Measuring Urban Shrinkage in India Using Night-Time Satellite Data

Abstract:

Urban shrinkage has become a global phenomenon, with an increasing number of cities experiencing population decline. However, research on urban shrinkage has primarily focused on Western cities, overlooking urban shrinkage in developing countries. Studies highlighted that India has a major concentration of shrinking cities in Asia. Thus, this study primarily aims to quantify urban shrinkage in India using night-light data, examining spatial patterns and verifying urban shrinkage with night-light and census data measures. The findings indicate a rising trend of urban shrinkage in India with clusters of shrinking cities in selective regions. Overall, 17.4 percent of urban units experienced high urban shrinkage intensity during 1992-2021. The spatial pattern of urban shrinkage was similar in both census and night-light datasets, however, night-light highlighted new shrinking urban units. Moreover, the statutory towns experienced a higher intensity of urban shrinkage compared to the other settlements. Understanding the paradoxical nature of urban shrinkage in a low-urbanized country like India is crucial for better urban planning. Furthermore, addressing the challenges posed by shrinking cities will help achieve sustainable development goals by adopting an inclusive approach for all urban settlements. Striving for balanced urban growth is crucial for fostering economic prosperity and reducing regional inequality.

Keywords: Urban shrinkage, shrinking city intensity, night-time light data, city growth.

1. Introduction:

The global phenomena of urban shrinkage:

Since the early twentieth century, shrinking cities have been a global phenomenon. The number of shrinking cities has increased faster than the number of growing cities. These cities are mostly concentrated in Central Europe, the United States, Japan, and Eastern Europe (Oswalt & Rieniets, 2006). However, recent studies have highlighted that this phenomenon is also prevalent in developing countries (Richardson & Nam, 2014). Despite steady urban growth and relatively low levels of urbanization, many urban centers experienced population loss, which is paradoxical (UN-Habitat, 2008). The term 'urban shrinkage' or 'shrinking city' has evolved from the German term "Schrumpfende Städte," meaning the issue of population loss addressed in the 1970s. It began to spread worldwide from East Germany and was first coined during the late 1970s, introduced by Göb and further explained by Häußermann & Siebel (1988). The term describes a type of city that experiences population loss and faces economic decline (Van den Berg et al., 1982). This phenomenon is primarily influenced by economic restructuring, suburbanization, deindustrialization, fertility decline, population aging, and selective out-migration (Cox, 2014; Hasse et al., 2016; Wiechmann & Pallagst, 2012; Zhai et al., 2022). According to the World Urbanization Prospect, population decline has been recorded in many cities across the globe, most of which are located in Asia and Europe (UNDESA, 2019). Evidence shows that urban shrinkage is predominant, especially in developed countries but also occurs in developing countries, while the nature, pattern and drivers are different (Pourahmad et al., 2016). Recent studies show that 54 percent of urban areas in Europe are shrinking (42 percent of them are large cities), 13 percent in the United States (Haase et al., 2016; Wiechmann & Pallagst, 2012), and 10.2 percent in developing countries.

Urban shrinkage is a multidimensional phenomenon, therefore there are several theories to explain this phenomenon. One of the pivotal theories that explains urban shrinkage is industrial transition theory. It suggests, urban shrinkage results from the shift from an industrial to a post-industrial society (Beauregard, 2009). As cities in the developed countries transitioned from manufacturing to a service and knowledge-based economies, traditional industrial areas started experiencing decline. Further it led to job losses, economic restructuring and, subsequently, population decline.

The globalization theory suggests that competition among the cities has been accelerated due to globalization and the competition led to growing cities and also declining cities. Cities, which are unable to attract population and investment are more prone to shrinkage (Rusk, 2023). Citi’s ability to provide an attractive quality of life, technological innovation and adaptation to changes play key role in the competition. Another perspective to look at urban shrinkage is socio-spatial polarization theory. It suggests that urban shrinkage results from increasing socio-spatial disparities among cities in an urban system. Economic transformations often lead to spatial divisions in the urban fabric, with prosperous areas attracting investments and declining areas experiencing neglect (Hamnett, 1994).

The Demographic Transition Theory underlines that changing population dynamics as a key factor for urban shrinkage. This theory suggests that declining birth rates, aging populations, and altered migration patterns are key drivers of urban shrinkage (Martinez-fernandez et al., 2012). Political-Economic Theory takes a broader perspective, linking urban shrinkage to political and economic structures at regional, national, and international levels. It argues that macroeconomic policies, political decisions, and larger economic cycles play a critical role in the decline or growth of cities (Logan & Molotch, 2007). Furthermore, ecological perspectives have also been employed to understand urban shrinkage. This theory suggests that cities, like natural ecosystems, go through stages of growth, maturation, decline, and rejuvenation (Pallagst, 2010).

The theories highlight that the nature of urban shrinkage varies across space and different socioeconomic setups, and it has wide implications for the quality of space.

Urban shrinkage in developing countries perspective:

In the context of global urbanization, much of the scholarly discourse has been dominated by narratives centered around the rapid urban growth characteristic of many developed nations. However, lurking in the backdrop of these narratives, especially in the context of developing countries, is the less discussed but equally significant phenomenon of shrinking cities. UN-Habitat (2008) conducted the first systematic study on shrinking cities in developing countries. While studying 1,408 cities in developing countries, it has been found that approximately 143 cities/towns experienced a population decline between 1990 and 2000; approximately 60 percent of the cities are in Asia. While China is most affected by the major share (58 percent) of the declining cities in Asia, Indian cities also account for a smaller share (18 percent). In a country such as India, historically celebrated for its pulsating urban centers and burgeoning metropolises, the reality of shrinking cities presents a paradox that requires careful examination (Gupta & Sharma, 2018). The concept of shrinking cities, although largely documented in the context of postindustrial landscapes of the West, has manifested distinctively in the developing world. However, studies have indicated a significant increase in the number of shrinking cities in several developing nations in Asia, Africa and Latin America (Rechardson & Nam, 2014).

Emerging methodology:

Demographic data collected by census clearly reflect the population dynamic as a whole. However, it does not reflect upon variation within the city with timely comparison. Hence, a comprehensive understanding of the urban shrinkage process is difficult to study with census data only for many countries. Night-time satellite images have become a new way to present the perspective of human activities even more accurately (Bennett & Smith, 2017; Elvidge et al., 2001; Huang et al., 2014; J. Wu et al., 2013). Studies show that night-light intensity is highly correlated with population distribution and economic activity (Doll et al., 2006; X. Wang et al., 2019). The time-series analysis of night-light data enhances a more profound understanding, capturing and monitoring of urban dynamics (Potere et al., 2009). It is much more useful for areas where official statistics are often not available in a timely manner (Wardrop et al., 2018). The night-time satellite data collected through remote sensing provide a track of changes taking place on the earth's surface as well as changing human activity.

Several studies have argued that these data can be viewed as a fair representation of changes in urban population, economics, society, and construction (Elvidge et al., 2014; F. Li et al., 2020). Additionally, time-series analysis of night-light data is especially useful for detecting, estimating, monitoring, and projecting urban developments in countries and subnational regions (T. Ma et al., 2012; Zhuo et al., 2009). It is also very helpful to understand the inequality in the region (R. Wu et al., 2018). Night-light data also provide an opportunity to go beyond the traditional administrative boundary to the microunits at each square kilometer. Several studies quantified the population growth, distribution, urban extent, urban growth, economic growth, and gross domestic product (GDP) using the same data (Bhandari & Roychowdhury, 2011; Henderson et al., 2012; Kummu et al., 2018).

