CHARACTERISING THE SLUM ENVIRONMENT FROM SPACE FOR ACHIEVING SDGs

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KEYWORDS: Slum development, SDG Index, Chennai, Remote sensing, Inclusive urban development

ABSTRACT:

With less than eight years left to achieve the Global Goals, nations are accelerating the design and implementation of sustainable solutions to the world's biggest challenges ranging from poverty to climate change. India has assessed its status in achieving SDGs through SDG Index, an aggregate measure that computes goal-wise scores on the 16 SDGs. For SDG 11, the 2020-21 assessment showed that all other 32 states scored above 65 as front runners except for seven. One such criterion to assess the progress of SDG11 is the "percentage of urban households living in Katcha houses". In the present study, to understand the slum development activities to attain sustainability at a city level, Chennai has been chosen as a case study. Using VHR data from Google Earth Pro, the slums of Chennai are mapped, and the recent changes in the slum status are identified.

The slums are categorised into four categories: existing, emerged, expanded and evicted slums, based on their characteristics. The study shows that between 2001 and 2011 there are 110 new slums emerged in the study area, which accounts for 1.43 sq. km. There are only a few slums that emerged between 2011 and 2022 (0.35 sq. km), but there was a considerable slum expansion (1.07 sq. km.) during that period, and some slums were evicted from their previous locations. The results based on satellite data have been verified and validated at the field level. The ongoing slum development programs in Chennai give optimistic hope for achieving inclusive urban development by 2030.

1. INTRODUCTION

Globally, Rapid urbanisation has been observed in many regions since the latter half of the 20th century. In 2008, the urban population surpassed the rural population for the first time, and predictions suggest it could reach 68% of the world's total by 2050 (United Nations, 2019). The majority of urban expansion occurs in developing countries, where there is a rapid migration from rural to urban areas. Rural unemployment, natural population growth and other factors drive migration from rural to urban (Jedwab et al., 2017). Cities often struggle to provide enough job opportunities for their rapidly growing populations, resulting in a high prevalence of insecure informal employment that pays low wages. The rural population migrates to cities for work/better living. Still, it often ends up in unsanitary housing clusters due to a lack of affordable housing, resulting in slums which provide substandard living conditions. The proliferation of slums in numerous Indian cities is causing difficulties in ensuring significant infrastructure and essential services. Thus, the foremost challenge facing urban areas is striking a balance between economic progress and sustainable development (Shekhar, 2021).

Urban development necessary for sustainable development. Sustainable cities drive it by providing job/business opportunities, safe and affordable housing, and robust societies/economies through investment in public transport, green spaces, and participatory planning/management (Thomas et al., 2021). Goal 11, "Sustainable Cities and Communities," is part of the 17 SDGs adopted by UN members to end poverty, protect environment, and achieve peace/prosperity by 2030, as defined by UNDP. Goal 11 (Sustainable Cities and Communities) is either directly or indirectly tied to Goals 1, 2, 3, 6, 7, 8, 9, and 10. Progress in any of these goals benefits sustainable cities and communities. India aligns its growth plan with the sustainable development goals as a global partner (Shekhar, 2021).

Chennai city, the capital of Tamil Nadu, has been selected as a case study for this research in order to comprehend the slum development efforts required for inclusive and sustainable urbanisation at the city level. The main objective of the study is to identify the present status of slums for achieving sustainable development goals and estimate the percentage of urban households living in Katcha houses for the year 2022.

2. MATERIALS AND METHODS

2.1 Study area

The study area is Chennai city (Figure 1), capital of Tamil Nadu, India. The city located between longitude 80° 08′3.9411″ E and 80° 20′ 2.398″ E and latitude 13° 06′ 26″ N and13° 14′ 3.924″N. The Chennai city covers an area of 426 sq. km, which is divided into 15 zones and 200 divisions for administrative purposes. The Cooum and Adyar river, along with several minor canals, flow through this region. According to the 2011 census, 5.41% of India's population, which is 65.5 million people, live in slums. In Tamil Nadu, 8% of the urban population or 5.8 million people, reside in slums (Census of India, 2011). In Tamil Nadu, Chennai has the largest slum population, estimated at around 1.3 million.

