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Population Pressure and Horizontal Urban Growth in Siliguri Municipal Corporation, West Bengal

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Abstract:

In most of the urban centres in India population pressure is increasing, which needs a proper planning by the government to avoid negative environmental and socio-economic impacts. It was found that population per unit area of built-up surface may serve as a good indicator of urban sprawl. Since the study area is the Siliguri Municipal Corporation, detailed ward wise decadal analysis is made. The temporal changes were calculated along with population using Location Quotient, in the last three decades. It is also observed that the urban density is higher in the central parts of the wards and lower in the northern wards as most of the northern part was covered by agricultural lands and open space. Siliguri urban agglomeration is extended in the districts of Jalpaiguri and Darjeeling. It incorporates the Bagdogra airport and Cantonment area to the West, New Jalpaiguri Railway Station to the South and Dabgram area to the North and East. The study investigated population growth occurring in the study area and the results show that the overall growth in built-up area is observed in the southeastern parts. The present study highlights the concentration of population ward wise, which necessitates decentralization of smart utility services to the peripheral areas for future planning. In order to ensure long term Sustainability, land resource management is required on priority basis with efficient use of modern techniques.

Keywords: Population, Urban growth, Location Quotient, Land Sustainability, GIS

1. Introduction:

Urban areas cover a very small fraction of the world's land surface (<1%) (Schneider, A., et.al. 2010; Potere, D., et.al2007; Seto, K. C, et.al 2011) their rapid expansion has significantly altered the natural landscape and created enormous environmental, ecosystem, (Deng, J. S., et.al,2009). and social impacts (Haregeweyn, N., et.al,2012; Mundia and Murayama, 2010; Weber & Puissant, 2003). The inevitable outcomes from this process are the spatial expansion of towns beyond their juridical limits in order to accommodate the growing urban population (Herold, M., et.al 2003; Gaffikin, F., et.al 2011; Mosammam, et al., 2016). The pressure of increasing population becomes burden on limited civic facilities (Fitzgerald, K. G., et.al,2014; Rukhsana,et.al,2021). With forecasts of global urban population growth of 2.5 billion between 2018 and 2050, (Mahtta, R., et.al,2022; Kundu, D., et.al,2020) there is an urgent need to understand how this massive demographic shift may affect the expansion of urban land areas (Mahtta, R., et.al 2022). As cities grow in population, they expand outwards, growing in area and converting more land to urban use (Kombe, W. J. (2005; Mundia, C. N., et.al,2005; Güneralp, B., et.al;2020). Land conversion to the built environment occurs with growth in

populations (Skog, K. L., et.al 2016). Globally, urban land is estimated to be expanding at double the rate of population growth (Tan, M., et.al,2005; Seto KC et.al:2011), with tripling occurring in some regions (European Environment Agency). According to the Census India's total population, from 79 million in 1961, i.e. 17.92%, to 388 million in 2011, i.e. 31.30%. (Rukhsana, Hasnine, M. (2021). Suburbanization is a common phenomenon in most urbanizing countries, (Champion, T. 2001; Leetmaa, K., et.al 2007) what makes India's predicament particularly worrying is that it is occurring at a relatively early stage of India's urban development. Likewise, Siliguri city is also developing beyond the municipal limits where to and for is highly engaged as there is much of pressure on land. The high population density has put a large pressure on land resources for a long time (Sarkar, C., et.al 2021;Roy, S.et.al 2024; Banerjee, I., et.al 2024).)Again, according to the latest census of 2011, in West Bengal there are 58 towns each having a population of at least 1,00,000(Mandal, S., et.al;2013). In 1991, the number of such towns was forty-four. Besides, as per the 2001 census, in India there are thirty-five urban agglomerations 8 having a minimum population of one million. The study area is having an urban population of 513,264 in 2011with 115191 households (Census of India;2011). Its population density has increased from 5178 persons per square kilometer to 12,250 persons per square kilometer in 1991.According to the census report of 2011, there lived, in West Bengal, a population of 91,276,115 of which 62,183,113(68.13%) lived in rural areas while the remaining 29,903,002(31.87%) lived in urban areas (Census of India,2011). It is a matter of great surprise to see that nearly 72 per cent of the urban population of the state of West Bengal lived in the city of Kolkata and towns like Asansol, Kharagpur, Andal, Durgapur, Habra, English Bazar, Raiganj, Nabadwip, Raniganj, Ranaghat, Krishnanagar, Berhampur,Balurghat, Siliguri, Alipurduar and some other towns(Konar, D. N;2009). This fast rate of urban population increase is due to migration of people on a large scale from rural and smaller towns to bigger cities in search for opportunities, employments and quality of life.

Urban encroachment and land use/land cover changes growing very fast particularly cities in the developing countries has drawn significant attention from urban and regional planner (Hassan, M. M., et.al,2016). Increasing population growth and density is the major factor causing LULC changes and urban sprawl (Naikoo, M. W., et.al;2020; Yasin, M. Y., et.al,2019). Urban density is one of the main terms used in urban planning as it is considered as an important factor in understanding how the urban areas are functioning (Boyko, C. T., et.al,2011). Urban density is the number of people living in a particular urban area, as number of people in a city grows beyond capacity, the local community person continues to spread and move farther and farther along from city centers. It is interlinking between population and the urban development, so in order understand the population, demography study has been carried out.

Literature Review:

Many literatures were collected from library books, journals, newspapers, internet, online journals etc. for the present study.Bothale and Sharma (2007) have studied the population growth analysis; ward wise occupancy analysis was done for all the 60 wards in the Jodhpur city. Further, quantification of urban expansion was done based on spatial extent of urbanization, density analysis, Shannon's entropy values and jaggedness degree. Nelson and Terry Moore (1993) has argued that many states in USA managing urban growth so that

development is directed to urban areas equipped to accommodate development and rural lands are preserved for resources and other non-urban uses. Chadchan and Shankar (2012) dealt with in-depth analysis of various urban development and issues with the post LPG and increase in urban housing shortage. Elisa Muzzini and Gabriela Aparicio (2013) studied that the location quotient analysis confirms that urban areas are service-oriented economies, with wholesale and retail trades being main contributors to urban employment. Praveen Kumar et al (2013) have studied that the urban land use classification requirement for urban planners and also talks about the site suitability analysis using the technique weighted suitability method in the area of Tirupati.

Madalasa Venkataraman (2014) has carried out a study on Analyzing Urban Growth Boundary Effects in the City of Bengaluru. Bangalore has witnessed significant increase in land prices over the last decade, making it increasingly unaffordable. Chandana Mitra et.al. 2012 as attempted a study on assessment and dynamics of urban growth in the city of Kolkata, India. The urban growth in Kolkata in the next 25 years can be analysed by rasterized maps representing parameters such as land use, existing and future transportation corridors, urban area, excluded areas and slope. Ramachandran. T. V. and Bharath H. Aithal, (2012) has analysed a study on Spatio-Temporal Pattern of Landscape Dynamics in Shimoga, Tier II City, Karnataka State, India Urbanisation and associated growth patterns (urban sprawl) are characteristic of spatial temporal land use changes taking place at regional levels. Basawaraja.R et.al. 2011 has made an analysis of the impact of urban sprawl in altering the land-use, land-cover pattern of Raichur City, India, using geospatial technologies. This paper exclaims about the implication of urban sprawl on the land-use and landcover pattern of a typical rural region, located in the State of Karnataka, India. Tamilenthi1.S et.al. 2011 has measured the dynamics of Urban Sprawl, Changing Direction and Mapping of Salem City, Tamil Nadu; India.

2. Study Area:

Siliguri is the tier-II or Y-type city and head quarter of the Darjeeling district, (Bhujel, B., et.al;2024) that falls on the border of West Bengal State. The emergence of the tourism industry has made Siliguri the third largest city by area in West Bengal (Sarkar, C., et.al;2021; Dolui, S., et.al;2022).). The city is located in North Bengal. It is situated on 26°42' N. latitude and 88°25' E. longitude and having attitude of 396 feet above mean sea level. (www.topographic-map.com).The city located on the Bank of river Mahananda a tributary of the Teesta River in the foothills of the Himalayas,(www.wbtourismgov.in) bounded on the north by the Himalayan ranges, on the east it is bounded by Jalpaiguri district, In the south it is demarcated by country Bangladesh, Uttar Dinajpur district of West Bengal and the Indian state of Bihar and on the west the boundaries of country of Nepal, thus strategically so important(Siliguri.gov.in.). The Siliguri City is divided into 47 wards (Saha, P. 1991; Chowdhury, I. R., et.al;2024). It covers an area of 41.09 sq. kms, the administrative boundary of the Siliguri Municipal Corporation (SMC) is divided into two parts: one part is in the Darjeeling district, with 33 wards out of 47 wards, while the remaining 14 wards fall in the neighboring Jalpaiguri district (siligurismc.in). Besides being the largest city in the Northern part of West Bengal (after Kolkata and Asansol) (www.siliguri.gov.in.), Siliguri has also gained the achievement of being the fastest-growing city in the state (Rukhsana, et.al 2022).

