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Relationship between Population Attributes and Built-up Area Expansion in Sargodha District, Pakistan

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Abstract
The evolution of Sargodha district's built environment and population dynamics over the years underscores a discernible trend of urbanization. This research analyzed the built-up area expansion due to population growth characteristics in the study area. The population data for the current study is acquired from the population census of 1998 and 2017 while the built-up area change is analyzed through satellite images. The expansion of housing units played a pivotal role in accommodating the growing population and urban infrastructure. The number of housing units rose significantly from 411,209 in 1998 to 592,044 in 2017. Such a surge underscores efforts to cater to the growing population and enhance infrastructure. Among the district's tehsils, Sargodha Tehsil experienced the most substantial surge in population density. From 704.1 persons per square kilometer in 1998, it soared to 999.45 persons per square kilometer in 2017, depicting a robust growth of 41.9% or 295.35 persons per square kilometer. With an average annual growth rate of 1.86%, Sargodha Tehsil's population increase remained consistent and noteworthy. In contrast, Shahpur Tehsil displayed a comparatively moderate growth in population density. The density grew from 341.7 persons per square kilometer in 1998 to 459.46 persons per square kilometer in 2017, implying a 34.5% rise or 117.76 persons per square kilometer. Shahpur Tehsil's average annual growth rate stood at 1.57%, indicating steady albeit relatively slower population growth.

Key Words: Built-up Area, Density, Expansion, Population growth, Urban Population

1 Introduction

Built-up area expansion, driven by rapid urbanization and population growth, has become a defining characteristic of contemporary urban landscapes (Reis, 2008; Riaz, 2017; Hashim et al., 2023). This phenomenon involves the conversion of natural landscapes, including vegetated areas and open spaces, into concrete jungles of buildings, roads, and infrastructure (Rozenstein & Karnieli, 2011; Saadani et al., 2020). The consequences of this expansion are profound and multifaceted, impacting various aspects of the environment, society, and urban planning (Bhatta & Fiaz, 2016).

From an environmental perspective, the transformation of natural ecosystems into built-up areas has significant implications for biodiversity and ecological balance (Qasim et al., 2024). The loss of green spaces and vegetation disrupts local ecosystems, leading to habitat fragmentation and loss of species diversity (Sajjad et al., 2015). This can result in decreased ecosystem services such as air and water purification, carbon sequestration, and temperature regulation. Moreover, the increased impervious surfaces exacerbate issues like the urban heat island effect, altering local weather patterns and exacerbating heat waves (Han, 2007; Handy et al., 2002).

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Socially, the expansion of built-up areas can lead to urban sprawl and fragmented communities. The spread of infrastructure often results in longer commutes, traffic congestion, and reduced accessibility to essential services, particularly for marginalized populations. Additionally, the loss of green spaces and recreational areas can diminish residents' quality of life and overall well-being, as these areas contribute to physical and mental health. The lack of planning for community spaces and social amenities within expanded built-up areas can lead to social isolation and unequal access to public resources (Angel et al., 2005; Yue et al., 2013).

Urban planning and governance also face significant challenges due to built-up area expansion. Inadequate planning and haphazard development can strain existing infrastructure and utilities, leading to inefficient resource allocation and increased vulnerability to environmental hazards (Lambin, 2003; Hashim et al., 2024). The unplanned growth of built-up areas can undermine sustainable land use management, potentially hampering future development options and exacerbating issues related to land degradation and soil erosion (Aliana et al., 2019; Opoko et al., 2014).

The expansion of built-up areas reflects the intricate interplay between urban development, environmental sustainability, and societal well-being. Addressing the negative impacts of such expansion requires integrated and holistic approaches to urban planning, encompassing strategies for biodiversity conservation, green infrastructure, equitable community development (Yasin & Qasim, 2020), and efficient resource management (Hasmadi et al., 2009; Kumar, 2012). Balancing the need for urban growth with the preservation of natural and social systems remains a crucial challenge for policymakers, urban planners, and communities worldwide. (Herold et al., 2003; Kerr et al., 2006).

1.1 Population and Built-up Expansion

The expansion of built-up areas is closely intertwined with population growth and urbanization, forming a complex relationship that shapes the modern urban landscape. As global populations continue to surge, cities are under increasing pressure to accommodate the influx of residents (Alexandratos, 2005). This demand for housing, infrastructure, and services drives the conversion of natural landscapes into built environments. The rapid pace of population growth, especially in developing countries, often leads to unplanned and sprawling urbanization, resulting in the expansion of built-up areas (Ghani et al., 2021).