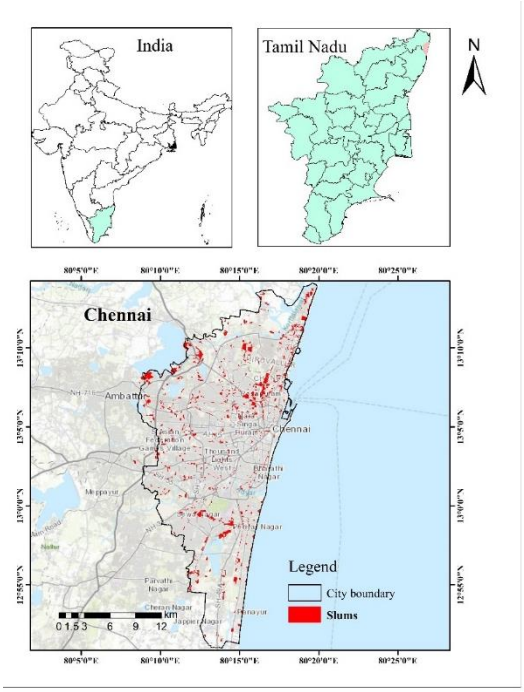

Figure 1. Study area Map

2.2 Dataset

The base data for Chennai slums was collected from Tamil Nadu Urban Habitat Development Board (TNUHDB). The base data contains the information related to slums and rehabilitated settlements (relocated settlements). This includes slum names (of 1131slums), ward numbers, zone numbers, the total number of households, the total population, and the spatial boundary (of the year 2014) of each slum. Google Earth time series imagery for the years 2001, 2011, and 2022 have been used in this study to find the spatial-temporal variation of slums.

2.3 Methodology

The following flow chart (Figure 2) shows the methodology adopted in identifying the characteristics of slums using spatial data.

Initially, an ESRI shapefile was created for the study area. The shapefile encompasses 15 zones, 200 ward boundaries of the Chennai, and delineated slum boundaries. It comes in seven distinct file formats, which include supplementary information such as spatial boundaries, attribute data, projections, and coordinate systems (Gruebner et al., 2014). The 2014 slum boundary was obtained from the TNUHDB, and based on that, slum boundary layers were created for the years 2001, 2011, and 2022 using Google Earth Pro.

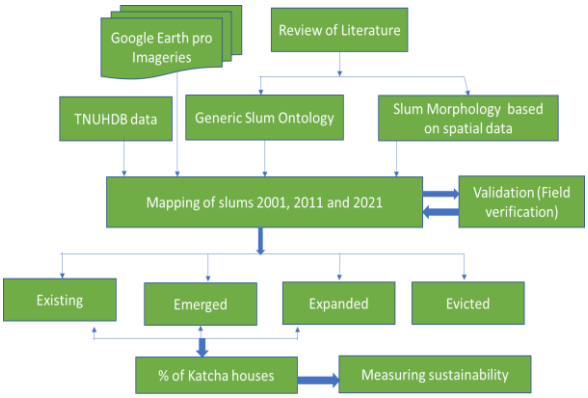

Figure 2. Methodology flowchart

2.3.1 Slum Mapping

This methodology for mapping slums is explained in this section. As previously mentioned in the dataset session, spatial-temporal analysis was conducted using historical images of Google Earth Pro from 2001, 2011, and 2022. The study was limited by the availability of high-resolution satellite imagery from Google Earth for the study area and the quality of the images, which could be impacted by clouds and shadows. The availability of historical imagery from Google Earth was also restricted by the amount of commercially available VHR data (Duque et al., 2017). Since 2001, historical VHR imagery for the Chennai district has been accessible. The years 2001, 2011, and 2022 were digitized from Google Earth's historical imagery, utilising the slum base data from TNUHDB as a reference.

Slums that were not previously included in the database have been digitized using a generic slum ontology and the characteristics of slum morphology. The term "Generic Slum Ontology (GSO)" refers to the worldwide understating of slums. GSO aims to bridge the gap by offering a thorough description of slums (Pratomo et al., 2017). The GSO categorises slums into three distinct spatial levels: the object level, which includes building and access network characteristics; the settlement level, which encompasses settlement shape and density; and the environs level, which refers to the location and neighbourhood features (Kohli et al., 2012, 2019; Shekhar, 2013, 2019). The morphology features used to identify slums include building size, height, density, orientation, and the diversity of patterns in the slum's spatial layout (Taubenböck, 2018). The Google Earth Historical imageries of 2001, 2011, and 2022 were used to create slum layers.

