defined time zone.

In the present study, the analysis of expansion has been done on census year or decadal basis, in which population related data has been calculated from population district census handbook and construction area through GIS. Built-up area boundary is calculated from Master plan of Bhopal and Satellite data for 1991, 2001, 2011 and 2020. The built up areas and population for all three time periods is represented in Table 1. This data depicts clear and better illustration of urban statistics of Bhopal city.

Post emergence of Bhopal as state capital in 1956, built-ups kept growing continuously with every decade, however, the growth reported was highest in the time frame of 1991-2001. By the year 2011, Bhopal had expanded horizontally with growth in built-up area. The population growth rate declined in this decade by -8.19%, mainly due to the formation of the state of Chhattisgarh from the state of Madhya Pradesh. Emergence of a new state capital caused migration from Bhopal metropolis to newly formed state of Chhattisgarh. There has been a rapid growth in the construction sector during this decade, showing a speedy sprawl. Growth rate for last decade seems to be nearly constant, both for population and built-up land. In these 10 years, the construction area of the city has increased at the average rate of 14.24 km² per year, which is the highest decadal increase so far.

Later from 2001-2011 the change in built-up area was comparatively low and nearly constant for the next two decades, viz. 100.63% & 107.38%, respectively, indicating rise in vertical growth along with horizontal expansion. Similar trend is observed for population growth in the last 2 decades. Population grew with time however the growth rate appears to be controlled in the later decades. This implied that growth in built-up areas was in commensurate with growth in population of the city.

Table 1 Built-up area of Bhopal city (1991-2001)

Decade	Built-up area (km ²)	Change in Built-up area from previous decade (km ²)	Percentage change w.r.t. previous decade	Population	Change in Total Population w.r.t. previous decade	Percentage change over the previous decade
1991	15.80	-	-	1,062,018	-	-
1991-2001	66	50.20	317.72	1,458,416	3,96,398	37.32
2001-2011	132.42	66.42	100.63	1,883,381	4,24,965	29.13
2011-2021	274.62	142.2	107.38	23,90,000*	5,06,619	26.89

Source: Population data – Census 1991, 2001, 2011 & Approximated data 2021 by Bhopal Master plan 2031

Table 2. Change in Built-up area and Population of Bhopal City (1991-2021)

Year		1991	2001	2011	2021
Total Built-up Area		15.8	66	132.42	274.62
Change in the Built-up Area from Base Year 1991	Area in sq km	-	50.2	116.42	258.82
	Area in percentage	-	317.72	736.83	1638.10
Total Population		1,062,018	1,458,416	1,883,381	23,90,000*
Change in the Population from Base Year 1991	Population	-	396,398	821,363	1,327,982
	Population in percentage	-	37.32	77.34	125.04

Source: Population data – Census 1991, 2001, 2011 & Approximated data 2021 by Bhopal Master plan 2031

A comparative analysis of Table 2 clearly shows that- rise in population appears to be quite insignificant as compared to built ups, percentage wise, but it's comparable when the figures are equated. This can be understood by studying per capita land consumption in the respective time scales. Overall in 30 years the population increased by 13, 27, 982 with an average change of 44, 266.06 person per year. In this line, another parameter of sprawl, i.e., built up land increased by 258.82 km² from 1991 to 2021, and urban area stretched annually by about 8.62 km² in the period of our study. Growth in the construction sector is synonymous with urban expansion. The fact that urban expansion is influenced by population growth is established. Population rise is a clear reason for rise in built-up areas, an indicator of sprawl. To support this fact, statistical analysis of the above data has been made.