The spatial distribution of population growth plays a crucial role in the pattern of built-up expansion. As urban centers attract more inhabitants the need for additional residential and commercial spaces surges swiftly (Aljaddani et al., 2022). This demand frequently translates into urban sprawl, characterized by the outward expansion of built-up areas into previously undeveloped or agricultural land. This outward growth is often accompanied by inadequate infrastructure, limited access to services (Qasim et al., 2023), and increased traffic congestion, ultimately affecting the quality of life for residents (Arshad et al., 2022).

Moreover, the link between population growth and built-up expansion has broader implications for resource consumption and environmental sustainability. The concentration of people in urban areas intensifies the demand for resources like energy, water, and food (Bakr et al., 2020). This heightened demand, coupled with the expansion of built-up areas, can lead to increased resource consumption, waste generation, and emissions of pollutants (Farooq et al., 2023). The conversion of natural landscapes into built environments contributes to habitat loss and reduces the capacity of ecosystems to provide critical services, exacerbating environmental challenges such as climate change, biodiversity loss, and air and water pollution (Naqvi, 2007; Qasim et al., 2024).

Addressing the interplay between population growth and built-up area expansion requires a multifaceted approach. Urban planning strategies should prioritize compact and efficient development,

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promoting higher population densities within existing urban areas to limit outward sprawl. Investing in sustainable infrastructure, efficient transportation systems, and accessible public services can mitigate the negative impacts of population-driven built-up expansion (Qasim et al., 2024). Furthermore, policies that encourage mixed land-use development, affordable housing, and the preservation of green spaces are essential for creating livable and resilient urban environments (Hashim et al., 2023). By understanding and managing the relationship between population dynamics and built-up expansion, cities can work towards achieving sustainable development goals (Farooq et al., 2023) and fostering a better quality of life for their residents (Mushtaq et al., 2020; Lopez et al., 2003).

2 Research Methodology

2.1 The Study Area

The district is bounded on North by Jhelum River, on East by Chenab River beyond which lies the districts of Mandibahaud din and Hafizabad, on South by Jhang district on West by Khushab district. The whole area is the part of Chaj Doab (The land lying between the two rivers of Chenab and Jhelum).The total area of the district is approximately 5854 square kilometers (2,264 sq miles) and has an average elevation of 607 feet above sea level. The population of the district is about 3.7 million more over urban population is 1.0 million which constitutes 37% of district population (GoP, 2017).