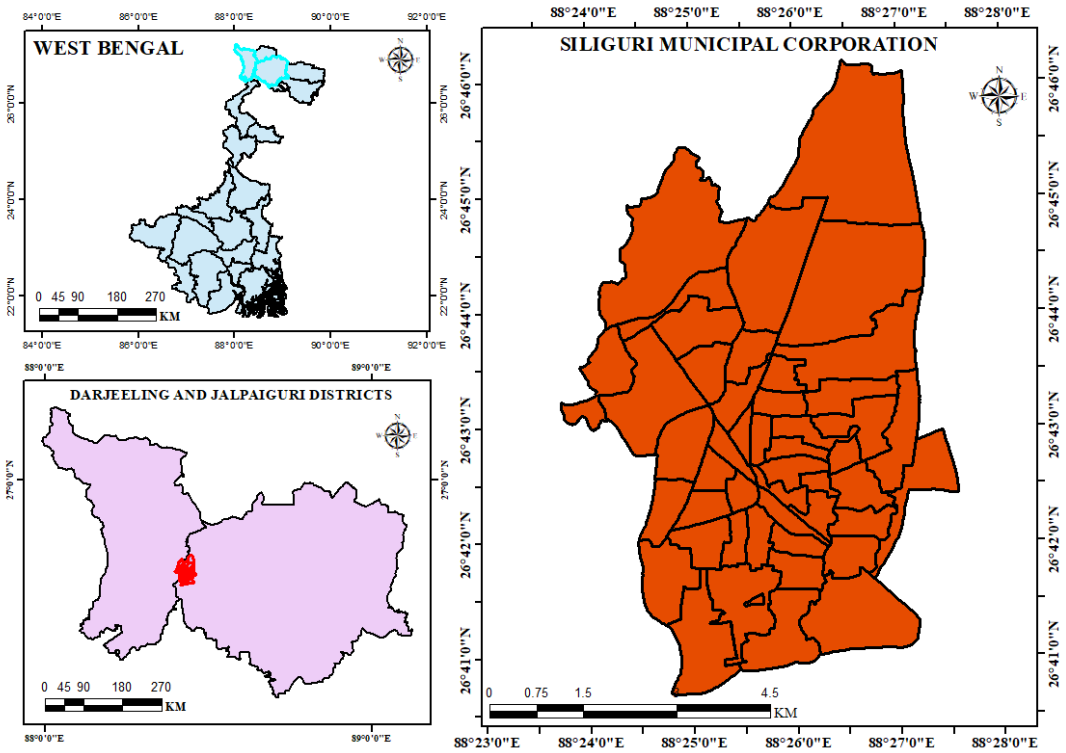


Fig 1: Location of the Study Area

3. Methodology and Materials:

The Present study is based on Secondary data collected from Census of India and other data and information are collected from Siliguri Municipal Corporation, District Statistical Handbook (1991,2001 and 2011), Socio-economic review of West Bengal Statistical abstract. Moreover, relevant information has been collected from a number of national and international publications, journal, books, government documents and other published and unpublished materials. The period from 1991 to 2011 is selected for observing in the pattern of Population density. The methodology involves, demographic analysis followed by location quotient analysis. The year 2001 population concentration were mapped from the statistical data and converted into digital format with the help of GIS. Next, for 2011, the same were mapped using location quotient analysis. Finally, the changes were mapped and measured to find out the growth. Based upon those the study has done to find out the concentration of urban population zone wise and also in ward wise in the study area. Further built ups are delineated using Landsat images the area was calculated to find out the urban density.

4. Results & Discussions:

5.1: Demographic analysis:

The population data spatially prepared and analyzed, it shows the population is higher in the middle zone and lower one found in the North zone and is shown in Figure 2 and ward wise population were classified into six categories and are shown in table 1. It shows that wards number 46 with high and ward number 11 with low population. Population density is a measure of population distribution and one of the most commonly used tools in the geographical

analysis of the population. Here population is depicted in choropleth diagram shown in figure 2.

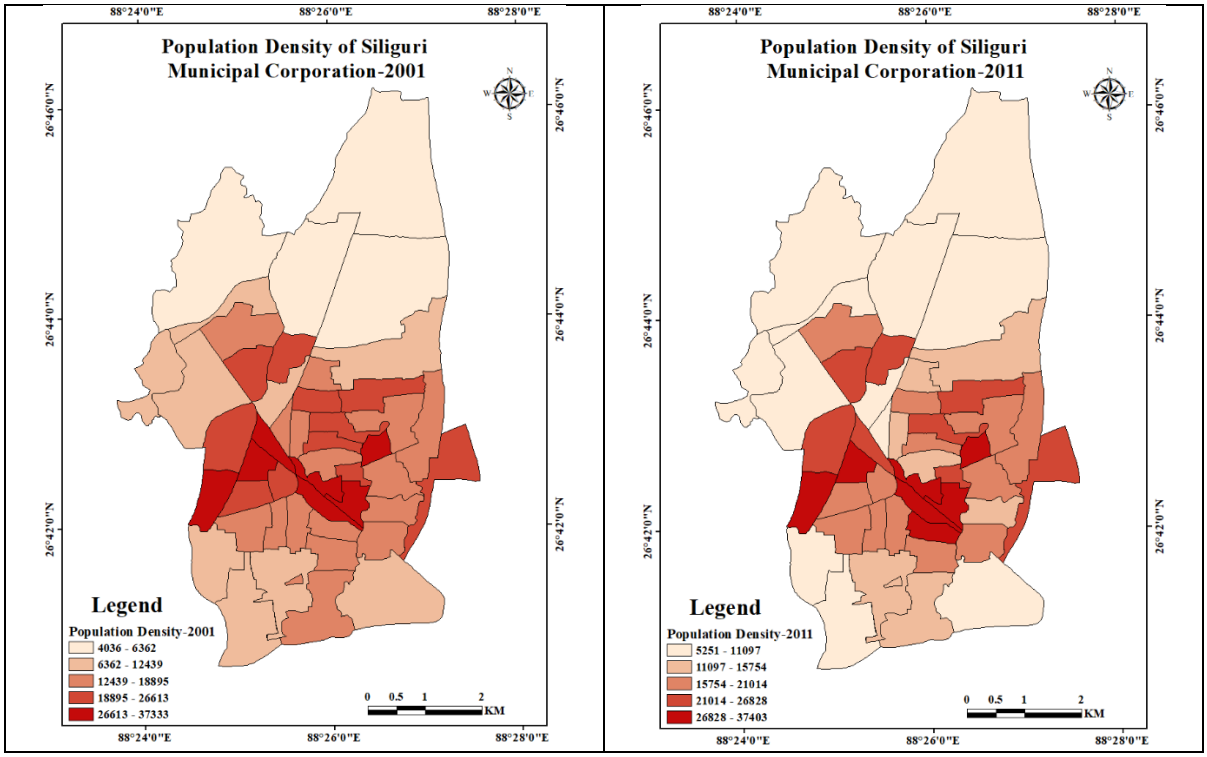


Fig 2: Population Density of Siliguri Municipal Corporation,2001-2011

5.1.1: Population size and Growth of Siliguri

Population growth of Siliguri is mainly dependent upon migration, refugee influx, and illegal immigrants (Kumari, M;2016). Due to large number of immigrants from neighboring countries like Nepal, Bhutan and Bangladesh and neighboring states such as Bihar, Assam and Sikkim, population of Siliguri Municipal Corporation is continuously rising (Paul, S;2022). In addition, formation of corporation in 1994 gave new momentum to the growth of population in the city (Siliguri Municipal Corporation Handbook). Latest census 2011 revealed that the population of Siliguri Municipal Corporation is 513,264 which is an increase from 472,374 in census 2001. Over the last 50 years, the number of populations increased about eight times and since Independence, the number increased by nearly sixteen times. During 1961-1971, decadal population growth rate declined from 9.94 percent to 4.89 percent, and thereafter, Siliguri experienced a continuous increase in the population growth rate and continued for next several decades. During the year 1991, Siliguri registered a high population growth rate of 8.01 percent, while during the previous decade (i.e.1971-1981), it was 7.05 percent. Population growth trends of the city are presented in the following table 1 and Fig.3. Siliguri municipality was administratively divided into 30 wards in 1991 and then it registered about 2, 77,000 population. Later on, a dramatic big jump of population was observed during the census, 2001. It may be the arrival of people from surrounding area due to attraction of facilities of the corporation city and inclusion of additional area from neighbouring Jalpaiguri district to Siliguri. The decadal population growth during 2001-2011 is 0.86 percent while in previous decade (1991-2001) it was 7.05 percent. Though the decadal population growth rate declined,

absolute population increased sharply during the latest census. However, the actual pressure of population upon Siliguri Municipal Corporation may be higher than what is estimated from various census reports published so far.