Rationale and aim of the study:

Urban shrinkage has become an increasing concern for many developing countries over the last few decades. Asian countries have been particularly affected, with India and China believed to have a high number of shrinking cities (UN-Habitat, 2008). The literature indicates that shrinking cities are a significant feature of India's urban landscape as well. Paradoxically, while only one-third of the population resides in urban areas and there is consistent growth in the urban populace, some urban centers are still witnessing population decline. However, there is a dearth of knowledge on the spatial pattern of shrinking cities in India, and areas such as the causes and consequences of urban shrinkage remain unexplored in the Indian context.

This study uses the unique approach of using night-time stable light data to identify shrinking urban centers in India. This study attempted to address two main objectives. One is to understand the spatial perspective of urban shrinkage in India by examining the spatial-temporal pattern of shrinking cities in India during 1992-2021. The other objective is to verify the spatial pattern of urban shrinkage using both satellite data and census data.

2. Methodology:

This exploratory research is based on various data sources, including night-time satellite data, spatial data layers, and census data. The primary objective of this study is to quantify urban shrinkage in India and validate it by comparing the results obtained from census and night-light data. The following section presents a detailed description of this study's data sources and methods.

2.1. Data sources:

The data sources included night-light data, population data, and multiscale boundary data. Table 1 provides a detailed summary of the data sources used in this study. The study is primarily based on the long-term night-light data. The NOAA's National Geophysical Data Centre and Earth Observation Group (EOA) are the primary source of night-light data. The annual DMSP/OLS night-light dataset provided by NOAA and NPP/VIIRS data was provided by EOG. These are widely used time-series data for studying urban growth dynamics and urban development (Ma et al., 2012; Zhang & Seto, 2011). Here, three data types are given: cloud-free coverage, night-light data with no further filtering, and night-time stable light data.

However, this study used night-time stable light data to fulfil the study objectives. The annual average data correct the error generated from sunlight, glare, moonlight, clouds, and ephemeral events, such as fires. The dataset consists of a raster layer containing digital number (DN) values. The value of DMSP/OLS data ranges from 1 to 63, where the background and noise are coded as no data or zero (Lowe, 2012; Yang et al., 2013). Further, NPP/VIIRS newly published data were to cover the recent years (2013-2021). The spatial resolution of the data is 15 arc second.

In the datasets, a higher value indicates higher brightness, and a lower value indicates darkness or less light. Several sensors were equipped over the years to capture the night-light reflection (Table 1). The DN value present in the data is the annual average night-light reflection of a particular location at a one-kilometer resolution.

Table 1: Description of the data used in this study.

Data	Data description	Time Period	Resolution	Source
DMSP/OLS	Annual night-time stable light data from Version 4 DMSP/OLS Night- Light Time Series Data	1992–2013	1 km	NOAA/NGDC (https://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html)
VIIRS	Annual night-time stable light data	2013-2021	0.5 km	Earth Observation Group (https://eogdata.mines.edu/products/vnl/)
Boundary layers	Spatial Data from the 2011 India Census (Balk et al., 2019)	2011	N/A	Socioeconomic Data and Applications Center (SEDAC) (https://sedac.ciesin.columbia.edu/data/set/india-spatial-india-census-2011/data-download)
Population data	Year-wise population data for all towns and cities	1991-2011	N/A	Census of India- town directory https://censusindia.gov.in

Furthermore, to verify the spatial pattern of urban shrinkage and urban shrinkage intensity in India, census data have been used to identify shrinking cities based on census population data. In this study, a shrinking city was defined as a city or town undergoing population decline for two time periods (Martinez-Fernandez et al., 2012).

The spatial data for the classification of settlement type were obtained from the Socioeconomic Data and Applications Center (SEDAC). The layer provided the shape area for different settlement types, such as rural, area, census town[1], statutory town [2]and outgrowth[3] (Balk et al., 2019). The data layers identifying settlement types were derived from official population and settlement tabulations, integrated with the Global Human Settlement Layer data. In this work, we have only considered the census town, statutory town and outgrowth as urban areas for further analysis. The analysis in this study required the administrative boundary of each town and city. However, due to the unavailability of an administrative outline of each town and city, we created a fishnet over the urban area shape file using the fishnet tool. The resolution of each box was 5 kilometers, and each box was considered an urban unit or a part of an urban center. Further analysis was performed to identify shrinking areas, considering the urban unit as a spatial unit of an urban area.

2.2. Methods:

The nature of shrinking cities is very complex; therefore, the definition varies among scholars. However, population decline has often been considered the key indicator of urban shrinkage due to the unavailability of data (Haase et al., 2016; H. Li & Mykhnenko, 2018). According to Haase et al. (2017),'shrinking cities' are cities that have population loss, economic downturn and related problems.

Table 2: Definition of shrinking cities

Authors	Year	Definition of shrinking City
Oswalt & Rieniets	2006	Cities where the total population loss is more than 10 percent or the average annual population loss for three consecutive years is more than 1 percent.
SCIRN	2012	A city with a population of more than 10000 experienced a population decline two times (Martinez-Fernandez et al., 2012).
Haase et al., 2017	2017	Cities that have population loss, economic downturn and related problems.
RE- CITY	2018	A shrinking city refers to an urban region with at least 5,000 inhabitants that has experienced a substantial decrease in its population over five years or more and exhibits signs of structural change (Re-City, 2018).

[1] Statutory town: All places with a municipality, corporation, cantonment board or notified town area committee, etc.

[2] Census towns: the places that follow all three criteria i) A minimum population of 5000 ii) At least 75% of the male main working population engaged in nonagricultural pursuits, and iii) A density of population of at least 400 persons per square kilometer.

[3] An Outgrowth (OG) is a village or hamlet with distinct boundaries and urban characteristics, located very close to a statutory town.

However, this study defines shrinking cities as any urban centers that have experienced negative population growth for two decades to understand urban shrinkage based on census data. This definition was followed because, in India, only decadal census data are available.