4.1 Statistical Analysis -

A linear graph has been drawn for the effectual understanding of the built-up and demographic dynamics of Bhopal in spatio-temporal context. Above stated factors are further supported by these graphs. Discussing first

about the change in built-up area, the deviation of slope from a perfect straight line ($R^2 < 1$) explains inconsistent change in built-up area with time. When we see the decadal change in built-ups, in the first decade it increased more than 4 times of the initial area available, accounting for highest % change i.e. 317.72%. After that in each decade built-up land of Bhopal almost doubled, i.e. 100% increase, to cater its growing needs. A sudden burst in built-up area by 50 km² from 1991 to 2001 can be devoted to development of Upper Lake for tourism purposes in the western side of the city on the highway connecting Bhopal with Indore. Also, new residential areas came into existence during this time. Although the city has expanded in all directions, the main growth was along the eastern parts of the city along National Highway No. 46. In the south east direction an industrial area was developed by the State govt. of the city. The Madhya Pradesh State Industrial, and Infrastructure Development Corporation has developed an Industrial Model Township on the Southern side of the city, a region which was prevented from development till 2001 due to its geographical design.

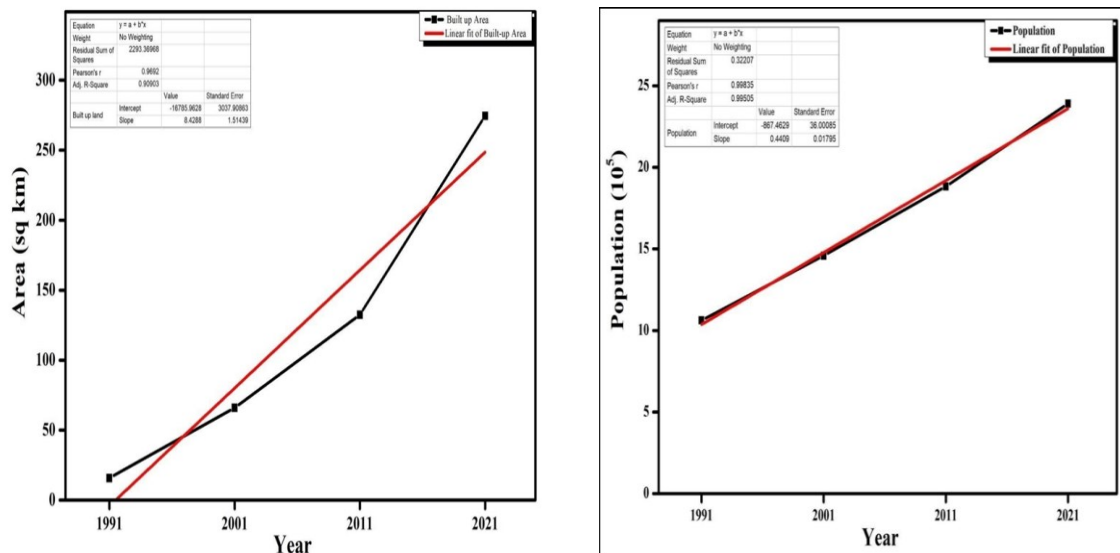


Figure 3. Comparative trend of built-up area and population

Study of slope value (8.4288) from 2011-2021 is highest than others, indicating that in last 10 years the built-up area has increased phenomenally i.e. ~142km² which is maximum in the 3 decades. Although growth rate was highest for the first decade, but from 2011-2021, Bhopal's potential was explored the most in all fields. Before this period although being a capital, Indore was preferred more by people of the state for job and educational purposes. By 21st century Bhopal became a city of choice for industrial, educational and service sectors.

Population of Bhopal has increased almost constantly with time, showing a perfect linear fitting, with a R² value of 0.999. This means average population change does not show much variation. The tentative population change for 2021 is also supposed to follow this trend, and fall in this same line.

Rate of population growth is plotted against different decades in Figure 3 This is however a declining graph, where slope value is 0.4409 with regression coefficient (R²) equals to 0.99505 Though population has increased decade by decade, but the rate is slower in comparison with its previous decade. In relation to constantly rising population in these decades the positive aspect was that the growth rate did not rise instead it decreased with every decade. The population growth rate for the last decade based on the estimated population deviates from this slope. Although the growth rate is lesser than the previous decade, contrary to this it has dropped with a slower pace. From 2001-2011 population growth rate dropped by 8%, whereas from 2011-2021 it is estimated to drop only by 3% approximately. However, even with the falling growth rate, the population increase was huge enough to invoke urban expansion and consecutive sprawling of Bhopal city.