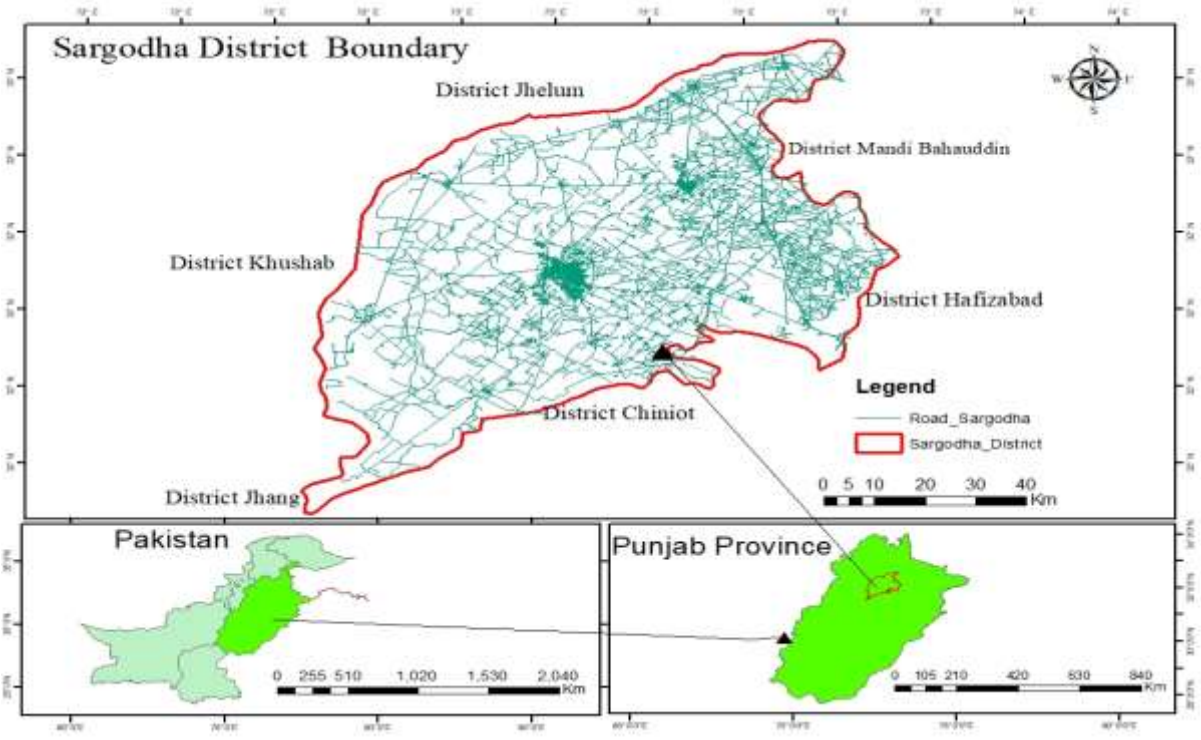

Figure 1 Location map of the Study Area

2.2 Research Method

This research is based on a mix approach of population data and satellite imageries. Population data is acquired from the last two population census of Pakistan; 1998 and 2017. The data is accessed through Pakistan Bureau of Statistics (PBS) and District Census Report (DCR) of District Sargodha. Along with the basic population data of the district, the data of all seven tehsil of the district is also analyzed. Other population attributes including urban population, rural population, housing statistics and population density

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are also part of the acquired population data. The built-up expansion in the study area is analyzed for last three decades from 1993 to 2023 with the interval of 10 years as study years including 1993, 2003, 2013 and 2023. Satellite images downloaded through USGS open source is analyzed with the help of supervised classification in Arc GIS.

3 Results and Discussions

3.1 Role of Population growth towards built environment

The table 1 presents a comparison of various characteristics between the 1998 and 2017 censuses. In 1998, the urban population accounted for 28.13% of the total population, with a count of 750,032 individuals. However, by 2017, there was a significant increase in the urban population, which reached 2,608,007 people, signifying a substantial trend of urbanization during this period.

Conversely, the rural population experienced a decline over the same time span. In 1998, the rural population represented 71.87% of the total, with 1,915,947 individuals. However, by 2017, the rural population decreased to 1,088,205, indicating a shift of people from rural to urban areas, possibly driven by better economic prospects and improved living conditions in urban regions (Table 1).

The total number of housing units showed substantial growth over the years. In 1998, there were 411,209 housing units, while by 2017, this number had risen to 592,044. This increase in housing units suggests an effort to accommodate the growing population, urbanization, and improving infrastructure (Table 1).

Regarding household sizes, there was a slight decrease in the average household size between 1998 and 2017. In 1998, the average household size was 6.5, while by 2017, it had reduced to 6.17. This decline could be attributed to changing family structures, increased urbanization leading to smaller living spaces, and a potential shift towards smaller family units (Table 1).

In terms of administrative changes, significant developments occurred between the two censuses. In 1998, there was no Metropolitan Corporation, only one Municipal Corporation, two Municipal Committees, and ten Town Committees. However, by 2017, the region had established one Metropolitan Corporation, eight Municipal Corporations, six Municipal Committees, and nine Town Committees, indicating a more organized and decentralized approach to governance, likely to address the challenges posed by rapid urbanization and population growth (Table 1).

The comparison of the 1998 and 2017 census data reveals a clear trend of urbanization, a decline in rural population, an increase in total housing units, a slight decrease in average household size, and significant changes in the administrative setup. These changes reflect the region's development and evolving socio-economic landscape during the intervening years (Table 1).

Table 1 Population Characteristics of district Sargodha

S. No.	Characteristics	Census 1998	Census 2017
01	Urban Population	750032 (28.13 %)	2,608,007
02	Rural Population	1915947 (71.87 %)	1,088,205
03	Total Housing Units	411209	592044
04	Pacca Housing Units	319740 (77.75%)	-
05	Average Household size	6.5	6.17
06	Metropolitan Corporation	-	01
07	Municipal	01	08

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	Corporation		
08	Municipal Committees	02	06
09	Town Committees	10	09

Source: (GoP, 1998; 2007)

Sargodha Tehsil had a total population of 1,081,459 in 1998, which slightly increased to 1,535,152 by 2017. This represents a significant growth of about 42.1% over the 19-year period. The area remained relatively stable at 1,536 square kilometers. However, the population density saw a considerable increase from 704.1 persons per square kilometer in 1998 to 999.45 persons per square kilometer in 2017. The average annual growth rate for Sargodha Tehsil was 1.86%, indicating a consistent and substantial rate of population growth (Table, 2).