2001: No of Slums = Existing Slums --------(1)

2011: No of Slums = (Existing slums + Spatial Expansion of slums+ Emerged slums*) – Evicted slums ----------(2)

2022: No of Slums = (Existing slums + Spatial Expansion of slums+ Emerged slums**) – Evicted slums ----------(3)

* Slums formed between 2001-2011

** Slums formed between 2011-2021

The above-said methodology has been used to determine the number of slums in 2001, 2011 and 2021 and to quantify the spatial variation or growth of slums between 2001-11 and 2011-22.

Characteristics	Informal (Slum)	Formal Built-up areas
Size	Small (substandard) building sizes and varied	Generally larger building sizes and varied
Density	High to Very high roof density Lack of open and green spaces within or in the proximity of slum areas.	Low to moderate density areas Presence of open and green spaces within or nearby areas
Pattern	Organic layout structure No planned street patten	Regular layout pattern with planned regular road
Site characteristics	Often at hazardous locations and vulnerable Proximity to transportation lines and livelihood opportunities	Land has the basic suitability for being built-up with necessary infrastructure

Table 1. Morphological features typical for slum areas (Adapted from Kuffer et al., 2016; Aminipouri et al., 2009)

2.3.2 Field validation

The digitized slums require validation and it was done through field verification. The slums in the Chennai city had been divided into four categories, and samples were obtained from Google Earth Pro imageries for each category. The samples were taken across the study area from 2001, 2011, and 2022 imageries and verified in the field to confirm the presence and the growth of slums.

2.3.3 Estimation of Katcha houses

To determine the "percentage of urban households living in Katcha houses", a hybrid method was employed. Which involves the use of secondary and primary data i.e., using existing slum database and field visits. The process of calculating this percentage started with the delineation of new slums/emerged slums and expanded slums, which are not available in the existing slum database. The number of Katcha houses in these slums were then determined through a combination of field visits and the use of Google Earth Pro.

A total of 95 slums were selected from the emerged slums, and out of those, fifty slums were visited to gather data on the number of Katcha houses in person. During these visits, the number of houses made of materials like mud, bamboo, or thatch, which are considered to be less permanent or sturdy, was counted. The remaining 45 slums were analysed using Google Earth Pro, which allowed us to calculate the number of Katcha houses remotely.

The following method was used to calculate the number of slum households living in Katcha houses, considering the field visits and the data from Google Earth Pro. Finally, the results were cross-verified using the 2011 census data to determine if the number of Katcha houses had increased or decreased. This hybrid approach helped to ensure the accuracy and reliability of the findings and provided a comprehensive picture of the housing situation in urban areas.

Total number of Katcha houses = No of Katcha houses in (existing Slums + emerged slums + expanded slums) ---------- (4)

3 RESULTS

This section elucidates the outcome of mapping informal settlements and their characteristics for achieving sustainable development.

3.1 Slum growth from 2001 to 2011

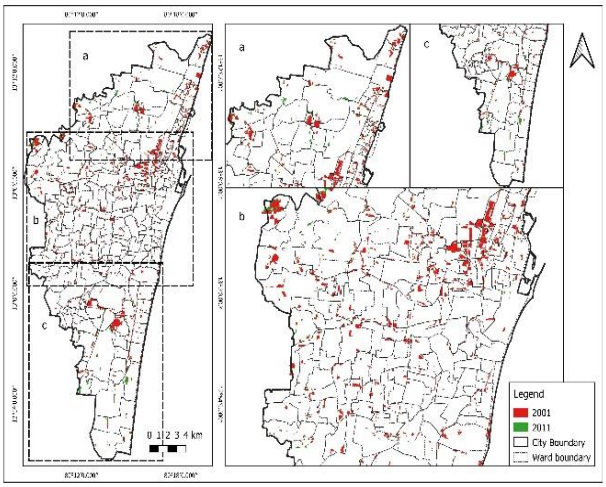

Figure 3. Spatial and temporal analysis of slums (year 2001 – 2011)

Figure 3 above shows the spatiotemporal variation of slums. The map was divided into three parts for better visualisation. A total of 110 slums underwent changes between 2001 and 2011. These slums are found in 50 wards out of 200 and spread across the fifteen zones of Chennai corporation (Table 2). A maximum of seven wards experienced the formation of new slums, and slum expansion comes under zone 3, Madhavaram and is followed by zone 9, Teynampet, where 6 wards underwent these changes. These are all the wards that show the invasion of slum settlements into areas previously not having slums. It has been identified that the slums which emerged in the following wards, numbers 8,14,28,39,63,77, 98,100,107,111,116,124, 125,176, and 194 were through the rehabilitation procedure. The rehabilitation process is part of TNUHDB activities which involve the rehabilitation and resettlement schemes to improve the environs of the slums and the living standards of the urban slum families (https://tnuhdb.tn.gov.in/).

