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ARTICLE

The Geographies and the Temporal Trends/Dynamics of Urban Sprawl in a Suburban Area

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ABSTRACT

Urban sprawl refers to the expansion of cities towards the countryside, associated with developed infrastructure facilities and transportation networks. Thus, this study aims to analyze the geospatial patterns/dynamics of the urban sprawl, examine the temporal patterns/dynamics of the urban sprawl, and investigate the causative factors of the urban sprawl in the Homagama Divisional Secretariat Division (DSD), Sri Lanka (1992–2022). Accordingly, this study was completely based on digitized buildings using Geographic Information System (GIS), and Remote Sensing (RS). Shannon's Entropy value and the intensity of urban sprawl were used to analyze the geospatial patterns of urban sprawl. Results revealed a transition pattern of building distribution from compact to dispersed patterns, with slow expansion intensity. Building density and sprawl direction were employed to examine the temporal pattern of urban sprawl. Accordingly, middle building density areas are distributed throughout the study area. Very high building density areas have agglomerated in specific areas associated with developed infrastructure facilities. In the evolution of directional expansion, the buildings in 1992 primarily expanded to the southwest. After this pattern gradually spread towards the southwest, northward, and northeastward directions from 2017 to 2022. Population density and transportation network were used to investigate the causative factors. The population density took an upward trend with the intensification of urban sprawl. The buildings were gradually increasing along primary and secondary roads with accessibility and connectivity. Based upon the findings demonstrated, this study suggests a sustainable urban master plan with an

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appropriate urban policy should be considered/established in order to manage this unplanned urban sprawl and mitigate socio-environmental challenges. Hence, this study sheds light on demonstrating the specific patterns of unplanned urban sprawls of suburb geographies in a low-middle income developing country.

Keywords: Buildings; Geographic Information System; Remote Sensing; Suburban Transition; Urban Sprawl

1. Introduction

Urbanization is a noticeable driver in shaping urban sprawl, reflecting a socio-economic transition from rural to urban populations [1–4]. In the past, industrialization led to an intensification of urbanization by drawing laborers to urban centers to fulfil the labor force [5–7]. As a result of the intensification of this migration pattern, population pressure was gradually increasing in major cities, like losing the balance of people and resources in urban area. Accordingly, people are gradually moving outward areas/country side from the urban cities. This process is called urban sprawl [8–10]. In that case, the growing demand for industrial, commercial, and residential spaces in peripheral areas is directly determining various patterns, trends, and intensity of urban sprawl spatially and temporally [11–13]. In particular, developing countries such as Asia, Africa, and Latin America are highly exemplifying this phenomenon rather than developed countries [1,4,14–16]. For instance, the population in Central and South Asia is expected to increase from 5% to 8% in 2050. Annual population growth in Afghanistan, Pakistan, India, Tajikistan, and Kazakhstan is predicted to increase by 3% [17,18].

Urban sprawl is further enhancing the association with the development of transportation networks and improving connectivity to Central Business Districts (CBDs). It contributes to converting rural geographical settings into the urban environment [11,15,19–21]. Accordingly, this extensive transportation network supports attracting more people, service centres, and developed infrastructure in suburban areas [22–24]. Furthermore, the evolutionary changes of urban sprawl differ across various institutional backgrounds [25]. In particular, understanding the interlace nature between suburban/urban land use management (e.g., including politics and planning) and institutional settings for the establishment of developed infrastructure facilities is very worthwhile [12,13,15].

The uncontrolled expansion of residential and commercial development beyond city limits has become a global issue, driven largely by technological advancements and economic growth. This defines elevated demand for dwelling units and commercial spaces in and around city centres [26,27]. Therefore, the availability of affordable land in rural areas further encourages urban sprawl, as individuals relocate away from CBDs to build residences and commercial spaces based on their preferences. Theories and models like the bid-rent theory, the Burgess model, and the multiple nuclei model provide ground frameworks for understanding these urban trends [28–31].