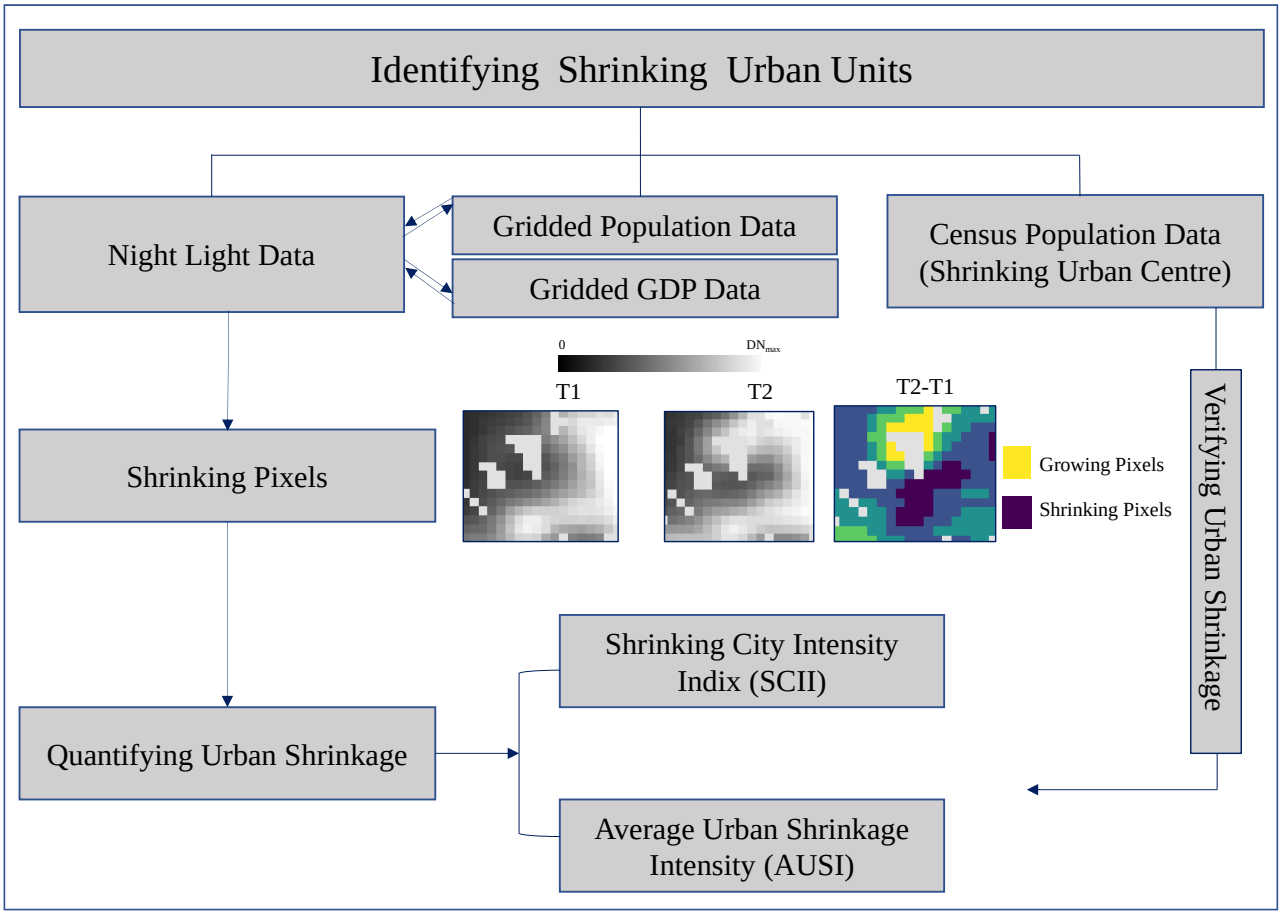


Figure 1: Procedure for measuring urban shrinkage in India (Wang et al., 2022; Yang et al., 2021).

The analysis in this study includes two major sections. In the first section, we tried to understand the night-light growth dynamics and shrinking cities during 1992-2021 in India. Further, the following formulas were implemented to quantify the urban shrinkage in India. A conceptual framework has been presented consisting of all details of the methods and interconnections (Figure 1).

The night-light growth rates were calculated using the following formula to identify high and low growth rate areas.

$$\text{Growth Rate}_{(t,t+1)}(m) = \frac{\text{Pixle Value}_{(t+1)} - \text{Pixle Value}_{(t)}}{\text{Pixle Value}_{(t)}} \times 100 \qquad \text{(Equation 1)}$$

The following two methods have been used to identify shrinking urban units and measure the intensity of urban shrinkage:
Shrinking City Intensity Index (SCII):

An index has been developed to quantify the urban shrinkage intensity by calculating the SCII. The SCII was calculated based on night-light time-series data from 1992 to 2021 and the total night-light value for two time periods in a city or town.

$$SCII_{(t,t+1)}(m) = \frac{TDN_{(t+1)}(m) - TDN_{(t)}(m)}{TDN_{(t)}(m)} \times 100 \qquad \text{(Equation 2)}$$

where $SCII_{(t,t+1)}(m)$ is the SCII of the m^{th} city from the t^{th} year to the $(t + 1)^{th}$ year, and $TDN_t(m)$ and $TDN_{(t+1)}(m)$ are the total DN values (TDN) values of the m^{th} city in the t^{th} and $(t + 1)^{th}$ years, respectively.

A city was considered shrinking if the TDN value decreased by more than one percent between time t and t+1. Further, based on the SCII valur urban centers were classified into categories such as no shrinkage, low shrinkage, medium shrinkage and high urban shrinkage.

Urban Shrinkage Intensity:
The spatial resolution of raster images allows us to analyze pixel shrinkage by measuring the intensity of shrinkage. Based on a previous study, we classify pixels as shrinking if their digital number (DN) decreases by more than 15 percent in successive years.
The urban shrinkage intensity (USI) is defined as the ratio of the total number of shrinking pixels to the total number of light pixels of the shrinking city, and the average urban shrinkage intensity (AUSI) is the average of the USI of each year.

$$USI_{(t,+1)}(m) = \frac{TSP_{(t,t+1)}(m)}{TLP_{(t)}(m)} \times 100 \qquad \text{(Equation 3)}$$

Furthermore, AUSI was derived based on the estimates of USI (Equation 3). It provides the average measure of USI per year.

$$AUSI_{(t,t+1)}(m) = \frac{\sum_1^y USI_{(t,t+1)}(m)}{y} \qquad \text{(Equation 4)}$$

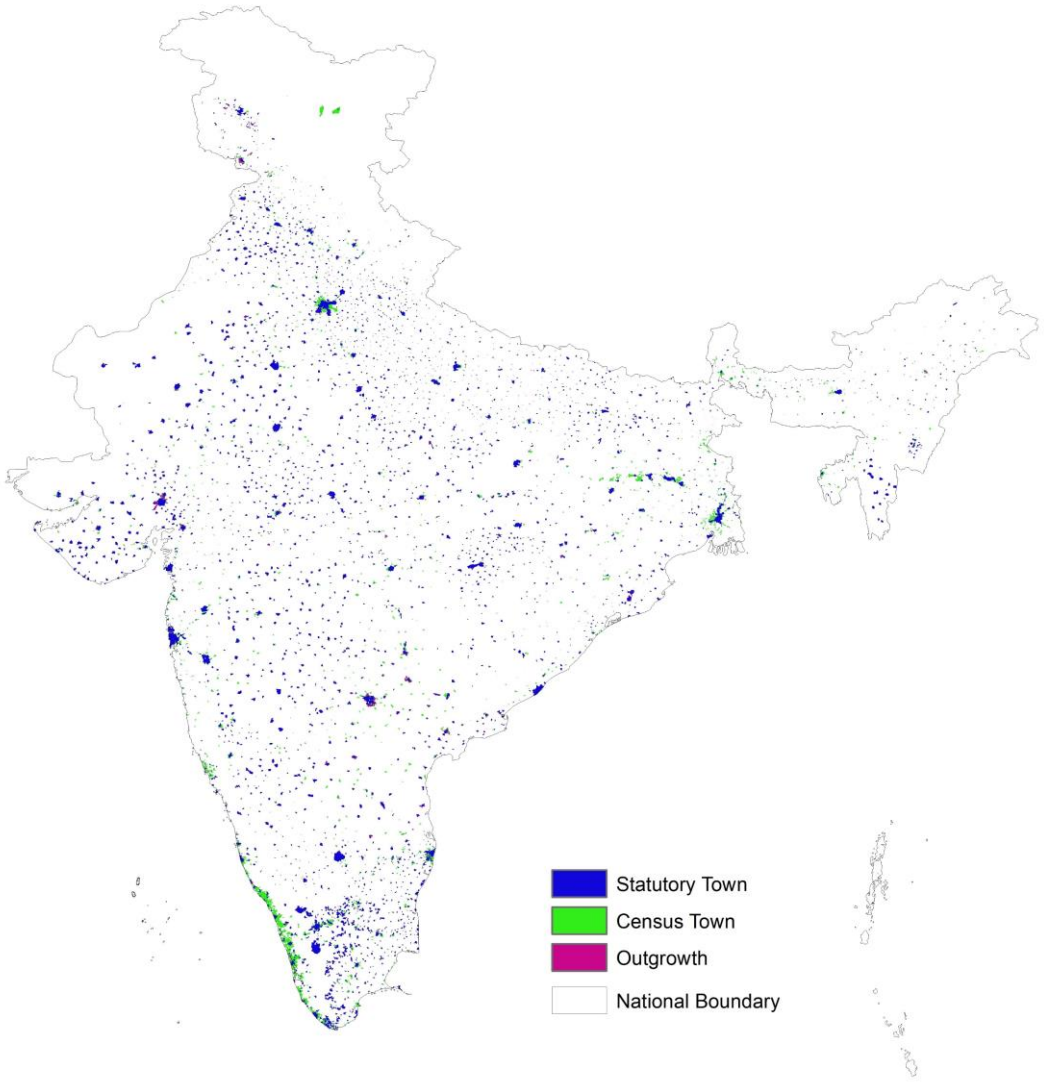
where $TSP_{(t,t+1)}(m)$ denotes the total number of shrinking pixels from year t to year (t+1) in shrinking city m. TLP(t)(m) denotes the total number of light pixels in year t for city m. AUSI(m) is city m's average urban shrinkage intensity, and y is the number of years.
Spatial overlapping was performed to compare the census and night-light results and a bivariate map was produced to identify the high intensity urban shrinkage areas.