2001 - 2011					2011-2022			
Zone number	**Ward Number of Emerged and Expanded Slums (A)**	**No of the Wards experienced (A)**	**Ward number of evicted slums (B)**	**No of the Wards experienced (B)**	**Ward Number of Emerged and Expanded Slums (A)**	**No of the Wards experienced (A)**	**Ward number of evicted slums (B)**	**No of the Wards experienced (B)**
1. Thiruvotriyur	4, 5, 7, 9	4	8, 14	2	-	-	14	1
2. Manali	16, 17, 18, 19, 20	5	-	-	-	-	17	1
3. Madhavaram	22, 24, 25, 27, 28, 29, 33	7	28	1	23, 24, 25, 28	4	-	-
4. Tondiarpet	37	1	39	1	34	1	42, 45	2
5.Royapuram	56, 57, 58, 59, 60	5	63	1	56	1	58, 59, 61, 63	4
6. Thiru. Vi. Ka. Nagar	70	1	77	1	65	1		
7. Ambattur	82, 83, 85	3	-	-	-	-	82, 90, 93	3
8. Anna Nagar	102	1	98, 100, 107	3	-	-	100, 106, 107	3
9. Teynampet	114, 117, 118, 122, 124, 126	6	111, 116 124, 125	4	-	-	110, 111, 117, 120, 122, 124	6
10. Kodambakkam	138, 139, 142	3	-	-	128,138,142	3	138, 142	2
11. Valasaravakkam	143	1	-	-	-	-	143,144	2
12. Alandur	156, 157, 160, 161	4	-	-	-	-	157	1
13. Adyar	171, 172, 173, 175	4	176	1	-	-	171, 172	2
14. Perungudi	183, 189, 191	3	-	-	-	-	187, 191	2
15. Sholinganallur	198, 200	2	194	1	-	-	196	1
Total number of wards		**50**		**15**		**10**		**30**

Table 2. Zone wise distribution of emerged and existing slums

3.2 Slum growth from 2011 to 2022

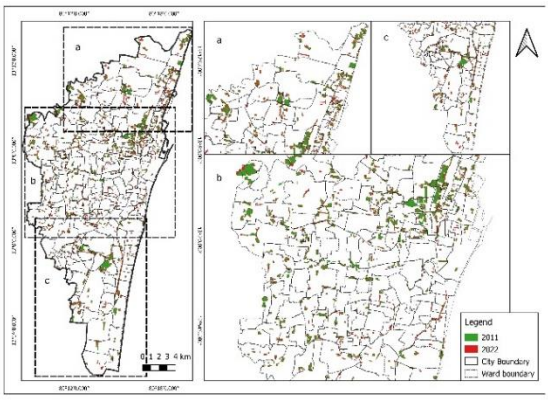

Figure 4. Spatial and temporal analysis of slums for the year 2011 – 2022

Figure 4 shows the spatiotemporal variation of slums from 2011 to 2022. The map was divided into three parts for better visualization. The new slums have emerged in wards 23, 24, 25, 28,34,56, 65, 128, 138, and 142. Again, the maximum of 4 wards in Madhavaram zone experienced the expansion of slum settlements in this decade. Slums were evicted from 30 wards distributed across the zones (Table2) during this period. Teynampet zone experienced more eviction than other zones. The output shows that compared to 2001 to 2011, eviction happened more frequently in the 2011 – 2022 period.

Year of Mapping	Based on the TNUHDB base layer	Based on slum ontology and slum morphology	Total number of slums@	The total area of slums km^2
2001	995	97	1092	18
2011	1103	99	1202	20.68
2022	1106	95	1201	22.1

Table 3. Growth of slums

@ Total number of slums do not include the evicted slums

Table 3 shows the growth of slums for 2001, 2011, and 2022. It also represents that the year between 2001 and 2011 there

are 110 new slums emerged in the study area. Since 2011, there were few slums formed between 2011 and 2022, and the total area showed an increase due to expansion of slum boundaries. Table 4 shows that northern Chennai has more slum growth than the central and south Chennai..