Bhalwal Tehsil experienced substantial population growth over the 19-year period. The total population increased from 254,732 in 1998 to 356,206 in 2017, a rise of approximately 39.8%. The area of Bhalwal Tehsil remained constant at 663 square kilometers. The population density rose significantly from 384.2 persons per square kilometer in 1998 to 537.26 persons per square kilometer in 2017, indicating a concentration of people in the region. The average annual growth rate for Bhalwal Tehsil was 1.78%, reflecting a steady population increase (Table, 2).

Bhera Tehsil witnessed notable population growth over the 19-year period, with the total population increasing from 226,365 in 1998 to 314,369 in 2017, representing a growth rate of approximately 38.8%. The area remained unchanged at 504 square kilometers. The population density saw a significant rise from 449.1 persons per square kilometer in 1998 to 623.75 persons per square kilometer in 2017. The average annual growth rate for Bhera Tehsil was 1.74%, indicating sustained population growth over the years (Table, 2).

Kot Momin Tehsil experienced considerable population growth between 1998 and 2017. The total population increased from 338,790 in 1998 to 451,978 in 2017, reflecting a growth rate of around 33.4%. The area of Kot Momin Tehsil remained at 948 square kilometers. The population density showed an increase from 357.3 persons per square kilometer in 1998 to 476.77 persons per square kilometer in 2017. The average annual growth rate for Kot Momin Tehsil was 1.53%, indicating a consistent growth pattern (Table, 2).

Shahpur Tehsil experienced notable population growth over the 19-year period. The total population increased from 262,747 in 1998 to 353,325 in 2017, representing a growth rate of approximately 34.4%. The area remained constant at 769 square kilometers. The population density rose from 341.7 persons per square kilometer in 1998 to 459.46 persons per square kilometer in 2017. The average annual growth rate for Shahpur Tehsil was 1.57%, indicating a steady and considerable increase in population (Table, 4.2).

Sahiwal Tehsil saw significant population growth between 1998 and 2017. The total population increased from 247,605 in 1998 to 340,695 in 2017, reflecting a growth rate of around 37.6%. The area of Sahiwal Tehsil remained constant at 829 square kilometers. The population density rose from 298.7 persons per square kilometer in 1998 to 410.97 persons per square kilometer in 2017. The average annual growth rate for Sahiwal Tehsil was 1.69%, indicating sustained population growth over the years (Table, 4.2).

Sillanwali Tehsil experienced significant population growth over the 19-year period. The total population increased from 254,281 in 1998 to 344,487 in 2017, representing a growth rate of approximately 35.4%. The area remained unchanged at 607 square kilometers. The population density increased from

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419.1 persons per square kilometer in 1998 to 567.52 persons per square kilometer in 2017. The average annual growth rate for Sillanwali Tehsil was 1.61%, indicating sustained population growth over the years (Table, 2).

The comparison of census data for each tehsil between 1998 and 2017 reveals significant population growth and an increase in population density across all tehsils. The average annual growth rates indicate a consistent pattern of population increase, reflecting the region's ongoing development and changing demographics over the studied period (Table, 2).

Among the seven tehsils of district Sargodha, Sargodha Tehsil experienced the highest increase in population density, growing from 704.1 persons per square kilometer in 1998 to 999.45 persons per square kilometer in 2017. This represents a substantial rise of 295.35 persons per square kilometer or 41.9% over the 19-year period. Additionally, the average annual growth rate for Sargodha Tehsil was 1.86%, indicating a consistent and significant population increase (Table, 2).

Shahpur Tehsil witnessed the least change in population density between 1998 and 2017. The population density grew from 341.7 persons per square kilometer in 1998 to 459.46 persons per square kilometer in 2017, resulting in an increase of 117.76 persons per square kilometer or 34.5%. The average annual growth rate for Shahpur Tehsil was 1.57%, indicating a steady but comparatively lower population growth rate (Table, 2).