3. Results:

3.1. Types of urban centers in India, 2011:

The Census of India classified the urban centers into three categories: census town, statutory town and outgrowth. In 2011, there were 4041 statutory towns, 3892 census towns, 981 outgrowths and 472 urban agglomerations in India (Roy et al., 2023). These urban centers are scattered across the states in India. Figure 2 depicts that statutory towns are the larger urban units where the agglomeration of towns and cities can be identified. In contrast, census towns are comparatively smaller urban areas with smaller populations. Census towns are distributed across all states. However, major clusters of census towns can be identified in the southern

states and eastern states of India (Balk et al., 2019). Generally, statutory towns hold a stronger administration than other settlements. In contrast, census towns are governed by the rural panchayat governance system. The higher density of the settlement clusters indicates a high concentration of towns and cities. Indirectly, it also reflects the urbanization scenario of a



particular state. It was observed to be the same as low urbanized states such as Bihar, Odisha, and Himachal Pradesh. Most northeastern states have a very small number of urban centers, and the settlements are also very small.

Figure 2: Classification of urban settlement in India, 2011

3.3. Night-light growth and urban shrinkage in India:

The DMSP and VIIRS data highlight the trend in the sum of night-light intensity and the growth rate at which light intensity is increasing in urban India. It has been found that the sum of night-light shows a rising trend from 1992 to 2021. However, the growth is inconsistent; it fluctuates over time, and the trend line indicates that the growth rate is slowing down.

Overall, the average share of shrinking cities in urban India is 16.8 percent. The annual share of shrinking pixels exhibits many fluctuations. Nevertheless, the recent decade shows more consistency in the share of shrinking pixels than the previous decade (Figure 3).

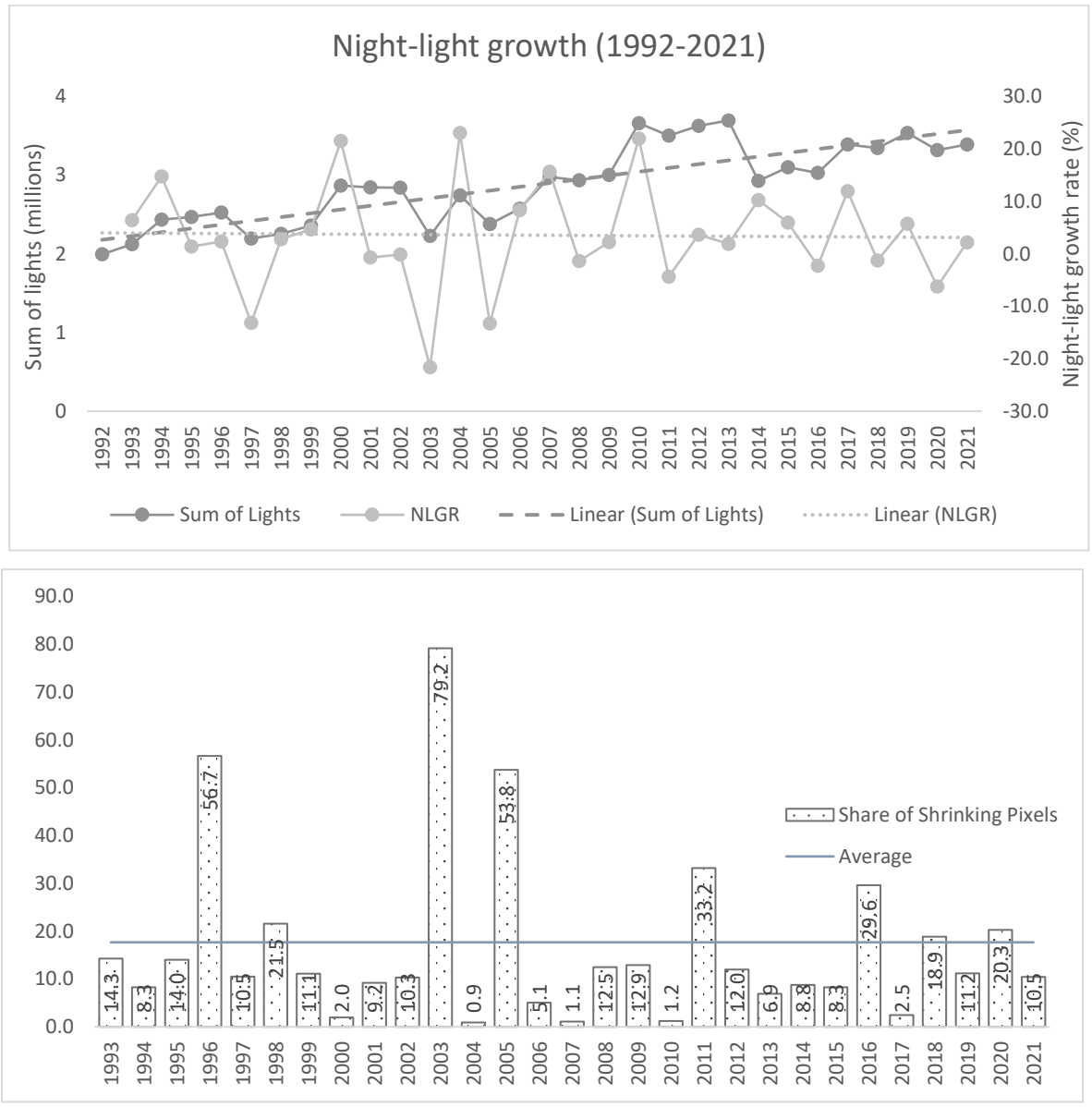


Figure 3: Variations in nightlight growth and shrinking pixels in urban India, 1992-2021.