Table 1: Population growth rate pattern of Siliguri, 1951 to 2011

Census Year	Population	Area (sq. km)	Population density (per sq. km)	Growth Rate	CAGR (%)	Number of wards	Remarks
1951	32480	9.32	3485	101.57(1951-61)	11.97		Post-independence migration due to partition
1961	65471	15.54	4213	48.89(1961-71)	7.26	7	The population growth between 1951-1981 is on account of the migration due to civil war of 1960, Indo-China and Indo-Pak wars of 1962 and 1971 respectively.
1971	97484	15.54	6273	57.80(1971-81)	4.06	12	
1981	153825	15.54	9899	126.51(1981-91)	4.67	19	
1991	216950	15.54	13961	35.56(1991-2001)	3.50	30	Self-induced growth.
2001	472374	41.90	11274	8.66(2001-2011)	8.09	47	Upgradation of Siliguri from Municipality to Corporation led to the population growth as more areas were included within the municipal boundary.
2011	513264	41.9				47	

Source: Compiled and computed from various census reports, District's Census Handbook of 1951,1961,1971, 1981, 1991 (Village and Town Directory), Census of India-2001,2011 WB, Series-20, Vo l.l, World population review (2024)

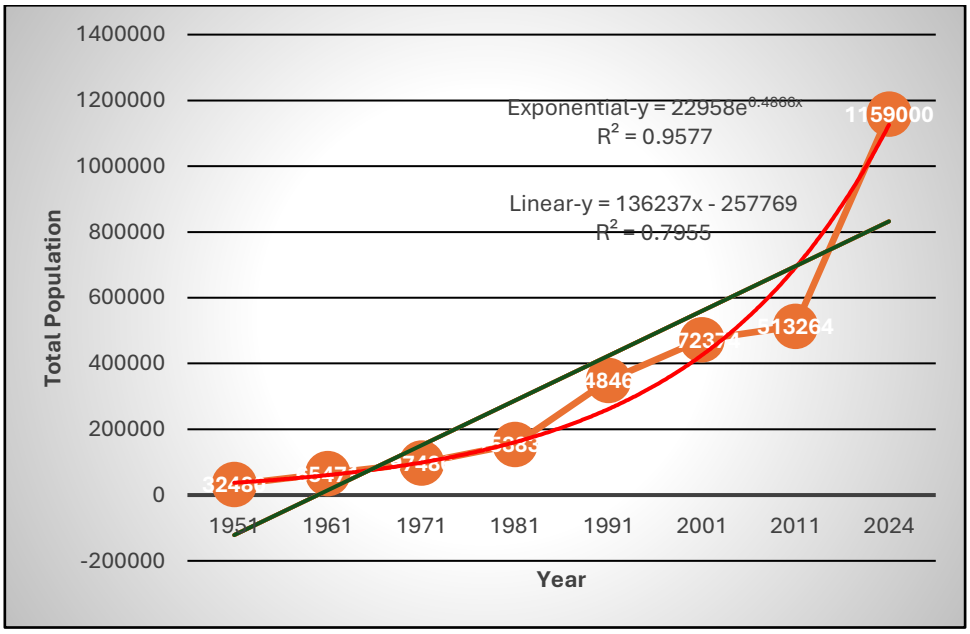


Fig.3: Trend of Population Growth in Siliguri Municipal Corporation

5.1.2: Location quotient analysis:

The location quotient is most frequently used in economic geography and locational analysis, (Islam, F. B. et.al,2015; Franconi, L., et.al,2024) but it has much wider applicability. Location quotient is useful in demographic studies because it shows what makes the regions demographics unique in comparison to its state and or the nation (Oka, M. 2023). The location quotient is an index for comparing an areas share of a particular activity/Phenomenon with the areas share of some basis or aggregate phenomenon (Kakon, A. N. 2007). It is important to find out the relation of that aspect in terms of proportion may be important at local level and not at regional or country or state level. Location quotient is very helpful in order to find out the proportion of any aspect in a district in relation to the state or country (Andresen, M. A. 2007). In a regional context, a higher or lower value of the location quotient indicates relative concentration or dispersion of the concerned attribute. Location Quotient gives us the relative picture of such proportion is defined as the ratio of the proportion of a particular characteristic in an area to the same proportion in the region and Location quotient is employed here as a benchmark in the analysis of the concentration or deconcentration of the urban population in different regions of Siliguri. Here it is used as a ratio of percentage of urban population in a region to the percentage of national urban population. It can be expressed as

$$\text{L.Q of Ward “X”} = \frac{\frac{P}{Pi}}{\frac{A}{Ai}} \quad \ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where, P=Total population of the ward “X”

Pi=Total population of the Siliguri Municipal Corporation

A=Total area of the ward “X”

Ai=Total area of the Siliguri Municipal Corporation

5.1.3: Location Quotient Analysis Population (2001-2011)

Base on the location quotient analysis data for population and its spatial distribution has been prepared for 2001 and 2011 and shown in Table 2.Location quotient analysis are done to find out the concentration of population in each ward and are categorized into five categories for those two years which are mapped and shown in Figure 4 and 5.The Changes in population are more observed in central parts of the study area.

Table 2: Location Quotient Analysis Population (2001-2011)

Ward No	Area(sq.km)	Total population	Population density (2001)	LQ=Pw-Pm/Aw-Am(2001)	Total population	Population density (2011)	LQ=Pw-Pm/Aw-Am(2011)	Changes
1	2.3	17843	10461	0.69	18928	11097	0.67	0.02
2	1.5	11436	13773	0.68	14327	17254	0.78	-0.1
3	1.02	11753	26613	1.02	10993	24892	0.88	0.14
4	1.13	20028	22138	1.57	20745	22931	1.50	0.07
5	1.22	15326	32627	1.11	16369	34847	1.10	0.01

6	0.2	9023	37333	4.00	6484	26828	2.65	1.35
7	0.32	9889	36195	2.74	7954	29113	2.03	0.71
8	0.2	7843	26269	3.48	5097	17072	2.08	1.4
9	0.28	7306	20879	2.31	6481	18521	1.89	0.42
10	0.77	4706	11508	0.54	4019	9798	0.43	0.11
11	0.16	4720	16272	2.62	1912	10608	0.98	1.64
12	0.24	2933	16637	1.08	2832	12491	0.96	0.12
13	0.28	3772	15827	1.19	4886	15253	1.42	-0.23
14	0.32	5070	20505	1.41	6566	21014	1.68	-0.27
15	0.34	6407	22922	1.67	8002	22636	1.92	-0.25
16	0.24	8103	23472	2.99	4922	19307	1.67	1.32
17	0.2	5984	15659	2.65	5029	14357	2.05	0.6
18	0.16	5485	29067	3.04	7774	28232	3.97	-0.93
19	0.2	8004	25819	3.55	3286	26242	1.34	2.21
20	0.24	3233	32967	1.19	9009	30094	3.06	-1.87
21	0.32	9869	32806	2.74	5624	31404	1.43	1.31
22	0.48	5875	18895	1.09	10182	18691	1.73	-0.64
23	0.28	10293	15418	3.26	6340	15754	1.85	1.41
24	0.48	6205	18354	1.15	11045	18157	1.88	-0.73
25	0.25	8525	17064	3.02	9459	18934	3.09	-0.07
26	0.24	4873	16723	1.80	5038	17290	1.71	0.09
27	0.36	5630	16263	1.39	6892	19909	1.56	-0.17
28	0.69	9578	34135	1.23	8836	31491	1.05	0.18
29	0.69	4783	16715	0.61	10703	37403	1.27	-0.66
30	0.43	6510	15250	1.34	7819	18316	1.48	-0.14
31	0.8	13414	9227	1.49	14424	9922	1.47	0.02
32	1.29	11845	7595	0.81	11334	7267	0.72	0.09
33	1.13	13543	12439	1.06	14518	13335	1.05	0.01
34	1.28	16560	15138	1.15	16999	15539	1.08	0.07
35	1.94	14945	8919	0.68	15820	9442	0.67	0.01
36	0.96	13553	20248	1.25	14734	22013	1.25	0
37	0.64	14431	18819	2.00	15690	20461	2.00	0
38	0.65	11235	14389	1.53	13022	16677	1.64	-0.11
39	0.78	11237	20169	1.28	12353	22172	1.29	-0.01
40	2.43	18164	10599	0.66	25152	14677	0.84	-0.18
41	3.24	12951	4200	0.35	17351	5626	0.44	-0.09
42	4.15	14711	4036	0.31	19139	5251	0.38	-0.07
43	1.77	9661	4558	0.48	16339	7708	0.75	-0.27
44	0.73	11522	24630	1.40	11843	25317	1.32	0.08
45	0.26	7117	9051	2.43	7001	8904	2.20	0.23
46	3.63	21222	6362	0.52	30665	9193	0.69	-0.17
47	0.68	8363	9487	1.09	9327	10581	1.12	-0.03
Total	41.9	4,72,374			5,13,264			