Overall, Sargodha Tehsil had the highest increase in population density and the maximum average annual growth rate, indicating significant urbanization and population growth in the region. On the other hand, Shahpur Tehsil had the least change in population density and a comparatively lower average annual growth rate, suggesting a relatively slower pace of development and population increase. These findings highlight the variations in population dynamics and development trends across the different tehsils during the 19-year period (Table, 2).

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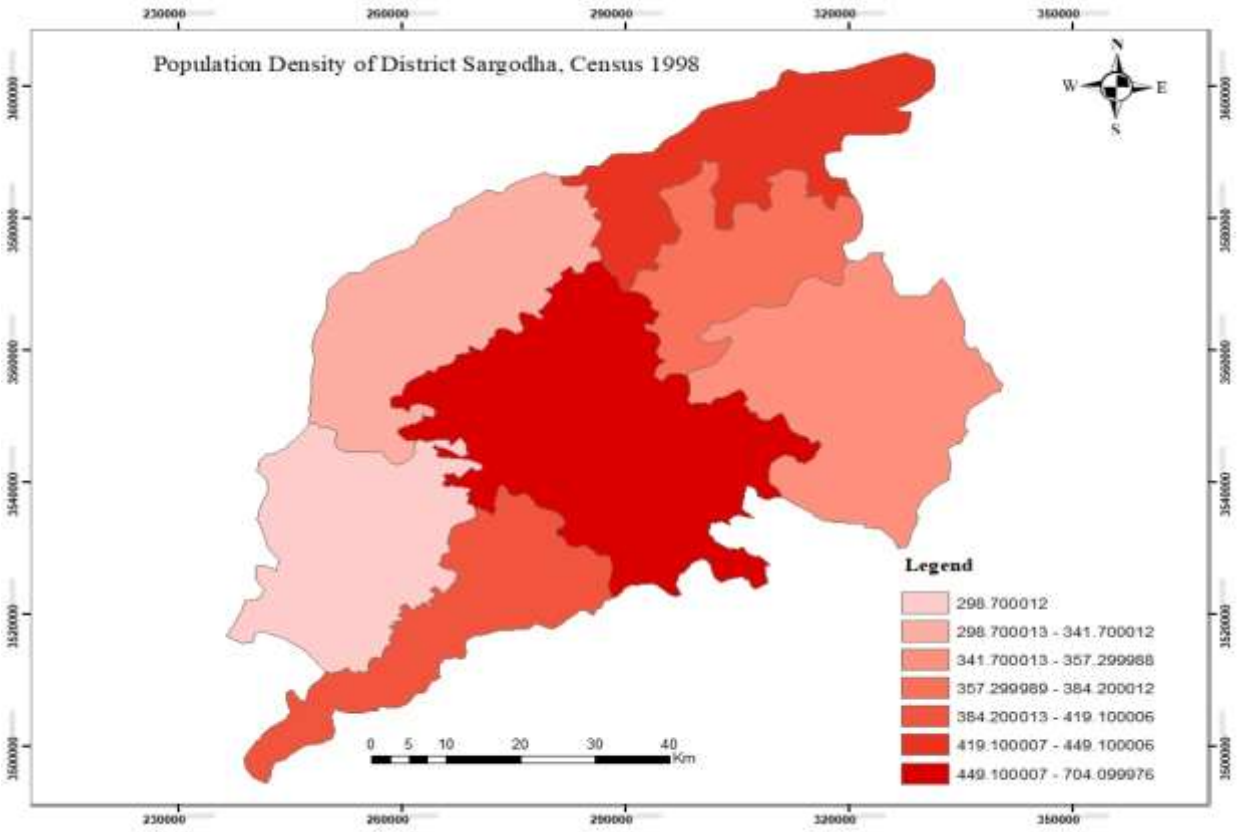

Figure 2Population density of District Sargodha 1998

Table 2 Population overview tehsil wise in Sargodha district

S. No.	Tehsil	Area	Total Population		Population Density		Average Annual Growth Rate
			1998	2017	1998	2017	
01	Sargodha	1,536	1,081,459	1,535,152	704.1	999.45	1.86
02	Bhalwal	663	254,732	356,206	384.2	537.26	1.78
03	Bhera	504	226,365	314,369	449.1	623.75	1.74
04	Kot Momin	948	338,790	451,978	357.3	476.77	1.53
05	Shahpur	769	262,747	353,325	341.7	459.46	1.57
06	Sahiwal	829	247,605	340,695	298.7	410.97	1.69
07	Sillanwali	607	254,281	344,487	419.1	567.52	1.61