SCII results indicate that shrinking intensity varies among urban units. Among all urban units, 26 percent experienced no shrinkage, while 11 percent experienced low shrinkage intensity. A majority of urban units, 45 percent, were in the category of medium shrinking intensity. Alarmingly, 17.4 percent of urban units experienced high intensity of urban shrinkage during the period from 1992 to 2021.

However, shrinking city intensity was not uniform across types of settlements. Statutory towns (18.2 percent) were more in the category of urban shrinkage compared to census towns (16.6 percent) and outgrowths (12.6 percent). In contrast, urban units that experienced no shrinkage or low shrinkage were highest among census towns.

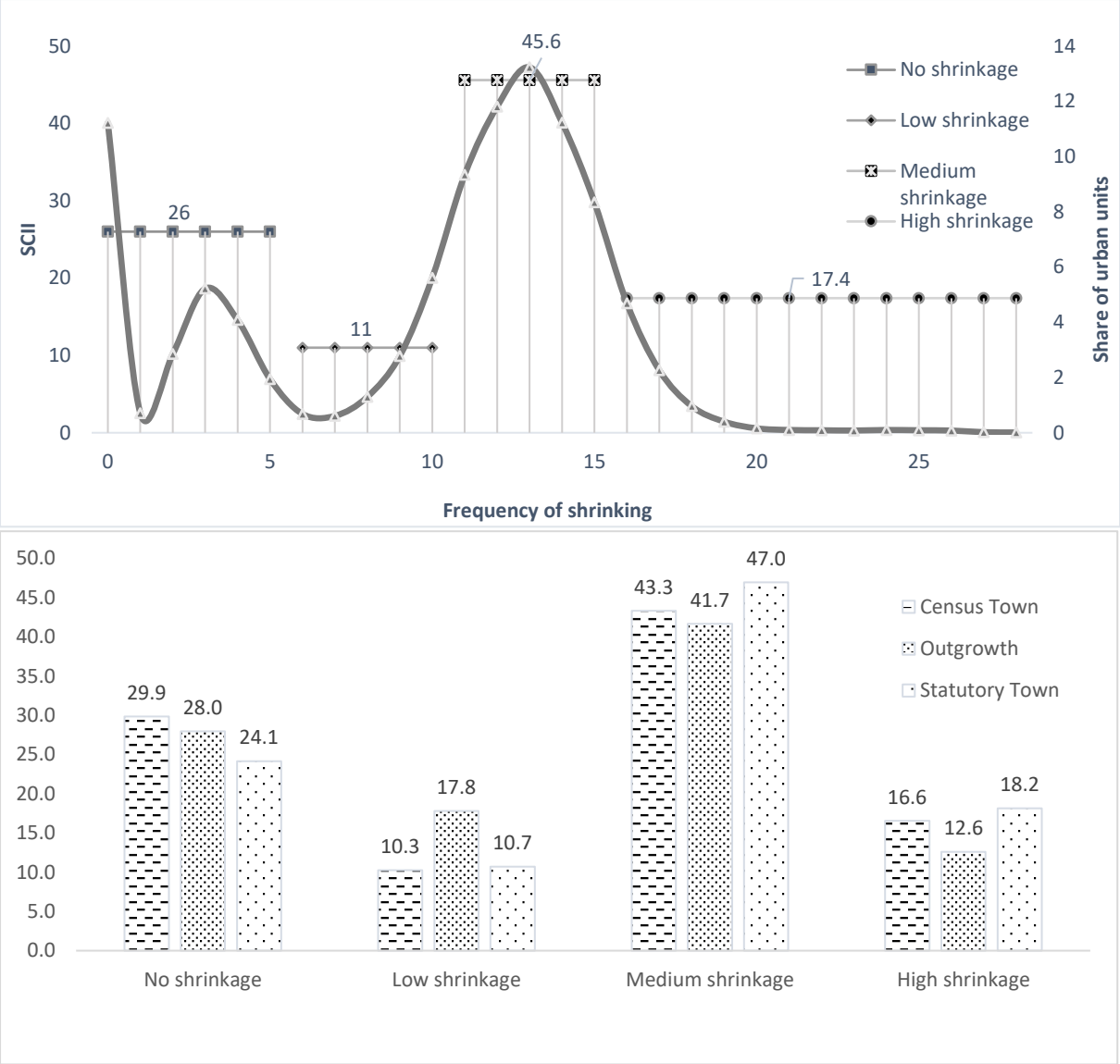


Figure 4: Shrinking city intensity index in India and variations across different settlements, 1992-2021.

3.3. Spatial pattern of urban shrinkage in India:

Compared to AUSI results, SCII results paint a different picture. They indicate the states with a high shrinking city intensity index. NCT Delhi (63 percent) has the highest SCII among the states. Other states with high SCII include Meghalaya (29 percent), Uttar Pradesh and Madhya Pradesh (both at 27 percent), and Assam (22 percent). Meanwhile, low SCII was recorded in states like Bihar, Goa, Arunachal Pradesh, and others (Figure 6).

The average urban shrinkage intensity in India stands at 17.7 percent from 1992 to 2021. However, it varies across states. AUSI is highest in states like Sikkim (24.8 percent), Meghalaya (24.3 percent), Tripura (23.4 percent), and Assam (21.2 percent), which are considerably higher than the national average. In contrast, AUSI is lower in states such as NCT Delhi, Punjab, Haryana, and Gujarat (Figure 5).