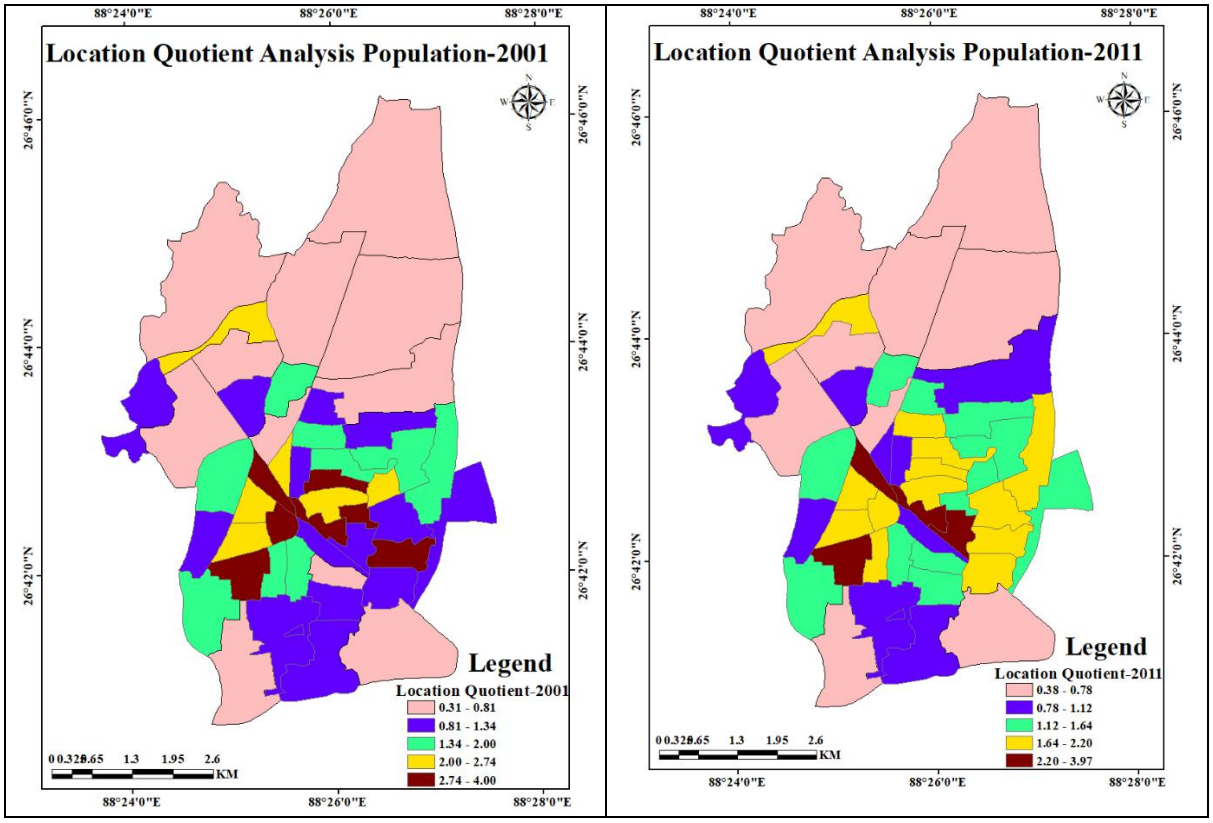


Fig 4: Location Quotient Analysis Population (2001-2011)

5.1.4: Trends of Population Density in Siliguri

Population density is a synthesis of all geo-economic conditions, and it is an ongoing process which with its dynamic nature determines the level of concentration and the resultant crowding and dissemination in spatio-temporal perspective. The density in an area increases proportionately whenever there is an increase in its population over a period of time with its area remaining unchanged. Similar situation has been witnessed by Siliguri Municipal Corporation too. The population density of the town at present is 23544 persons per km^2(2011) spread over an area of 41.9 km^2.

Table 3. Year wise Population Density and Annual Growth Rate of Siliguri Municipal Corporation

Year	Annual Growth Rate	Density
1951		3485
1961	7.26	4213
1971	4.06	6273
1981	4.7	9934
1991	3.46	13961
2001	8.09	11274

2011	7.4	23544

Sources: Census of India

Table-3 depicts the density, and annual growth rate of population in the Siliguri Municipal Corporation, where it is found that the density of population in the study area was substantially high over the decades. The density of population in Siliguri Municipal Corporation was significantly higher than that of the density in other municipal corporation in the state except Kolkata and Howrah Municipal Corporation, where the density of population was much higher than the density of Siliguri Municipal Corporation in 2011.The annual growth rate of Siliguri Municipal Corporation during the period of 1991-2011 was not only higher (7.4%) than the North Bengal region (2.51 %) but was also higher than the growth rate of all the municipal corporations in West Bengal.It has also been observed that the inflow of population was highest in the study area during the period 1991-2011 with 7.4 percent urban growth rate, which was largely due to the reclassification of the municipal area and immigration from the neighboring districts and from within the district.

Various studies stated that on the whole, during the period of 1951-71, the huge influx of population to Siliguri Municipality was the immigrant refugees from East Pakistan (Bangladesh). Large number of refugees from border areas due to Indo-China border conflict coupled with construction of military establishments and increase in communication facilities, all contributed to the steady growth of migrant population. They came and majority having settled in the plains of Siliguri sub-division. Further in 1971-81, the Bangladesh war added to the already broad population base but after 1981, important state government offices were established in Siliguri to facilitate administration while attracting employment in the tertiary sector.

5.1.5: Urban Density:

A most popular dimensional index of urban growth and sprawl is the urban density, it refers to the relationship between inhabitants and built-up area per census district. Frenkel & Ashkenazi, (2008), stated that a measurement of the number of people living per unit of an area that the population density can be measured using the formula:

$$D=\frac{Population}{Area} \dots\dots\dots\dots\dots\dots\dots 2$$

The urban density of Siliguri is increasing continuously. In 2001, the urban population density of Siliguri is 11274 Sq. Km. In 2011; the density of Siliguri is increased up to 23544 Sq. Km. In the two decades, urban density is increased by 12270 persons per Sq. km. The density of urban population is increased due to industrialization, transportation hub, education and entertainment facilities and availability of jobs in Siliguri urban area.

Table 4: Urban Density of Siliguri Municipal Corporation,2001-2011

Ward No	Area(sq.km)	Total population	Population density (2001)	Total population	Population density (2011)
1	1.70564	17843	10461	18928	11097
2	0.830318	11436	13773	14327	17254

3	0.44162	11753	26613	10993	24892
4	0.904662	20028	22138	20745	22931
5	0.469731	15326	32627	16369	34847
6	0.241686	9023	37333	6484	26828
7	0.273208	9889	36195	7954	29113
8	0.298556	7843	26269	5097	17072
9	0.34991	7306	20879	6481	18521
10	0.410145	4706	11508	4019	9798
11	0.180241	4720	16272	1912	10608
12	0.226711	2933	16637	2832	12491
13	0.320325	3772	15827	4886	15253
14	0.312453	5070	20505	6566	21014
15	0.353494	6407	22922	8002	22636
16	0.254933	8103	23472	4922	19307
17	0.350273	5984	15659	5029	14357
18	0.275357	5485	29067	7774	28232
19	0.125215	8004	25819	3286	26242
20	0.299353	3233	32967	9009	30094
21	0.179081	9869	32806	5624	31404
22	0.544733	5875	18895	10182	18691
23	0.402436	10293	15418	6340	15754
24	0.608284	6205	18354	11045	18157
25	0.499576	8525	17064	9459	18934
26	0.291381	4873	16723	5038	17290
27	0.346173	5630	16263	6892	19909
28	0.280586	9578	34135	8836	31491
29	0.286147	4783	16715	10703	37403
30	0.426878	6510	15250	7819	18316
31	1.45365	13414	9227	14424	9922
32	1.55957	11845	7595	11334	7267
33	1.08867	13543	12439	14518	13335
34	1.09389	16560	15138	16999	15539
35	1.67549	14945	8919	15820	9442
36	0.669327	13553	20248	14734	22013
37	0.76681	14431	18819	15690	20461
38	0.780792	11235	14389	13022	16677
39	0.557136	11237	20169	12353	22172
40	1.71363	18164	10599	25152	14677
41	3.08353	12951	4200	17351	5626
42	3.6448	14711	4036	19139	5251
43	2.11955	9661	4558	16339	7708
44	0.467785	11522	24630	11843	25317

45	0.786236	7117	9051	7001	8904
46	3.33545	21222	6362	30665	9193
47	0.881443	8363	9487	9327	10581

Source: Compiled and computed from various census reports.

The ward wise urban density has been worked out, based on the formula, ward wise spatial distribution has been prepared and it is shown in table 5 and 6. Here the built-up area were delineated from the images and the area were calculated so as to find the built up density and the results were categorized. In 2001 census Ward No's 3,5,6,7,8,18,19,20,21,28,44 are the area having very high population density (population density > 24001 person/sq. km). because those areas are fully settled and located near the center of Siliguri with available basic amenities. High population density (from 20001-24000 person/sq. km) is found in ward no 4, 9, 14, 15, 16, 36, and 39, which are located near the central area of Siliguri town. In 2011, very high population density is found in ward number of 3,5,6,7,18,19,20,21,28,29, and 44 (population density > 24001person/sq. km). It may be noted that from the very beginning those areas were already very high population density for the availability of all kinds of facilities. Wards 4, 14, 15, 36, 37, and 39 are the high population density area. Results shows that higher density was found in the southwestern area and lower one in the northern part. The zone wise urban populations are also calculated and are tabulated in Table 5 and 6 from this it is clearly understood that the west zone urban density is highest in the last two decades and so the urban sprawl it towards the southern direction.