Socio-ecological factors are equally valuable for accounting population change. Like, Bhopal gas tragedy in 1984 caused a huge mortality rate (Litt et al. 2017), thereby bringing a downfall in 1991 population count. The steepness of slope changes for next decade, showing a greater declining growth rate in 2001, is awarded to the state of Chhattisgarh being carved out and separated from Madhya Pradesh prompting migration of many government employees to the newly formed state.

Spatial and Temporal Changes: Urban sprawl is characterized by change in spatio-temporal characteristics of the area. Its overall a spatial and demographic phenomenon, occurred due to concentration of population within a specific society and economy (Li et al. 2012). Population trends in the city and urban sprawl refer to the area expansion of urban concentration beyond what they have been. This rise in population in turn demands more residential land and hence affects land cover within and around the urban area including forest cover, green cover, agricultural land, waste land, water bodies etc. (Alaguraja, P., et al. 2010) This demand is compensated either by discrete construction in urban fringes or multi-storied constructions within the city and filling the gaps in the urban space. The job of accommodating the growing population and making enough space for all is carried out by the department of town planning. The team based on GIS data and Remote Sensing images, prepares a future map to deal with the future needs, and this involves study of spatial and temporal structures in morphology of the city. Sprawling of Bhopal in terms of built-up area and land cover for different decades is shown in Figure 4.