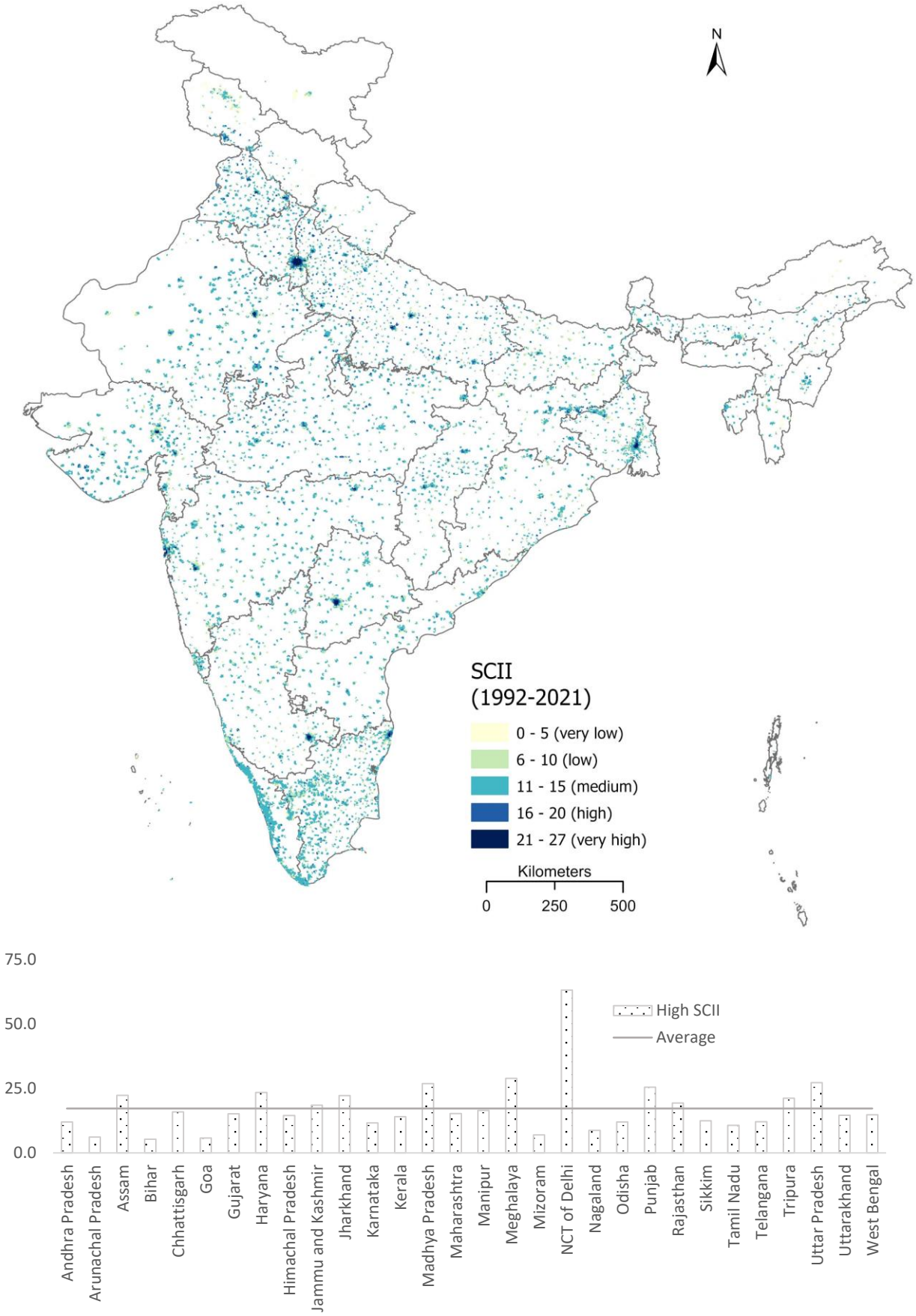


Figure 5: Spatial pattern of shrinking city intensity index intensity in India, 1992-2021.

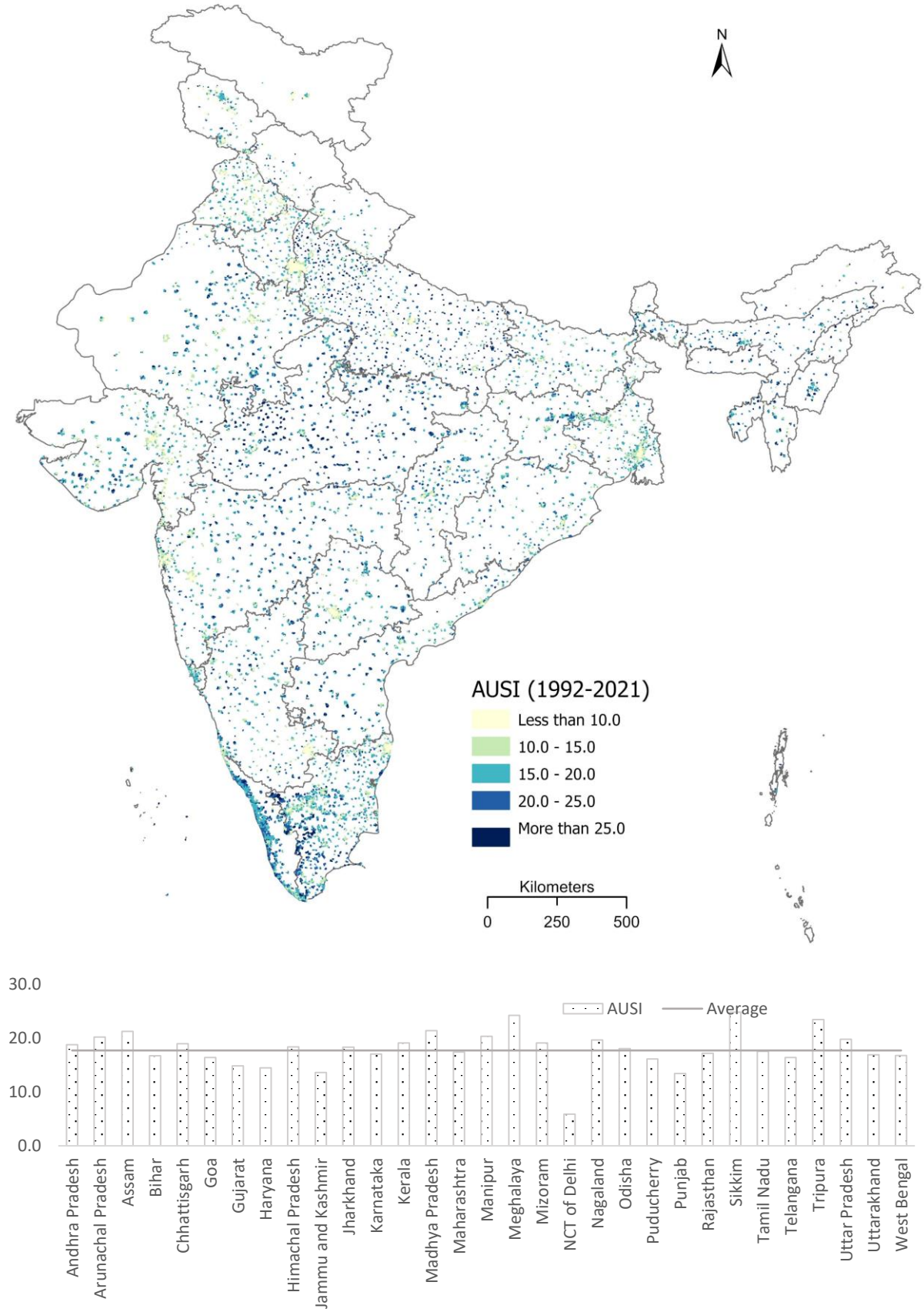


Figure 6: Spatial pattern of average urban shrinkage intensity in India, 1992-2021.

The spatial pattern of SCII and AUSI across urban centers indicates that AUSI is higher among the core cities but the intensity at which it is shrinking is low. However, there are clusters where both the measures were recorded higher (Figure 5 and Figure 6).

3.5. Verifying urban shrinkage in India:

The Census of India provides data on the decadal population variation for towns and cities in India. It does not provide information on changes in built-up land, but these data can help understand the long-term population trend of a town or city. Therefore, we identified shrinking cities based on the annual exponential growth rate of the population of each town and city. Here, two types of towns and cities were presented: one is where population growth was negative during the last two-decade period, and the other is where growth was negative for the last two consecutive decades. Figure 7 compares the spatial pattern of shrinking cities identified based on census and night-light data.