In Sri Lanka, urban sprawl has unique historical and socio-economic characteristics. Before colonization, the country had a predominantly rural setting with no significant urban areas. However, the British invasion in 1796 marked a turning point, leading to the development of cities such as Colombo, Galle, and Kandy into central business hubs [32]. Accordingly, the first population census in 1871 laid the foundation for tracking urban growth [33]. The urban population in Sri Lanka was approximately 4.2 million in 2022 [34]. Although urbanization showed an upward trend from 1871 to 1981, it took a downward trend after 1987 due to the restructuring of administrative boundaries and the reclassification of urban areas [4]. For instance, around 87 town councils were restructured into Pradeshiya Sabhas (rural councils) [4]. On the other hand, the definition of distinguishing urban from suburban is getting a challenge as the classification of municipal, urban, and town councils [35]. Hence, urban sprawl is occurring in suburban areas, demonstrating unique/diverse geospatial and temporal patterns.

Geographic Information Systems (GIS) and Remote Sensing (RS) are advanced geospatial technologies to capture, store, manipulate, and analyze spatial and non-spatial data on the Earth's surface [36,37]. These techniques are noticeably applied for detecting and monitoring land use and land cover changes, such as the identification of the distribution of urban sprawl [38]. The integration of GIS and RS into urban geography began in 1993, with Baudot's analysis of Satellite Pour l'Observation de la Terre (SPOT) Extended Spectral (XS) + Panchromatic (P) data in Marrakech, Morocco [4]. At present, GIS and RS are utilized not only for analyzing urban sprawl but also for sustainable urban planning. For instance, Dubai's vision for a sustainable city by 2050 employs GIS and RS for land suitability analysis and 3D modelling [39].

The majority of studies on urban sprawl in the Sri Lankan context have focused on major cities such as the Colombo Metropolitan Area and Kandy City. Some research has employed GIS and RS technologies to examine urban sprawl. For instance, Antalyan and Weerasinghe used Landsat 8 imagery along with various indices, including the Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Built-up Index (NDBI), in order to assess land use/cover changes in the city of Colombo, Sri Lanka [40]. However, the application of GIS and RS in urban sprawl studies within the Sri Lankan context remains limited, according to the extant literature. Hence, the present study sheds light on analyzing the spatial and temporal aspects of urban sprawl in the highly dynamic and heterogeneous suburban/geographical settings of the city of Colombo [4]. Accordingly, several ongoing studies in urban geography mostly use these technologies. For instance, Manawadu has contributed significantly to urban planning using GIS and RS techniques, although specific studies on urban sprawl are still underrepresented [41]. Similarly, Panditharatne contributed to demonstrating Sri Lanka's urban context based on theoretical backgrounds [35].

Hence, this study contributes to filling the research gap by using advanced GIS and RS techniques to analyze geospatial and temporal patterns of urban sprawl in the Homagama Divisional Secretariat Division (DSD). Another significant matter is that this study applies prominent analysis techniques to analyze urban sprawl over a 31-year period. Accordingly, the objectives of this study are to (1) analyze the geospatial patterns/dynamics of urban sprawl from 1992 to 2022, (2) examine the temporal patterns of urban sprawl from 1992 to 2022, (3) investigate the causative factors of urban sprawl from 1992 to 2022.

This paper is structured as follows: Section 2 designates the methodological approach, followed by the results and discussion in Section 3, and Section 4 concludes with findings and proposes recommendations for future implications.

2. Materials and Methods

2.1. Study Area

The Homagama Divisional Secretariat Division (DSD) (**Figure 1**) in the Colombo administrative District, situated in the Western Province of Sri Lanka, is considered the study area for investigating the spatial and temporal patterns of urban sprawl. Homagama DSD, covering an area of 121.0 km^2, is one of the rapidly transforming suburban regions located approximately 23 km from Colombo city. The geographic coordinates of the area are approximately 6°84′58″ N latitude and 80°00′35″ E longitude. The Homagama DSD comprises 81 Grama Niladhari Divisions (GNDs). A GND is a fine-grained administrative unit within the Sri Lankan administrative hierarchy, and the country comprises more than 14,000 GNDs in total.