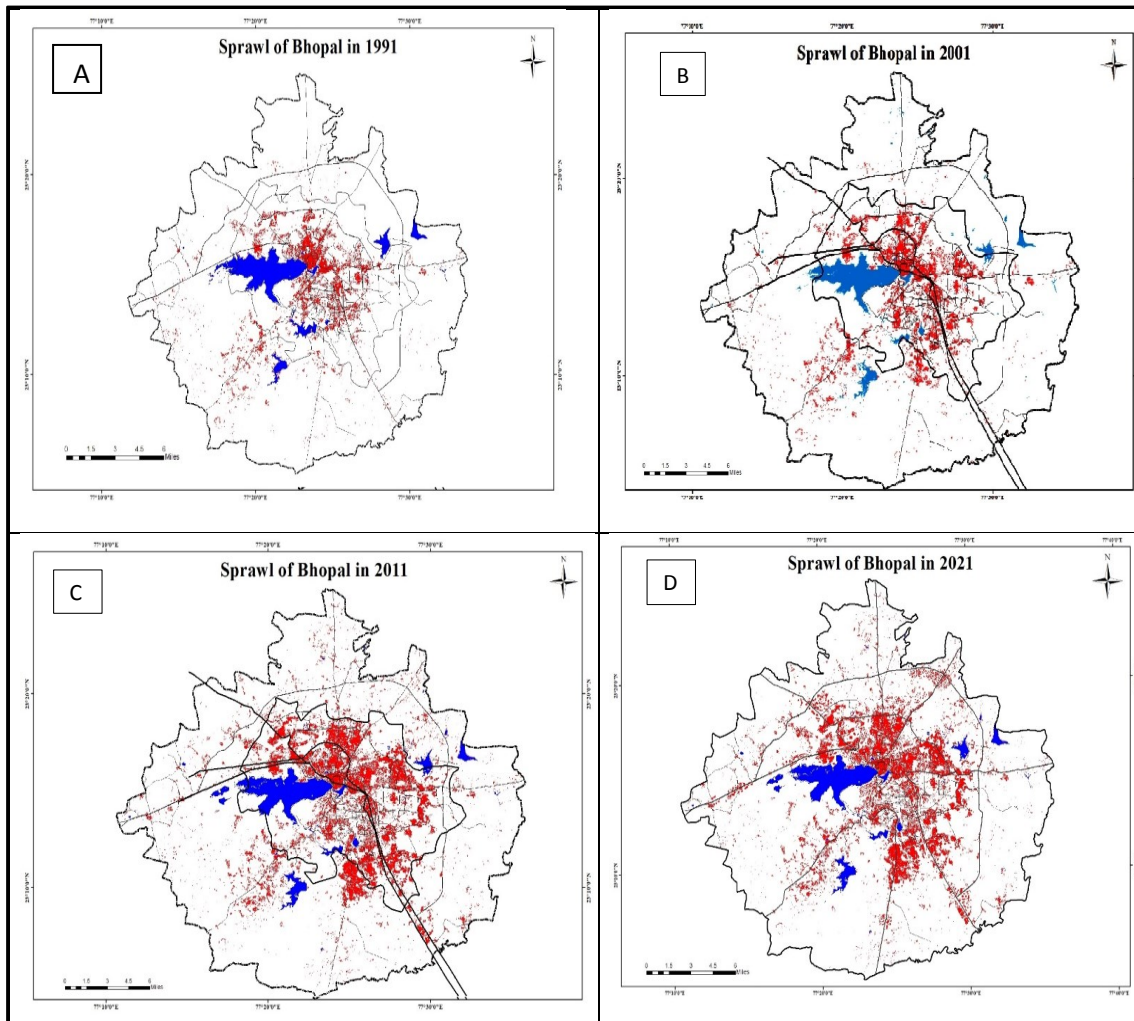


Figure 4. Decadal Change in Built-up Area

Sprawling pre-1991: Till 1991, the total population of city - 1,062,018 was spread over total built-up area of 15.8 km², as reported. Remote sensing images of Bhopal district display semi-radial development around CBD, until 1991. The pressure of continuously expanding city centres, when gradually affects the associated environment and neighbourhoods, around the edge of the core, is termed as radial contiguous sprawl. Often, CBD is the urban area which is most densely populated. Old Bhopal was the only CBD of the city. In radial sprawling, development of the peripheral area of the CBD (Central business district) takes place coupled with city roads. An excessive construction work from Old Bhopal towards the outer boundary demarcates urban expansion in pre-1991.

All sorts of facilities viz residential, commercial, health, entertainment etc. got concentrated in the core of the city. The area in and around city centre became densely populated. Rise in degree of residential inaccessibility served as an impetus for people to settle at urban fringes of the Bhopal district. To cater the lack of functional space initially, new colonies began to develop in unplanned and isolated form known as termed as breed or diffusion growth

Spatial temporal Sprawl: From 1991 to 2001 – There has been a rapid growth in the construction sector during

this decade. Where the total built up area was 15.8 sq km in 1991, it increased to 66 sq km in 2001, showing rapid expansion of the city. Data table and GIS images altogether display that during 1991 to 2001, the built-up area grew at the rate of 5.02 sq. km per annum with a tenuous growth of 317.72 percent. The main reason for the rapid expansion during this period was the successful implementation of Bhopal Development Plan 1991 by the state government. Many development schemes were implemented in the city, as a part of the Development Plan which became the reason for prompt expansion.

The construction work before 1991 was mainly unplanned, except for that in the BHEL residential area. After 1991 BHEL stretched in the east towards Raisen Road, in the North East towards Vidisha Road (bypass); and in the southeast towards Misrod along the Hoshangabad Road fragmented expansion of the city is observed. The direction of enlargement of the city is determined by its geographical distribution. Presence of lake in the south-west hindered growth of city in that direction.

Satellite imageries of Bhopal for 1991 to 2001 confirmed the major developments took place alongside the lower lake. In the southern periphery Berasia road, in south east direction Pratap Nagar and Old Subhash Nagar on the Hoshangabad road alongwith NH-12 were affected by

expansion of Old Bhopal. This semi-circular development occupied BHEL Township in East and Sagar-Raisen road (NH-86) in North East of Bhopal. Growth of Lalghati from Old city besides the upper lake in the north-west completes the semi-radial pattern of development.

Spatial temporal Sprawl: 2001-2011 - A decadal growth of 100.63 per cent is observed in this decade. The total construction area during this period increased to 132.42 sq km with an increase of 66.42 sq km at the rate of 6.64 sq km per annum. As stated before, declined growth rate in this decade, is mainly due to the division of the state of Chhattisgarh from the state of Madhya Pradesh. Due to this, the state capital was changed, resulting in the migration of people from Bhopal metropolis to Raipur, also there was a decline in rural migration towards Bhopal.