Table 5. Spatial variation in population density, 2001

Population density (Persons/km2)	**Category**	**Wards**	**%to Total wards**
< 6000	Very Low	41,42,43	6.38
6001-10000	Low	31,32,35,45,46,47	12.76
10001-14000	Moderate	1,2,10,33,40	10.63
14001-20000	Moderately high	11,12,13,17,22,23,24,25,26,27,29,30,34,37,38	31.91
20001-24000	High	4,9,14,15,16,36,39	14.89
> 24001	Very high	3,5,6,7,8,18,19,20,21,28,44	23.4

Source: Compiled and computed from various census reports.

Table 6. Spatial variation in population density, 2011

Population density (Persons/km^2)	**Category**	**Wards**	**%to Total wards**
< 6000	Very Low	41,42	4.26
6001-10000	Low	10,31,32,35,43,45,46	14.89

10001-14000	Moderate	1,11,12,33,47	10.64
14001-20000	Moderately high	2,8,9,13,16,17,22,23,24,25,26,27,30,34,38,40	34.04
20001-24000	High	4,14,15,36,37,39	12.77
> 24001	Very high	3,5,6,7,18,19,20,21,28,29,44	23.4

Source: Compiled and computed from various census reports.

Table 7. Correlation between Area and Population Density, 2011

Ward	Population Density	Area in Sq.km	R1	R2	D	$(D)^2$
01	11097	1.70564	6	39	-33	1089
02	17255	0.830318	14	11	3	9
03	24892	0.44162	25	44	-19	361
04	22931	0.904662	12	45	-33	1089
05	34848	0.469731	23	43	-20	400
06	26828	0.241686	42	22	20	400
07	29113	0.273208	40	14	26	676
08	17072	0.298556	36	42	-6	36
09	18522	0.34991	32	40	-8	64
10	9799	0.410145	27	18	9	81
11	10608	0.180241	44	46	-2	4
12	12492	0.226711	43	12	31	961
13	15253	0.320325	33	28	5	25
14	21014	0.312453	34	5	29	841
15	22637	0.353494	31	8	23	529
16	19307	0.254933	41	4	37	1369
17	14357	0.350273	30	1	29	841
18	28232	0.275357	39	20	19	361
19	26243	0.125215	46	34	12	144
20	30095	0.299353	35	29	6	36
21	31405	0.179081	45	6	39	1521
22	18692	0.544733	21	2	19	361
23	15754	0.402436	28	3	25	625

24	18158	0.608284	19	25	-6	36
25	18934	0.499576	22	21	1	1
26	17290	0.291381	37	16	21	441
27	19909	0.346173	29	10	19	361
28	31491	0.280586	38	19	19	361
29	37404	0.286147	36	47	-11	121
30	18317	0.426878	26	7	19	361
31	9923	1.45365	9	13	-4	16
32	7267	1.55957	8	26	-18	324
33	13336	1.08867	10	9	1	1
34	15540	1.09389	11	24	-13	169
35	9442	1.67549	7	37	-30	900
36	22013	0.669327	18	35	-17	289
37	20461	0.76681	17	32	-15	225
38	16678	0.780792	16	17	-1	1
39	22172	0.557136	20	15	5	25
40	14678	1.71363	5	33	-28	784
41	5627	3.08353	3	27	-24	576
42	5251	3.6448	1	31	-30	900
43	7709	2.11955	4	41	-37	1369
44	25317	0.467785	24	38	-14	196
45	8904	0.786236	15	30	-15	225
46	9194	3.33545	2	36	-34	1156
47	10582	0.881443	13	23	-10	100
Total						20761

Source: Computed by the authors

(R1= Rank of Area, R2= Rank of density, d= differences in the rank of two variables)

$$P= 1-6\Sigma d^2/n^3-n \quad (3)$$

$$P= 1-6x20761/ (47)^3-47$$

$$P= 1-124566/103823-47$$

$$P= 1- 124566/103776$$

P= 1-1.20

P= -0.2

5.1.6: Land Consumption Rate (LCR):

Another indicator of urban sprawl is a Land Consumption Rate. It is a measure of compactness which indicates a progressive spatial expansion of a city (Li, C., et.al,2021; Nicolau, R., et.al,2018; Yeates, M., & Garner, 1976). Land Consumption Rates depicts per person land consumed in the process of urbanization. In Siliguri city, increasing urbanization resulted into a change in the per person land consumption rate from 1951 to 2021.The formula for LCR is given below:

$$LCR=\frac{A}{P} \dots \dots \dots \dots \dots \dots \dots \dots (4)$$

Where, A = Areal extent of the city in hectares

P = Population

Table 8: Land Consumption Rate of Siliguri City 1951-2021

Year	Area (Sq. Km) Hectare	Population	LCR (Hectare/person) =A/P
1951	9.32(932 Hectare)	32,480	0.0286
1961	12.87(1287Hectare	65,471	0.0196
1971	15.54(1554 Hectare	97,484	0.0159
1981	15.54(1554 Hectare	153,825	0.0101
1991	15.54(1554 Hectare	216950	0.0071
2001	41.9(4190 Hectare	284602	0.0147
2011	41.9(4190 Hectare	509709	0.0082
2021	41.9(4190 Hectare	1159000	0.0036

Source: Compiled and computed from various census reports. (Notes:2021 data was projected)

Table 8 shows that in 1951, Land Consumption Rate in Siliguri Municipal Corporation was 0.0286 hectare/person, but in 1991, it reduced slightly and became 0.0071 hectare/person. However, by 2021 Land Consumption Rate became 0.0036 hectare/person, which is quite reduced from 1991. It can be derived from the results of Table 8 that urban sprawl has remained a consistent feature of Siliguri. It is not a worthy that although Land Consumption Rate decreased from 1991 to 2021, but the difference was very small. The current study indicates that population growth, land demand and land speculation, increase of living and property cost in the inner city and growth of transport are the main factors of expansion of the city into peripheral areas.

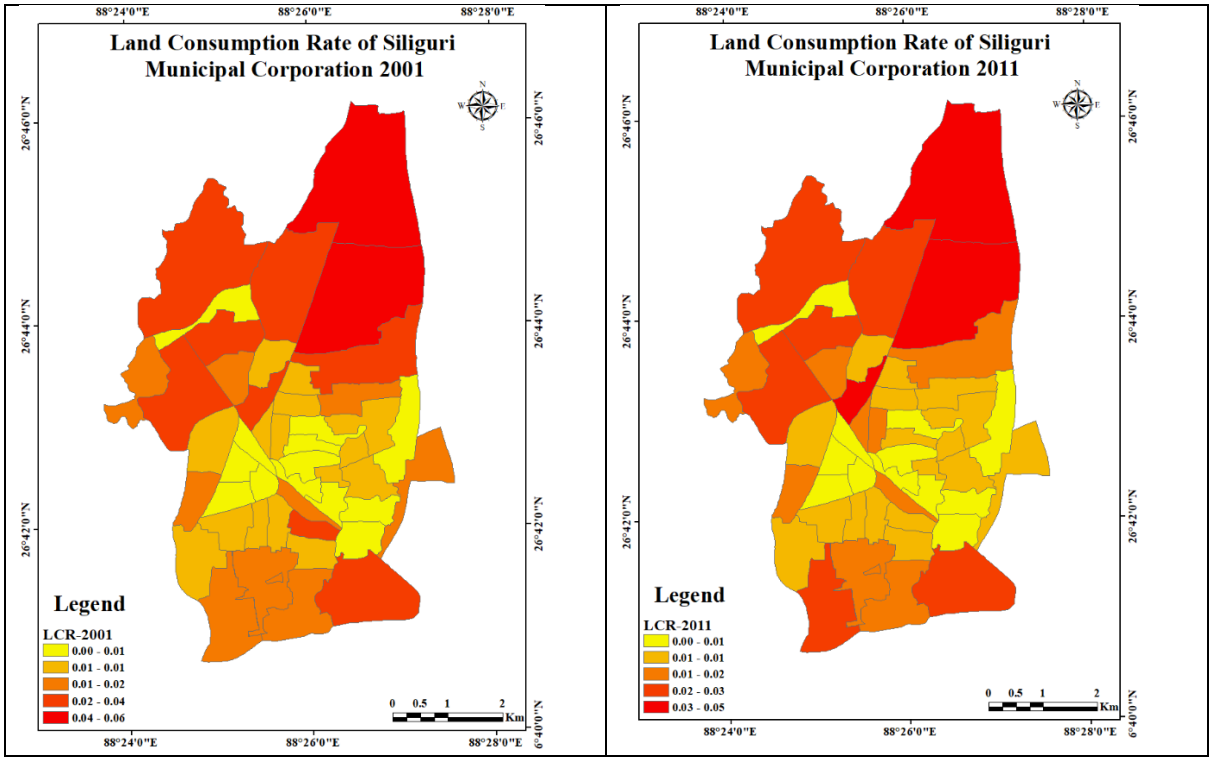


Fig 5: Land Consumption Rate of Siliguri Municipal Corporation-2001 and 2011

5.1.7: Land Absorption Coefficient (LAC):