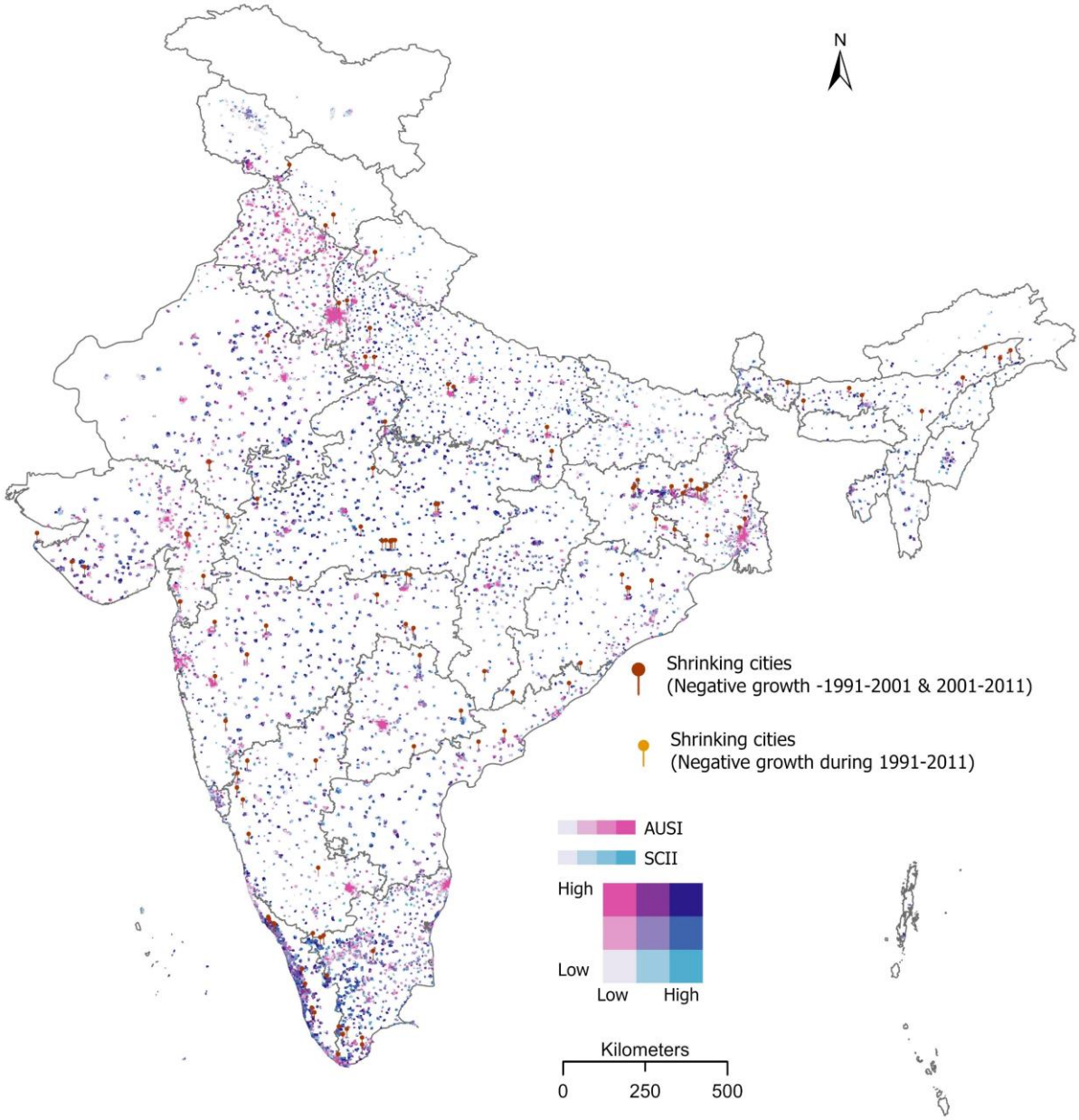


Figure 7: Comparing spatial pattern of urban shrinkage using night-light (1992-2021) and census data (1991-2011).

Using census data, we identified 276 urban centers that experienced population decline from 1991 to 2011. Additionally, 125 towns were identified as shrinking towns or cities that have experienced population decline in two consecutive decades, 1991-2001 and 2001-2011, while many of these towns or cities have been shrinking for the last three decades. The overlay map suggests that a similar spatial distribution can be observed in the census shrinking towns and night-light shrinking towns, validating the existence of shrinking cities in India. These shrinking urban centers are scattered across the states in India. However, census data indicate significant concentrations in the eastern region (industrial mining belt of West Bengal and Jharkhand), Kerala and Assam. Night-light shows a higher density of shrinking cities, as it portrays at the urban unit level distributed widely across all states. Furthermore, night-light data identified many new shrinking urban units in central, western and southern parts that were not identified as shrinking in census data. It is evident that in last three decades the intensity of urban shrinkage has increased, so probably in the next census a large number urban centers will be identified as shrinking city.

4. Discussion:

4.1. Urban shrinkage in India:

Urban shrinkage has been measured using several urban aspects; however, population decline has been the central aspect of this phenomenon. In this study, we used census and night-light data to identify shrinking cities in India. The night-light data measures have developed a unique approach to understanding the global urban shrinkage process (Yang et al., 2021).

The night-light results indicates that urban India has experienced substantial increase in night-light however the intensity of growth has reduced since the last decade. Over all 17.7 percentage of pixels experienced shrinkage in light during 1992-2021, which is higher than the intensity in China (Yang et al., 2021). SCII results highlighted that around 17.4 percent of the urban units experienced high shrinking intensity, while a majority with medium shrinkage and 37 percent experienced very low shrinkage or no shrinkage. Moreover, statutory towns experienced a higher urban shrinkage intensity than other settlements. The spatial pattern highlights that the concentration of shrinking urban centers is higher in selected states of India. It also indicates that the core of larger cities is shrinking, however the intensity at which it is shrinking is lower.

The pattern of shrinking cities was also verified with census population datasets. In both results, shrinking cities were similarly distributed in different parts of the country, with a significant concentration in the northern, eastern, and southern regions. These urban centers are mainly located in both advanced states and less developed states. In developed states, shrinking cities are larger in size and population. However, in less developed regions, shrinking towns are small in size. Moreover, shrinking cities can be identified across all the states in India.

Comparing urban shrinkage based on two datasets further demonstrate that the urban shrinkage exceeds the measure given by the census data. Though point has to be taken that census data

has provided insights for two decades but night-light data for three decades. Which indicates that in recent decade the extent of urban shrinkage is higher and a greater number of urban centers are shrinking compare to the numbers came out from census data.

4.2. The paradox of urban shrinkage:

India has experienced steady urbanization in the last few decades, and as per the 2011 census, 31.1 percent of the total population was living in urban areas. In this context, urban shrinkage is paradoxical. However, there are wide variations in the level of urbanization and other socioeconomic and demographic indicators across the states. Urban shrinkage in India is very much linked with socioeconomic and demographic disparities across the region. A similar situation is happening in many developing countries, such as China, South Korea, Iran and many African nations (Zhai et al., 2022).

India has a top-heavy urban structure, and urban areas are the most dynamic and diverse population concentrated in urban settlements to fulfil their needs. Major urban centers are hubs for economic opportunities and services, creating an enormous labor demand. People from small urban settlements or rural areas migrate to these places to fulfil this demand. Therefore, the population drains from smaller urban settlements to larger ones. Therefore, larger settlements attract more population with a magnetic power of attraction. In contrast, few cities are experiencing urban shrinkage due to the hollowing-out effect, where people move out to the suburbs from the city's core, which leads to the shrinking of the core. For example, cities such as Kolkata, Mumbai, and Delhi experienced population decline in the core of the city in the recent past. Thus, the paradox of urban shrinkage in India functions in these conditions. Furthermore, following the recent demographic trend across the states of the country, it can be predicted that phenomena such as shrinking cities can be a major challenge in future urban scenarios.