Studying the spatio-temporal changes from 2001 to 2011, by aid of remote sensing images show that in south eastern direction development took place along NH-12 from Railway colony to Misrod and in northwest this highway extended besides lake along Vallabh Nagar. In the south eastern side of Bhopal sprawl is visible in Avadhपुरi, Jharkheda, Shobhapur, Toomda, Mandideep, Obaidullaganj and ThunaKalan areas. Development was also observed beside Kolar road marks expansion in the southern direction. NH 86 was also hit by sprawling in the northeast face as a consequence to which KainchiChola, Navjivan Colony, Nawab Colony, Devki Nagar, NariyalKheda along by-pass and area around Trilanga were affected by it. NH-18 in the western direction of Bhopal spread across Lalghati into Pooja Shree Nagar, Hemu Colony etc.

Spatial temporal Sprawl: 2011-21 - There was a decadal growth of 107.38% during this time period. In this time, the construction area of the city has increased at the rate of 14.24 sq. km per year, which is the highest increase in decades so far. The total construction area during this period increased to 274.62 sq km with an increase of 142.2 sq km. Many new urban settlements have come out of Bhopal city and are part of the city. These small or big new urban centers are clear results of the leapfrogging expansion of the Bhopal city.

Misrod, Mandideep Industrial Hub, Kolar, Kotra Sultanabad, Anand Nagar, Lalghati, Bairagarh etc. are the areas which are result of sprawling in previous decade and have become so densely populated that they itself popped out as core areas for further stretching out of the city. For example, Golden city, Shri Ram Colony, Sneh Nagar, Bhairapur have developed around Misrod expanding the south western boundary of Bhopal along NH-12. Another well-known characteristic of this sprawl is it favours development of parcels located further out in the counties over the empty lands adjacent to existing development (Torrens et al. 2000). A few developments around Kolar in the South can also be named out from the map- Sarvadharam colony, Mahabali Nagar, Shridipuram, Banjari, GehunKheda, Rajharsh colony etc. Kamla Nagar, Gomti Colony, Type-9, C-Sector, Dwarikapuri colony are the areas developed with respect to Kotra Sultanabad along Bilkisganj road. The eastern boundary of the city has

expanded around Anand Nagar area in the form of Siddharth Lake City, Press colony, Gopalnagar, Sukhsagar etc. NH-18 in the northwest side of Bhopal also shows immense growth.

Leapfrogging creates functional decentralization and haphazard development patterns in fringe areas. This development consumes large amount of land and causes land fragmentation. This growth is characterized by dispersed development of residential, semi-public and industrial area. With the advancement in time, these sprawling patterns show interconversion due to rapid growth. Here we can see how radial contiguous sprawl in 2001 and ribbon development in 2011 has converted to leapfrog development in 2021 for the case of Bhopal city.

5. Conclusion

This research conceptualized urban sprawl from a geographic perspective in order to assess the spatial distribution of sprawl patterns. In this work, with the use of GIS and remote sensing technology an attempt has been made to study the criteria and patterns of expansion of state capital of Madhya Pradesh with respect to direction in the recent three decades. An alteration in spatial-temporal pattern of urban area from radial to leap-frogging via linear is seen. It also helped to understand the need of built up area for the growing city and the way in which the demand is being fulfilled. Bhopal has proved to be good example for quite a planned expansion compatible with sustainable development. However, there is further need to zoom in this study to particular targeted areas, to understand the nature of development of those locations. Apart from population and built-up land, there are many other reasons which visibly support this phenomenon- such as rise in expenditure, capacity, living standard, transportation cost etc. Future study could be directed towards studying these supporting factors and widespread effects of sprawl. There is further scope to analyze changes in land use pattern as a consequence of urban sprawl. This will give a clear idea of how demographic transitions have lead to the shaping of the city into this present metropolitan landscape.

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