Land Absorption Coefficient (LAC) is a measure of change in consumption of new urban land by each unit increase in urban population (Samuel, K. J., et.al,2019; Sandhya Kiran, G., et.al,2013; Yeates, M., & Garner, 1976). The formula for LAR is given below:

$$LAR=\frac{A2-A1}{P2-P1} \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where, A1 and A2 = Areal extents (in hectares) for the early and later years, and P1 and P2 = Population figure for the early and later years, respectively

Table 9: Land Absorption Coefficient of Siliguri City 1991-2021

Year	Area (Hectares)	Population Increase	LAC (Hectares/person) =A/P	Hortas & Solé, (2010) classified urban land
1951-1961	9.32(932 Hectare)	32991	0.0282	high sprawled pattern
1961-1971	12.87(1287Hectare	32013	0.0402	high sprawled pattern
1971-1981	15.54(1554Hectare	56341	0.0275	high sprawled pattern
1981-1991	15.54(1554Hectare	63125	0.0246	high sprawled pattern
1991-2001	15.54(1554Hectare	67652	0.0229	high sprawled pattern
2001-2011	41.9(4190 Hectare	225107	0.0186	high sprawled pattern

2011-2021	41.9(4190 Hectare	649291	0.0064	compact urbanized land

Source: Compiled and computed from various census reports. District's Census Handbook of 1951,1961,1971, 1981, 1991 (Village and Town Directory), Census of India-2001,2011 WB, Series-20, Vo l.l, World population review (2024)

According to table 9, the result of the study illustrates that, the Land Absorption Coefficient for the periods 1991-2001,2001-2011, and 2011-2021 is 0.0229, 0.0186 and 0.0064 respectively. The Land Absorption Coefficient reduced during the period 2001-2011 and 2011-2021.This indicates in the period between 1951 - 1961 the population was mostly concentrated within the city, but after 1961 people moved to the peripheral area of the city.

Hortas & Solé, (2010) classified urban land as :< 75m^2 per person as compact urbanized land, between 75m^2 and 160 m^2per person as the medium sprawled pattern and 160 m^2 up to> 700m^2 per person have a high sprawled pattern. Based on the result of table 9, the Land Absorption Coefficient between 1951-1961,1961-1971,1971-1981,1981-1991,1991-2001 and 2001-2011 was 282m^2 per person,402 m^2 per person,275 m^2 per person,246 m^2 per person,229m^2 per person, and 186m^2 per person respectively. Therefore, the pattern of urban sprawl in Siliguri Municipal Corporation was high sprawled pattern between 1951- 2011 and 2011-2021 was Compact urbanized respectively.

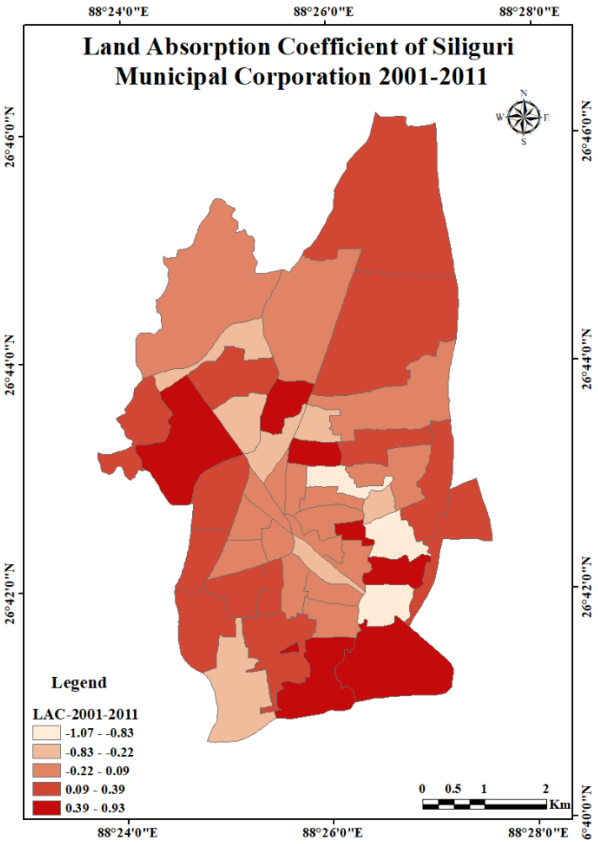


Fig 6: Land Absorption Coefficient of Siliguri Municipal Corporation 2001-2011

5.1.8: Trends of Urban Sprawl in Siliguri Municipal Corporation:

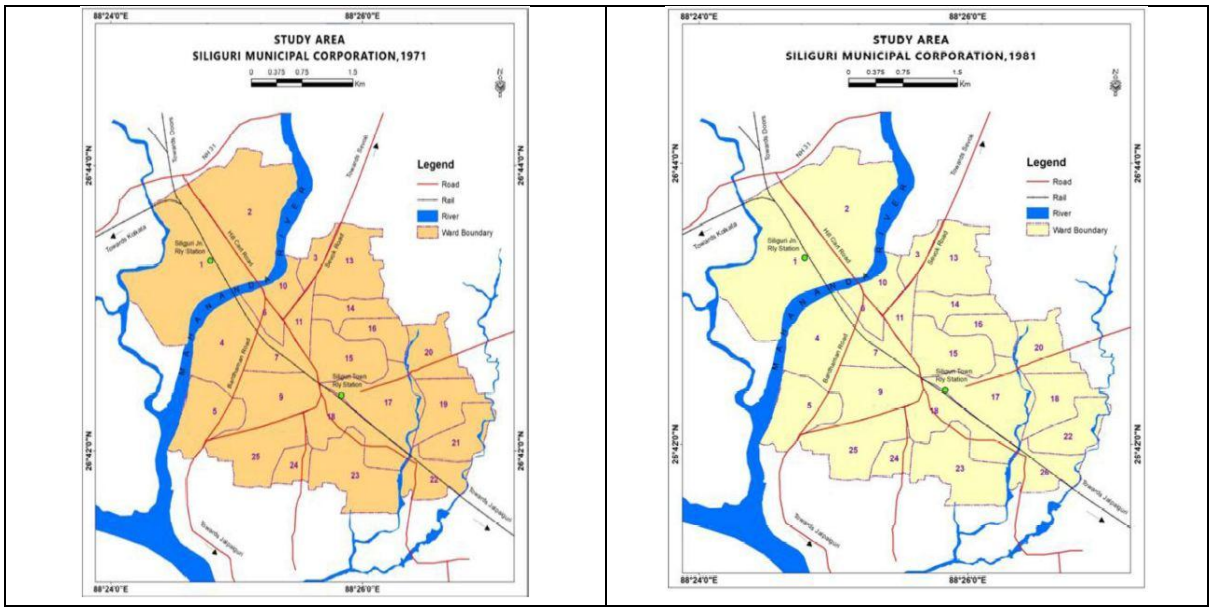
Rapid expansion of urban sprawl of Siliguri city is not only affecting the demographic structure of the city, but it also consumes the most valuable agricultural land of its surrounding rural areas.

Table 10 and Fig:2.1 is showing the horizontal expansion of Siliguri Municipal Corporation between 1951 and 2021.The city occupied only 9.32 sq.km in 1951 which increased to 41.9 sq.km in 2021. In the period of 1951 to 2021 Siliguri has engulfed 40.58 sq.km area. It indicates that the city has expanded at a very fast rate in the last 70 years which is 435.41 per cent. During the first 10 years from 1951 to 1961 the city was expanding at the rate of 3.80 per cent per annum, but in the last 10 years from 2011 to 2021 the expansion rate has Zero. Overall, per annum expansion of Siliguri city is 6.22 per cent from 1951to 2021.

Table 10: Expansion of Siliguri Municipal Corporation 1951-2021

Year	Area in (km^2)	Total Change in (km^2) = (Present-Past Area)	Total Change in Percentage= (Present-Past Area)/Past*100	Per cent Per Annum Change=Total change in %/10
1951	9.32	-		
1961	12.87	3.55	38.09	3.80
1971	15.54	2.67	20.74	2.07
1981	15.54	0	0	0
1991	15.54	0	0	0
2001	41.9	34.36	169.63	16.96
2011	41.9	0	0	0
2021	41.9	0	0	0
Change in area 1951-2021		40.58	435.41	6.22

Source: Compiled and computed from various census reports, District's Census Handbook of 1951,1961,1971, 1981, 1991 (Village and Town Directory), Census of India-2001,2011 WB, Series-20, Vo l.l.