Region	Zone number	2001 – 2011		2011 - 2022	
		Total number of wards (Formation of new slums and Slum expansion)	Total number of wards (Slum eviction)	Total number of wards (Formation of new slums and Slum expansion)	Total number of wards (Slum eviction)
North Region	1, 2, 3, 4, 5	22	5	6	8
Central Region	6, 7, 8, 9, 10	14	8	4	14
South Region	11, 12, 13, 14, 15	14	2	-	8

Table 4. Distribution of slums at regional level

Being elongated in shape, Chennai is divided into three regions namely Northern Chennai, Central Chennai and South Chennai. The number of wards have slum population is high in northern Chennai compared to other regions. Presence of industrial and commercial activities along with more open space during 2000s also reasons for major slum growth and slum expansion in this region.

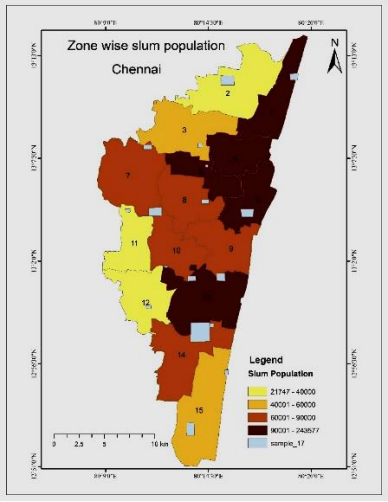

Figure 5. Zone wise slum population of Chennai district

Figure 5 represents the zone-wise slum population of the Chennai. The result of the study mainly reveals that 28% of Chennai's urban population lives on 5.16% of the land. The slum population has been divided into four categories, and four samples have been taken from each category (4x4=16) of slums. The samples were collected for the years 2001, 2011, and 2022 from Google Earth Pro. The samples were used for the ground validation and to confirm the growth of slums.

	200 1	2011	2022
A			
	4.71 hectare	2.18 hectare	2.18 hectare
B			
	7.48 hectare	8.37 hectare	3.81 hectare
C			
	9.47 hectare	8.25 hectare	7.24 hectare
D			
	4.54 hectare	4.05 hectare	2.35 hectare
E			
	NIL	0.09 hectare	0.19 hectare
F			
	77.66 hectare	90.15 hectare	55.57 hectare
G			
	NIL	0.82 hectare	0.89 hectare
H			
	5 hectare	13.27hectare	16.76hectare
I			
	4.53 hectare	6.43 hectare	8.73 hectare
J			
	21.89 hectare	22.24 hectare	23.3 hectare

K			
	11.72 hectare	13.29 hectare	12.98 hectare
L			
	0.48 hectare	1.23 hectare	1.44 hectare
M			
	1.05 hectare	2.32 hectare	2.48 hectare
N			
	3.56 hectare	4.45 hectare	4.75 hectare
O			
	2 hectare	2.59 hectare	3.65 hectare
P			
	10.89 hectare	11.59 hectare	13.2 hectare

New slums and slum expansion
Slum Eviction
Slums

Table 5. Samples show the Changes in slum areas

Table 5 represents the growth of slums, and columns show that times 2001, 2011, and 2022 and rows show the 16 samples by alphabet. The table represents the expansion of existing slums, formation of new slums, and eviction of existing slums that had taken place in the study area.

3.3 Katcha houses

In the SDG index, for SDG 11, "Sustainable cities and communities", the year 2020-21 assessment showed that except for seven states in India, all other 32 states scored above 65 as front runners. One such criterion to assess the progress of SDG11 is the "percentage of urban households living in Katcha houses". Tamil Nadu state has scored 79 out of 100 for SDG11, with only 0.8 per cent of households live in Katcha houses. In the present study, to understand the slum development activities to attain inclusive and sustainable urbanisation at a city level, Chennai, the capital of Tamil Nadu, has been chosen as a case study. Using high-resolution spatial data from Google Earth Pro, the slums of Chennai are mapped, and the recent changes in the slum status are identified.

The 2011 census showed that Chennai had a total of 12,60,298 households. Out of these households, 3.7% or 47,446 were identified as Katcha houses (Office of Registrar General of India, 2011). This term refers to houses that are made of materials like mud, bamboo, wood, thatch or plastic (polythene), which are not permanent or sturdy. These houses are considered to be less secure and have poor living conditions compared to houses made of more durable materials. Thus, they represent the slum households.