In accordance with the population census data, the population in the study area increased approximately 30% from 2001 to 2012 [42,43]. Economically, in terms of livelihood strategies, most GNDs in Homagama were engaged in the industrial and service sectors by 2020, with fewer than twenty GNDs involved in agriculture and fewer than ten in livestock farming [44]. Regarding land use, gardens and paddy fields occupy approximately 70.358 km^2 of the total area, while plantations of coconut, rubber, and other crops are also present. Also, marshy lands are located along the rivers, and barren and scrub lands can be identified in the study area [45].

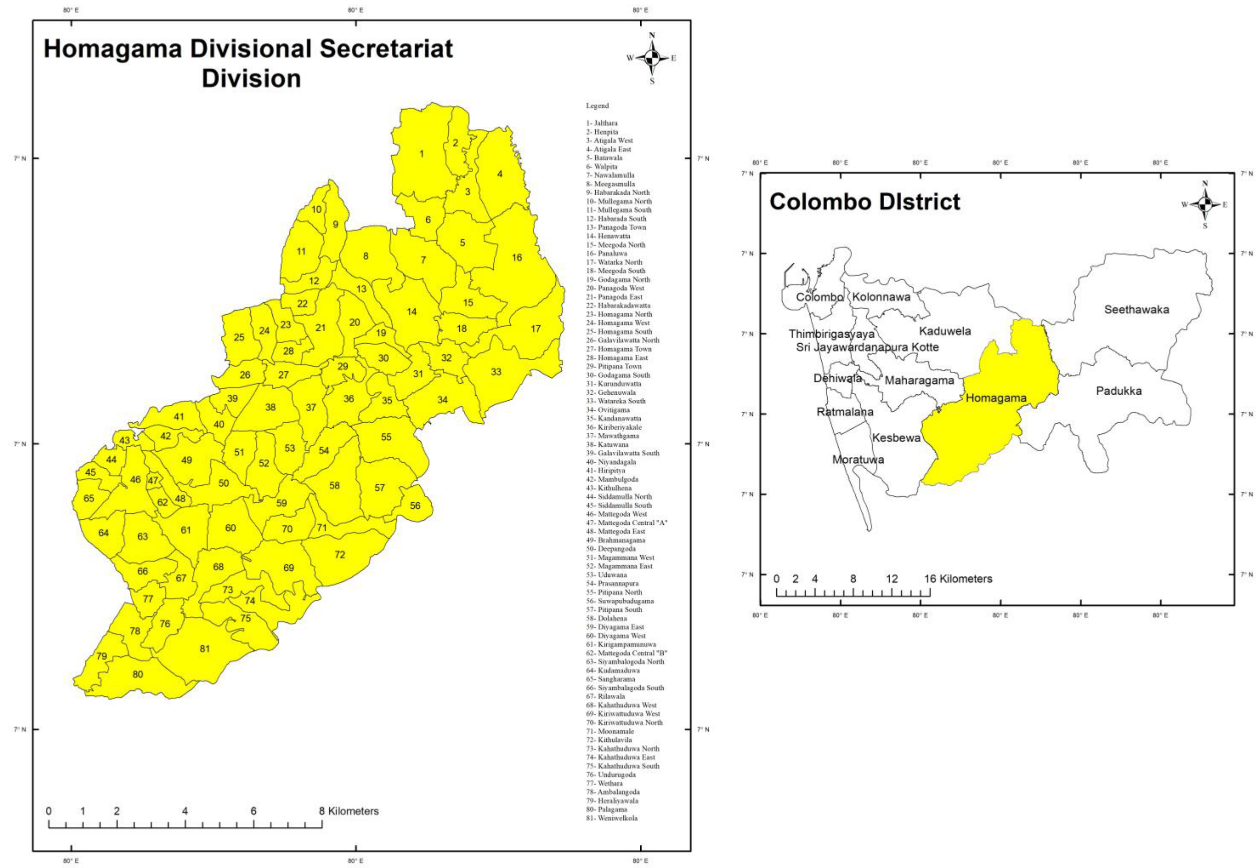

Figure 1. Relative location and local admin boundaries of the study area.

Source: Compiled by authors, 2025.