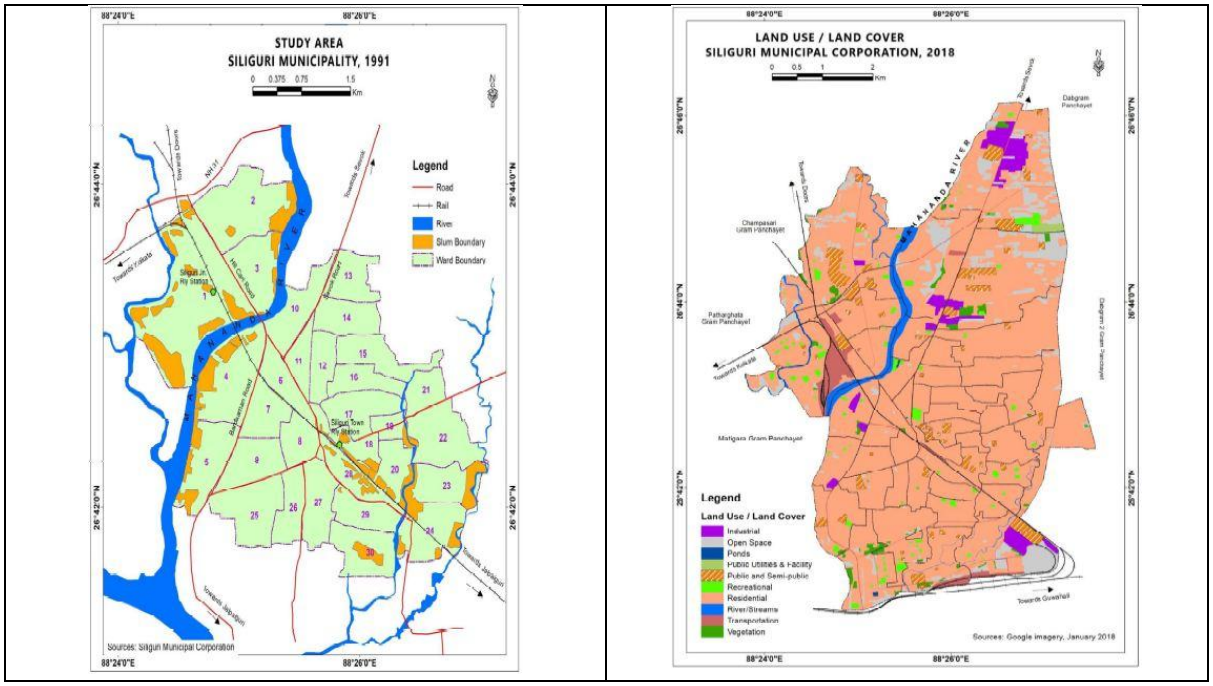


Fig 7: Spatiotemporal Expansion and Growth of Siliguri Municipal Corporation in Different Year of 1971, 1981, 1991, and 2018(Source: Siliguri Municipal Corporation)

5. Conclusion:

In the last three decades, the pressure of population in Siliguri Municipal Corporation is increasing and it has resulted into an increase in the incidence of urban sprawl. The built-up has more than doubled in comparison to the city population. Density of population in the city has increased in the recent pasts which also indicate towards increasing urban sprawl. Besides population density, an increase in Land Consumption Rate and Absorption Coefficient also indicates increase of urban sprawl of Siliguri Municipal Corporation.

The present paper gives a vivid picture of the demography of the study area and its urban density was worked out for zone wise and ward wise. The temporal changes were also calculated along with population. In the last two decades, urban density is higher in the west zone and lower in the north zone. In order to plan and implement various developmental activities, spatial data and monitoring the dynamics of the urban land use are the two basic things for suitability analysis. Identification of suitable land for urban development is one of the current critical issues of smart planning. The suitability of land for urban development is based on a set of some physical parameters and economic factors. The cumulative effect of this factor determines the degree of suitability and also helps in further categorizing of the land into different orders of development. The assessment of the physical parameters of the land is possible by analyzing the land use, soil, slope, geology, flood hazard, Physiographic, distance from the road network and railway stations etc. and which are very much amenable to GIS analysis.

6. Recommendation:

This study is one of such efforts aimed at providing information that would aid in developing sustainable urban land use policies in Siliguri Municipal Corporation. This is necessary as the

natural land cover of Siliguri Municipal Corporation continues to be removed in ecologically significant amounts for construction and other urban usage. Thus, the study recommends further research toward these synergetic factors driving land use changes in Siliguri.

- In light of the need for more housing in Siliguri.
- The study also recommends a review of the existing urban planning practices to include Strategic Environmental Assessment (SEA) for housing projects in Siliguri where the overall impacts of large-scale housing projects can be identified and mitigated accordingly.
- Lastly, high-rise housing units should be encouraged as against the single-unit bungalows that consume large land area with just a few thousand units.

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Author contributions:

B. Hembram designed the research, performed the analyses and interpreted the results and wrote the paper. N. C. Jana commented on the draft and final manuscript and provided additional significant edits. Both authors approved the manuscript for submission.

Competing interests

The authors declare no competing interests.

References:

"Siliguri-about location". www.wbtourismgov.in. Archived from the original on 30 April 2019. Retrieved 8 June 2024.

"Urban Agglomerations/Cities having population 1 lakh and above" (PDF). Provisional Population Totals, Census of India 2011. Archived from the original (PDF) on 22 November 2020. Retrieved 23 May 2024.

"Siliguri-description". www.siliguri.gov.in. Archived from the original on 8 June 2019. Retrieved 8 June 2024.

Topographic map of Siliguri". www.topographic-map.com. Archived from the original on 30 March 2024. Retrieved 21 May 2024.

"About Siliguri Subdivision". Siliguri.gov.in. Archived from the original on 13 March 2019. Retrieved 10 March 2024.

"Siliguri Municipal Corporation: About Us". siligurismc.in. Archived from the original on 29 October 2020. Retrieved 30 September 2020.

Nelson, A. C., & Moore, T. (1993). Assessing urban growth management. The case of Portland, Oregon, the USA's largest urban growth boundary. Land Use Policy, 10(4), 293-302. https://doi.org/10.1016/0264-8377(93)90039-D.

Bothale and Sharma, (2007) Urban Sprawl Mapping and Land Use Change Analysis Using Remote Sensing and GIS (Case Study Of Bhubaneswar City, Orissa).

Chadchan J & Shankar R, (2012). An Analysis of Urban Growth Trends in the Post Economic Region Period in India", Dept of city regional planning, Saudi Arabia, International journal of Sustainable Built environment, 1, 36-49.

Praveen Kumar Mallupattu and Jayarama Reddy Sreenivasula Reddy, (2013) "Analysis of Land Use/Land Cover Changes Using Remote Sensing Data and GIS at an Urban Area, Tirupati, India" The Scientific World Journal, Vol 2013, Article ID 268623,6 Pages.

Elisa Muzzini and Gabriela Aparicio (2013). Urban Growth and Spatial Transition in Nepal, 91 – 124.

Mundia, C. N., & Murayama, Y. (2010). Modeling spatial processes of urban growth in African cities: A case study of Nairobi City. Urban Geography, 31(2), 259-272.

Weber, C., & Puissant, A. (2003). Urbanization pressure and modeling of urban growth: example of the Tunis Metropolitan Area. Remote sensing of environment, 86(3), 341-352.

Mosammam, Hassan Mohammadian, Nia, Jamileh Tavakoli, Khani, Hadi, Teymouri, Asghar & Kazemi, Mohammad. Monitoring land use change and measuring urban sprawl based on its spatial forms: the case of Qom city, Egypt. J. Remote Sens. Space Sci. http://doi.org/ 10.1016/j.ejrs.2016.08.002.

Rukhsana, Hasnine, M. (2021). Population Pressure and Urban Sprawl in Kolkata Metropolitan Area. In: Rukhsana, Haldar, A., Alam, A., Satpati, L. (eds) Habitat, Ecology and Ekistics. Advances in Asian Human-Environmental Research. Springer, Cham. https://doi.org/10.1007/978-3-030-49115-4_9

Mahtta, R., Fragkias, M., Güneralp, B. et al. Urban land expansion: the role of population and economic growth for 300+ cities. npj Urban Sustain 2, 5 (2022). https://doi.org/10.1038/s42949-022-00048-y

European Environment Agency. Urban sprawl in Europe.EEA Report No. 11/2016, Publications Office of the European Union, Luxembourg; 2016

Seto KC, Fragkias M, Güneralp B, Reilly MK. A meta-analysis of global urban land expansion. PLOS ONE. 2011;6(8): Articlee23777.

Kombe, W. J. (2005). Land use dynamics in peri-urban areas and their implications on the urban growth and form: the case of Dar es Salaam, Tanzania. Habitat International, 29(1), 113-135.

Mundia, C. N., & Aniya, M. (2005). Analysis of land use/cover changes and urban expansion of Nairobi city using remote sensing and GIS. International journal of Remote sensing, 26(13), 2831-2849.

Güneralp, B., Reba, M., Hales, B. U., Wentz, E. A., & Seto, K. C. (2020). Trends in urban land expansion, density, and land transitions from 1970 to 2010: A global synthesis. Environmental Research Letters, 15(4), 044015.

Seto, K. C., Fragkias, M., Güneralp, B., & Reilly, M. K. (2011). A meta-analysis of global urban land expansion. PloS one, 6(8), e23777.

Potere, D., & Schneider, A. (2007). A critical look at representations of urban areas in global maps. GeoJournal, 69(1), 55-80.

Schneider, A., Friedl, M. A., & Potere, D. (2010). Mapping global urban areas using MODIS 500-m data: New methods and datasets based on 'urban ecoregions'. Remote sensing of environment, 114(8), 1733-1746.