Source: (GoP, 1998; 2007)

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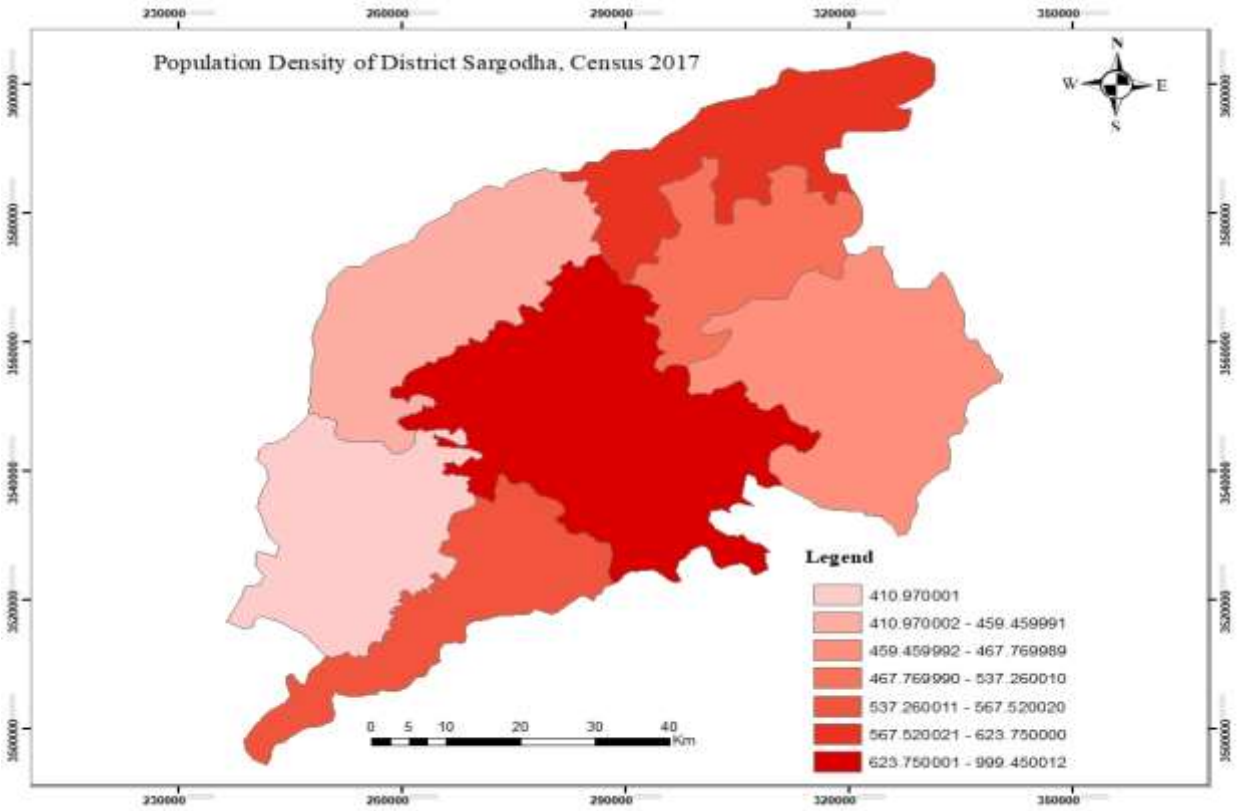

Figure 3Population density of District Sargodha 2017

Among the seven tehsils, Sargodha has the highest urban population with 658,208 individuals, constituting 42.88% of its total population. This indicates a significant level of urbanization in the Sargodha Tehsil, likely driven by its status as a major urban center and economic hub. Sahiwal follows with the second-highest urban population of 76,207, comprising 22.37% of its total population. While Sahiwal is not as urbanized as Sargodha, it still shows a notable concentration of people in its urban areas. On the other hand, Kot Momin and Sillanwali have the lowest urban populations among the tehsils, with 65,499 and 37,719 urban residents, respectively. These two tehsils exhibit lower levels of urbanization, with Kot Momin having 14.49% and Sillanwali having 10.95% of their total populations residing in urban areas. This suggests a more rural-oriented demographic in these tehsils (Table, 3).