In 2022, the result of this study shows that the percentage of urban households living in Katcha houses in Chennai had increased to 4.58% or 57,771. This represents a significant increase from the previous census and highlights a growing concern for adequate housing in the city.

4. DISCUSSION

The slums are grown rapidly in Chennai since 2001. Various factors have contributed to slum growth, such as rapid population growth and rural-urban migration. In recent decades, developing extensive industrial facilities in Chennai and its suburbs has led to a significant population increase (Viswanatha and Tharkar, 2010). Migration occurs due to push factors such as limited job prospects, inadequate wages, drought, unavailability of essential amenities, lack of land ownership, and social issues in rural areas. Conversely, pull factors such as increased job opportunities, higher wages, improved infrastructure, and access to better facilities attract migration from rural to urban areas (Zhang 2016). Urban areas can't provide impoverished migrants with enough jobs, infrastructure, and secure tenure. Migrant labourers choose settlement sites depending on job prospects, leading to slum expansion (Shekhar, 2021). In 1971, Chennai's migrant population was 0.78 million and increased to 0.98 million in 2001(Krishnamurthy and Desouza, 2015). According to the 2011 census, 1.32 million people migrated; within that, 0.96 million were intra-state migration, and 0.33 million were inter-state migration (Census of India, 2011). Consequently, the disparity between the requirement and availability of essential services and infrastructure in metropolitan areas increases, negatively affecting the standard of living (Shekhar, 2019). In 2001, Chennai's urban population lived in slums was 18.9%, which increased to 28% in 2011 (CMDA 2008; Office of Registrar General of India, 2011). This figure shows the rapid growth in the slum population in the study area.

Since 1901, Chennai's spatial size or area has expanded from 68 km^2 to 426 km^2(Krishnamurthy and Desouza, 2015). The city has had to expand its spatial boundary due to its natural growth and immigration. As per the survey conducted in

1986, there were 996 slums in the city, and in 2014, 1131 slums were surveyed by TNUHDB. The results show that between the years 2001 to 2011, 125 new slums emerged, and from 2011 to 2022, 37 new slums emerged, and spatial expansion of slums took place.

Though all the zones underwent changes in their slum characteristics, some of them experienced notable changes. The northern Chennai had a significant growth of slums and the Madhavaram zone had more emerged slums during 2001-11 and 2011-22 due to its large informal sector and vacant land. Textile-based business activities in the Teynampet zone also attracted new slums during that period. But the Teynampet zone also experienced more slum evictions during 2001-11 and 2011-22; because of its high commercial land value and high density, the slums were resettled in various other zones.

Due to the Millennium Development Goal developmental activities and the Slum-free India mission of the Government of India, Slum development program initiatives from the State Government, the emergence of new slums was reduced between 2011 and 2021. At the same time, many slums underwent spatial expansion during this period, along with rehabilitation and in-situ development.

But the increase in the number of Katcha houses from 2011 to 2022 in Chennai is worrying and it may be due to various factors such as population growth, urbanization, and limited availability of affordable housing options, etc. This data underscores the need for action to address the housing challenges faced by the residents of Chennai, including improving the living conditions of those living in Katcha houses.

5.CONCLUSION

The result of the study shows that Chennai experienced significant slum growth during 2001- 2011 and slum expansion during 2011-2021. In this study, Google Earth Pro open-source software was predominantly used for slum mapping and validation. The findings revealed the emergence of slums and indicated that 28% of urban dwellers live on 5.16% of the land. As part of Slum development programs of both Central and State Government schemes, slums have been evicted from their original habitation and resettlement or rehabilitation taken place in many wards of Chennai. As a result of this study, an updated dataset was prepared for 2022. The result also shows that 57,771(4.58%) Katcha houses exist in Chennai. Compared to the 2011 census, the present study showed an increase in the number of households living in Katcha houses. This demands an urgent need for affordable housing and the implementation of central and state Government schemes effectively. The eleventh goal of Sustainable development is exclusively for inclusive slum development. This is possible with inclusive urban planning involving the slum community, Public and private partnerships, Community-Based Organizations or Non-Government Organizations and all other stakeholders. The present study is an earnest attempt in this direction using openly available spatial data. Urban planners and urban local bodies can use this dataset or spatial database and can make informed decisions for slum development to achieve sustainable urban development. The decisions we make and actions we take today will have momentous consequences for future generations.

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