Haregeweyn, N., Fikadu, G., Tsunekawa, A., Tsubo, M., & Meshesha, D. T. (2012). The dynamics of urban expansion and its impacts on land use/land cover change and small-scale farmers living near the urban fringe: A case study of Bahir Dar, Ethiopia. Landscape and urban planning, 106(2), 149-157.

Deng, J. S., Wang, K., Hong, Y., & Qi, J. G. (2009). Spatio-temporal dynamics and evolution of land use change and landscape pattern in response to rapid urbanization. Landscape and urban planning, 92(3-4), 187-198.

Gaffikin, F., & Morrissey, M. (2011). Planning in divided cities. John Wiley & Sons.

Herold, M., Goldstein, N. C., & Clarke, K. C. (2003). The spatiotemporal form of urban growth: measurement, analysis and modeling. Remote sensing of Environment, 86(3), 286-302.

Rukhsana, & Hasnine, M. (2021). Population pressure and urban sprawl in Kolkata metropolitan area. Habitat, Ecology and Ekistics: Case Studies of Human-Environment Interactions in India, 163-178.

Fitzgerald, K. G., & Caro, F. G. (2014). An overview of age-friendly cities and communities around the world. Journal of aging & social policy, 26(1-2), 1-18.

Kundu, D., & Pandey, A. K. (2020). World urbanisation: trends and patterns. Developing national urban policies: Ways forward to green and smart cities, 13-49.

Mahtta, R., Fragkias, M., Güneralp, B., Mahendra, A., Reba, M., Wentz, E. A., & Seto, K. C. (2022). Urban land expansion: the role of population and economic growth for 300+ cities. Npj Urban Sustainability, 2(1), 5.

Skog, K. L., & Steinnes, M. (2016). How do centrality, population growth and urban sprawl impact farmland conversion in Norway? Land use policy, 59, 185-196.

Tan, M., Li, X., Xie, H., & Lu, C. (2005). Urban land expansion and arable land loss in China—a case study of Beijing–Tianjin–Hebei region. Land use policy, 22(3), 187-196.

Leetmaa, K., & Tammaru, T. (2007). Suburbanization in countries in transition: Destinations of suburbanizers in the Tallinn metropolitan area. Geografiska Annaler: Series B, Human Geography, 89(2), 127-146.

Champion, T. (2001). Urbanization, suburbanization, counter urbanization and reurbanization. Handbook of urban studies, 160(1), 143-161.

Roy, S., & Roy, R. (2024). Dynamics of Peri-Urban Land Alteration in and Around Siliguri City, India: A Geo-Spatial Study. Current World Environment, 19(1), 454.

Sarkar, C., & Kar, B. K. (2021). Growth and Development Dynamics of Siliguri City, West Bengal, India. Urban India, 41(1), 49-71.

Banerjee, I., & Dutta, R. (2024). Modelling spatio-temporal pattern of urban sprawl with geospatial techniques: a case of Siliguri city, West Bengal, India. Letters in Spatial and Resource Sciences, 17(1), 23.

Mandal, S., & Ray, R. (2013). Measures of urbanization in West Bengal: A statistical analysis. Asian Journal of Research in Social Sciences and Humanities, 3(3), 79-90.

Konar, D. N. (2009). Nature of urbanization in West Bengal in the POST-independence period. Economic Affairs, 54(3and4), 149-164.

Hassan, M. M., & Nazem, M. N. I. (2016). Examination of land use/land cover changes, urban growth dynamics, and environmental sustainability in Chittagong city, Bangladesh. Environment, development and sustainability, 18, 697-716.

Naikoo, M. W., Rihan, M., & Ishtiaque, M. (2020). Analyses of land use land cover (LULC) change and built-up expansion in the suburb of a metropolitan city: Spatio-temporal analysis of Delhi NCR using Landsat datasets. Journal of Urban Management, 9(3), 347-359.

Yasin, M. Y., Yusof, M. M., & Noor, N. M. (2019). Urban sprawl assessment using time-series LULC and NDVI variation: a case study of Sepang, Malaysia. Applied Ecology & Environmental Research, 17(3).

Boyko, C. T., & Cooper, R. (2011). Clarifying and re-conceptualising density. Progress in planning, 76(1), 1-61.

Bhujel, B., & Sinha, S. (2024). English in the mallscape: Exploring linguistic landscape (LL) of quasi-public space in India. Discourse and Interaction, 17(2).

Sarkar, C., & Kar, B. K. (2021). Growth and Development Dynamics of Siliguri City, West Bengal, India. Urban India, 41(1), 49-71.

Dolui, S., & Sarkar, S. (2022). Land suitability analysis for settlement concentration in fringe area of Siliguri town, West Bengal (India)—A GIS-based multi-criteria decision-

making approach. In Livelihood Enhancement Through Agriculture, Tourism and Health (pp. 349-387). Singapore: Springer Nature Singapore.

Chowdhury, I. R., Roy, S., Bose, A., & Mustafi, S. (2024). Factors Determining Health Status among Elderly in Urban Slums: An Insight from Siliguri City, West Bengal, India. In Sustainable Urban Forms and Communities: Urban Geographies of Eastern India (pp. 183-202). Routledge India.

Saha, P. (1991). Problems and prospects of development of Siliguri and Jalpaiguri towns: a comparative study (Doctoral dissertation, University of North Bengal).

Rukhsana, Alam, A., Khan, A., & Ghosal, N. (2022). Sustainable Smart City Planning Using Spatial Data and Risk Reduction: A Case Study on Siliguri Municipal Corporation. In Disaster Risk Reduction for Resilience: Disaster Risk Management Strategies (pp. 379-398). Cham: Springer International Publishing.

Franconi, L., Mantuano, M., & Ichim, D. (2024). Population grid and location quotient of land cover to capture the urban-rural nature of labour market areas in Italy. GeoJournal, 89(1), 6.

Islam, F. B., Mubassirah, F. A., Siddiq, F., Hossain, D., Sharmin, N., & Haque, A. (2015). Economic growth analysis of six divisions of Bangladesh using location quotient and shift-share method. Journal of Bangladesh Institute of Planners, 135-144.

Oka, M. (2023). Conceptual and Methodological Arguments against the Use of Location Quotient as an Area-Based Measure of Residential Segregation: A Measurement Perspective. Societies, 13(12), 256.

Kakon, A. N. (2007). Analysis of the trend and inter-regional variation of urbanization in Bangladesh.

Andresen, M. A. (2007). Location quotients, ambient populations, and the spatial analysis of crime in Vancouver, Canada. Environment and Planning A, 39(10), 2423-2444.

Hortas-Rico, M., & Solé-Ollé, A. (2010), Does Urban Sprawl Increase the Costs of Providing Local Public Services, Evidence from Spanish Municipalities, Urban Studies, 47(7), 1513-1540.

Yeates, M., & Garner, B. J. (1976), The North American city, Harper, Collins Publishers.

Frenkel, A., & Ashkenazi, M. (2008), Measuring Urban Sprawl: How can we deal with it, Environment and Planning B: Planning and Design, 35(1), 56-79.

Venkataraman, M. (2014). Analysing urban growth boundary effects on the city of Bengaluru. Economic and Political Weekly, 54-61.

Mitra, C., Shepherd, J. M., & Jordan, T. R. (2012). Assessment and dynamics of urban growth in the City of Kolkata. Facets of social geography: International and Indian perspectives, 541-555.

Ramachandra, T. V., & Bharath, H. A. (2012). Spatio-temporal pattern of landscape dynamics in Shimoga, tier II city, Karnataka state, India. International Journal of Emerging Technology and Advanced Engineering, 2(9), 563-576.

Basawaraja, R., Chari, K. B., Mise, S. R., & Chetti, S. B. (2011). Analysis of the impact of urban sprawl in altering the land-use, land-cover pattern of Raichur City, India, using geospatial technologies. Journal of Geography and Regional Planning, 4(8), 455.

Tamilenthi, S., Punithavathi, J., Baskaran, R., & Chandra Mohan, K. (2011). Dynamics of urban sprawl, changing direction and mapping: A case study of Salem city, Tamil Nadu, India. Archives of Applied Science Research, 3(1), 277-286.

Nicolau, R., David, J., Caetano, M., & Pereira, J. M. (2018). Ratio of land consumption rate to population growth rate—Analysis of different formulations applied to mainland Portugal. ISPRS International Journal of Geo-Information, 8(1), 10.

Li, C., Cai, G., & Sun, Z. (2021). Urban land-use efficiency analysis by integrating LCRPGR and additional indicators. Sustainability, 13(24), 13518.

Sandhya Kiran, G., & Joshi, U. B. (2013). Estimation of variables explaining urbanization concomitant with land-use change: a spatial approach. International Journal of Remote Sensing, 34(3), 824-847.

Samuel, K. J., & Atobatele, R. E. (2019). Land use/cover change and urban sustainability in a medium-sized city. International Journal of Sustainable Society, 11(1), 13-28.

Kumari, M. (2016). Contested Spaces: Population Dynamics, the Refugees and Changing Social Landscape of Siliguri (1835 To 2011 CE).

Paul, S. (2022). Displacement, Rehabilitation and Resettlement: Bengali Migrants from Assam to Siliguri (1947-1991).