Sillanwali has the highest rural population among the tehsils, with 306,768 individuals residing in rural areas. This accounts for 89.05% of its total population, indicating a predominantly rural landscape. Bhalwal follows with 234,249 rural residents, making up 65.76% of its total population. These two tehsils have a strong rural presence, reflecting their agricultural and rural-based economies. Conversely, Sahiwal and Sargodha have the lowest rural populations in relative terms, with 22.37% and 57.12% of their total populations residing in rural areas, respectively. These tehsils have higher levels of urbanization and a greater focus on urban economic activities (Table, 3).

Sillanwali has the largest average household size among the tehsils, with 6.63 persons per household. This higher household size is typical of rural areas where extended families live together in one household. Bhalwal and Shahpur follow with average household sizes of 5.57 and 5.95 persons, respectively. These tehsils have relatively smaller household sizes compared to Sillanwali, indicating a

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potential shift towards smaller family units. On the other hand, Sahiwal and Sargodha have the smallest average household sizes, with 6.32 and 6.23 persons per household, respectively. These tehsils exhibit a trend towards smaller household sizes, likely influenced by urbanization and changing societal norms (Table, 3).

The data further reveals variations in urban and rural population distributions and average household sizes among the tehsils. Sargodha and Sahiwal stand out as more urbanized tehsils, while Sillanwali and Bhalwal have a stronger rural presence. The average household sizes vary across tehsils, with Sillanwali having the largest and Sahiwal and Sargodha having the smallest household sizes. These differences highlight the diverse socio-economic and demographic characteristics of each tehsil. Each tehsil of the district have its significant and valuable role in strengthening urban population in the study area district Sargodha. As district, the urban expansion in each tehsil have influential role (Table, 3).

Table 3 Urban Population data of district Sargodha, 2017

S. No.	Tehsil	Urban Population	Rural Population	Percentage of Urban Population	Average Household Size
01	Sargodha	658,208	876,944	42.88	6.23
02	Bhalwal	121,957	234,249	34.24	5.57
03	Bhera	59,953	254,416	19.07	5.89
04	Kot Momin	65,499	386,479	14.49	6.41
05	Shahpur	68,662	284,663	19.43	5.95
06	Sahiwal	76,207	264,488	22.37	6.32
07	Sillanwali	37,719	306,768	10.95	6.63

Source: (GoP, 1998; 2007)

3.2 Built up area expansion during 1993 to 2023 in the study area

The provided data showcases the expansion of the built-up area in Sargodha district from 1993 to 2023. Over the three decades, there has been a steady increase in the built-up area, indicating urban growth and development within the district. In 1993, the built-up area covered 308.2 km2, which accounted for 5% of the district's total area. This signifies the initial stage of urbanization and the presence of urban infrastructure within the district (Figure, 4).

By 2003, the built-up area expanded to 453.6 km^2, representing 8% of the total area. This indicates a notable increase of 3% in the built-up area over the course of one decade. The accelerated growth suggests a growing population, economic activities, and the need for additional commercial, residential, and industrial spaces. Continuing the trend, the built-up area further expanded to 541.3 km^2 in 2013, constituting 9% of the district's total area. This reflects a 1% increase in the built-up area over the decade. The expansion demonstrates the ongoing urbanization process and the continuous demand for urban infrastructure and services (Figure, 4).

Looking ahead to 2023, there was a significant acceleration in the expansion of the built-up area, reaching 765 km^2, which accounted for 13% of the district's total area. This represents a remarkable 4% increase in the built-up area over the past decade. The substantial growth in the built-up area indicates rapid urbanization, the establishment of new settlements, and the expansion of existing urban centers (Figure, 4).

The continuous expansion of the built-up area has both positive and negative implications. On one hand, it signifies economic growth, employment opportunities, and improved infrastructure. On the other

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hand, it can lead to the loss of agricultural land, increased demand for resources, and potential environmental challenges. To manage the urban growth and its impacts effectively, it is crucial to implement sustainable land use planning, promote efficient land management practices, and strike a balance between urban development and the preservation of natural resources. This will ensure the long-term sustainability and well-being of Sargodha district (Figure, 4).