4.3. Drivers of urban shrinkage in India:

While studying urban shrinkage and the development of towns and cities, researchers have identified a set of factors for urban shrinkage or slow growth of towns and cities. The major reasons for shrinking cities are inadequate physical infrastructure, a lack of amenities, healthcare facilities and employment opportunities (Bhagat, 2004; Ganapati, 2014; Guin, 2019), selective out-migration, unemployment in the place of origin (Marchang, 2017; UN-Habitat, 2008), wage differences among the towns (Indian Council of Social Science Research, 2011), etc. Out-migration is one of the primary causes of population decline, with movement often occurring from underdeveloped to more competitive areas (Wiechmann & Wolff, 2013), a trend that is likely to continue in future decades due to changes in labor market demand (Bhagat & Mohanty, 2009; Dyson & Visaria, 2004).

Furthermore, investment, policy implementation, resource availability, quality of life, and facilities all play a critical role in urban shrinkage (Hamilton & Colocousis, 2004; Kundu, 2005; Ma et al., 2020). Based on these findings and previous research, a framework for growing and declining towns was developed. Another important reason for urban shrinkage is strict urban definitions, which result in the declassification of existing towns into rural settlements (Ganapati, 2014). Similarly, a study done by Eric Denis and Marius-Gnanou argued that the

level of urbanization could be higher if the United Nations standard Geopolis approach is considered for measuring urbanization (Denis & Marius-Gnanou, 2011). So, it may be urban shrinkage is occurring at high urbanization stage.

It is evident that the current demographic trend plays a vital role in the process of urban shrinkage. Developing countries are passing through a rapid demographic transition (Bongaarts, 2015; He et al., 2016). Low fertility trends and aging are crucial in slowing the population growth of developing nations (Lee, 2016; Yi & Vaupel, 1989). In this context, internal migration plays a key role in urban growth processes. Areas are experiencing rapid growth where in-migration is higher, while the population is shrinking where out-migration is taking place (Bhagat & Jones, 2013).

The spatial patterns of urban shrinkage reveal that it is prevalent in both developed and less developed states. This shrinkage is notably evident in the northeastern states, where the level of urbanization is exceptionally low and fewer cities are located. The absence of a driving force for urban growth results in this shrinkage. Eastern states are also undergoing urban shrinkage. Many towns in these states depend on natural resources, and once these resources are exhausted, the towns are often abandoned without any sustainable intervention (Ganapati, 2014; Roy et al., 2023).

Low fertility rates are among the primary reasons for urban shrinkage in several states. In states such as Kerala, Tamil Nadu, Sikkim, Gujarat, and Delhi, the urban fertility rate is even lower than that of many European countries (International Institute for Population Sciences, 2020). Consequently, due to this natural decline, many urban centers are experiencing population decreases, exacerbated by factors such as internal migration. In India, internal migration is significantly influenced by socioeconomic disparities across regions. This plays a pivotal role in the emergence of shrinking cities. Migration patterns in India are predominantly directed toward larger cities. States with higher urbanization levels attract many migrants, while states with lower urbanization levels often become sources of out-migration. Urban-to-urban and urban-to-rural migration trends have notably increased over the past two decades (as shown in Table 4). This migration, typically from less prosperous urban centers to more prosperous ones or even villages, results in the shrinkage of the less affluent towns.

Table 4: Migration volume and share in different migration streams from 1991-2011.

	Volume (Million)			Share		
Year	1991	2001	2011	1991	2001	2011
Inter-State Out-Migration						
Rural - Rural	2.89	4.47	7.81	26.27	27.3	33.66
Rural - Urban	3.59	6.37	6.39	32.57	38.88	27.56
Urban - Rural	0.94	1.05	4.11	8.53	6.43	17.70
Urban - Urban	3.59	4.49	4.89	32.63	27.40	21.09
Total	11.02	16.39	23.2	100	100	100
Intra-State Out-Migration						
Rural - Rural	43.35	48.88	59.12	62.24	62.50	52.09
Rural - Urban	13.18	14.22	21.85	18.92	18.18	19.25

Urban - Rural	5.14	5.21	10.08	7.38	6.67	8.88
Urban - Urban	7.98	9.90	22.45	11.46	12.66	19.78
Total	69.66	78.21	113.50	100.0	100.0	100.0

Source: Census of India 2011, 2001 and 1991.

It is also evident that urban shrinkage will present numerous challenges for urban planners and policymakers. However, it is argued that as the population in Indian towns declines, there will be an economic downturn and a degradation in spatial quality. Li and Long contend that the impacts of population reduction will not manifest immediately but will emerge gradually. Similarly, the combined effects of population and economic decline will progressively deteriorate the quality of space. Economic stagnation and spatial decay will likely persist without timely intervention as the population diminishes. (Li & Long, 2019).

5. Strengths and limitations:

Compared to conventional data, the night-light dataset utilized in this research effectively comprehends the long-term trajectories of shrinking cities, particularly in regions where administrative boundaries are frequently adjusted. The study analyzed the spatial patterns of urban shrinkage and growth, revealing interesting findings using these datasets. Moreover, the global scale of the night-light dataset enables potential global comparative research in the future. Apart from these strengths, this study has some limitations. Due to the unavailability of the administrative boundary of each town and city, this study used the fishnet grid method. However, a town or city-level shapefile would have been appropriate for the analysis. Furthermore, due to the unavailability of recent census data this study relies on the 2011 census data to verify urban shrinkage pattern in India. Recent census data would have helped much in understanding the recent trend in urban shrinkage provided by night-light measures.

6. Conclusion:

India has one of the largest and unique urban systems in the world. It is experiencing rapid urbanization as a whole and urban shrinkage at the same time. In this study, we used the geospatial approach to quantify the intensity of urban shrinkage in India using time series night-light data and examined the spatial pattern. The study indicates that there is an uprising trend in the number of shrinking pixels in India. The SCII and AUSI measures indicate spatial clusters of shrinking cities in several parts of the country where cities are shrinking at higher intensity. The results from census and night-light data confirm that the global phenomenon of urban shrinkage is an undeniable fact in India. Also, night-light data-based measure indicates that the extent of urban shrinkage is higher that the urban shrinkage measured based on census data. This phenomenon is driven by several factors, as urban growth and shrinkage are very much linked with the variation in demographic trends and internal migration patterns across the region. Therefore, India has concerns about both the rapid unplanned growth of cities and shrinking cities. Urban authorities in India need to recognize the inevitability of the process of urban shrinkage and take necessary precautions. Identifying shrinking cities and comprehending their spatial and temporal patterns are crucial for formulating effective policies and implementing smart shrinkage (Rhodes & Russo, 2013). It is also clear that urban shrinkage is a pressing issue that undermines sustainable urban development and rural-urban

interaction. Therefore, to achieve sustainable development goals, it is necessary to address both rapidly growing and shrinking cities, as both have significant implications for development processes. An inclusive approach needs to be taken for all categories of human settlements. Balanced urban growth initiative would benefit the country's economic growth and the population's well-being**.** Further exploration is required to understand the urban shrinkage among different types of towns and explore the drivers and consequences. Case-specific studies of selected shrinking cities may help reveal the causes and consequences of urban shrinkage in developing nations.

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