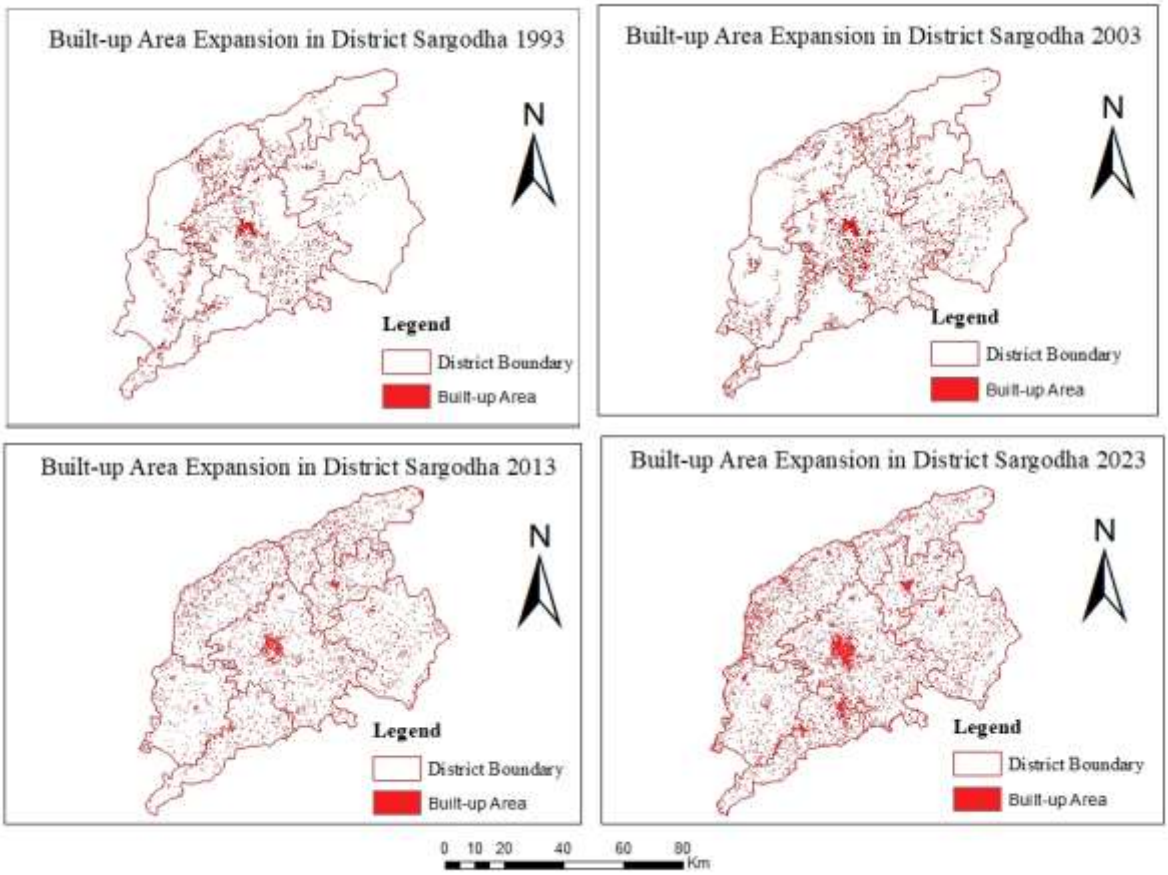

Figure 4 Built up area of District Sargodha 1993 - 2023

Conclusion

This study focused the population growth and associated population traits which instigated the expansion of built-up area in district Sargodha from 1993 to 2023. For this purpose the population characteristics of the study area for the years 1993 and 2017 are evaluated with the help of population census data of 1998 and 2017. The expansion in built up area is analyzed for the four study years; 1993, 2003, 2013 and 2023 using satellite images. The transformation of Sargodha district's landscape and population dynamics over time highlights a clear trend toward built-up area expansion. The surge in population prompted a pivotal role for housing units in accommodating the growing population and sustaining urbanization. The number of housing units surged significantly from 411,209 in 1998 to 592,044 in 2017, illustrating concerted efforts to meet the housing needs of the expanding population and enhance overall infrastructure. The expansion of urban areas, accompanied by a decline in rural populations,

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indicates the appeal of improved urban living standards and economic prospects. The rise in housing units and population density in specific areas emphasizes the importance of effective urban planning and infrastructure development to manage growth while maintaining a balance between urban and rural domains. As the district continues its path of built-up area expansion, proactive measures to manage resources, safeguard agricultural land, and tackle challenges stemming from rapid urban expansion are crucial for sustainable development and the well-being of its residents.

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