2.2. Data Collection

This study is primarily based on secondary data sources. The 1:2,000 grid reference was overlaid on the study area to download high-resolution satellite images from Google Earth Pro under the Remote Sensing aspect. In particular, the main reason for using Google Earth Pro was the free availability of satellite images over a long time period. Furthermore, the reason for selecting the period (1992–2022) was to identify the growth of the number of buildings broadly and to avoid the influence of cloud cover.

The satellite images in the study area for 1992, 2007, 2017, and 2022 were downloaded from Google Earth Pro based on the 1:2,000 grid reference. Afterward, all buildings within the Homagama DSD were digitized for the above years and converted to the local coordinate system, the Kandawala coordinate system, using ArcGIS 10.8. A cross-validation with digitized buildings was used to validate the accuracy of the buildings in the considered period. The road network data for the study area was extracted from the "Open Street Map" database using the OpenStreetMap (OSM) tool in QGIS 3.20. Additionally, population density maps for 2000, 2007, 2017, and 2020 were obtained from the "Worldpop" data source [46]. The Geographic Information System was used to fulfill these steps.

2.3. Shannon's Entropy Values

The analytical approach employed multiple-ring buffer zone analysis on digitized building layers in 1992, 2007, 2017, and 2022 to calculate Shannon Entropy values utilizing ArcGIS 10.8 and Microsoft Excel. The following equations (Equations (1) and (2)) were used to calculate Shannon Entropy values [11,38,47–49]. The number of zones with various radii has been utilized across different urban sprawl studies, contingent upon the study area's size and the expansion of buildings (**Table 1**). According to **Table 1**, most of the empirical studies have a standard distance of buffer zones. It was a 2,000 m interval distance and created buffer zones to cover the entire buildings in the study area [38,50]. Therefore, this study employed five zones, each with a radius of 2,000 m, 4,000 m, 6,000 m, 8,000 m, and 10,000 m from the city center to encompass the entire land area and quantify building areas.

Table 1. Different indicators to compute Shannon Entropy.

Case Study	Number of Zones	Interval of Radius
Small and medium towns in Sri Lanka [38]	4	2,000 m
Al Ain Municipality, United Arab Emirates [25]	3	1,000 m
Major cities in the Himalayan Region [49]	4	Not mentioned
Silicon Valley, India [51]	17	1,000 m
Tiruchirappalli City, India [52]	52	2,000 m

Source: Compiled by authors, 2025.

The absolute entropy value:

$$\mathrm{H}_n = \sum_i^n P_i log_e\left(\frac{1}{P_i}\right) \tag{1}$$

Where P_i is the proportion of the key variable (build-up area) in the *i*th zone and *n* is the total number of zones [38,40,48].

The relative entropy value:

$$\mathrm{H}_n = \sum_i^n P_i log_e\left(\frac{1}{P_i}\right) / \, log_e\left(n\right) \tag{2}$$

The absolute and relative entropy values range from 0 to 1. A score of 0 implies that the build-up pattern is exceedingly compact. A score of 1 implies that the pattern of build-up areas is dispersed or disordered [38,40,47,48].

2.4. Urban Expansion Intensity Index (UEII)

Urban expansion intensity indexes were computed to determine the intensities of urban sprawl, which is calculated by Equation (3) [38,53,54].

$$UEII = \left(\frac{ULA_{ib} - ULA_{ia}}{t}\right) / \, TLA_i \times 100 \tag{3}$$

Where $UEII_{it}$ is the annual average urban expansion intensity index of (*i*th) zone in period (*t*), ULA_{ia} and ULA_{ib} are the quantity of built-up area at periods *a* and *b* in (*i*th) spatial zone, respectively. TLA_i is the total area of (*i*th) spatial zone [55]. Accordingly, the build-up areas were extracted by calculation of buildings' areas using the geometry calculation tool in ArcGIS 10.8.

2.5. Building Density Analysis

A point density analysis was employed to examine building density and assess urban expansion and its variations [56,57]. Accordingly, it calculated the number of buildings located per unit area for 1992, 2007, 2017, and 2022 using ArcGIS 10.8. According to ArcGIS 10.8, a radius of 479.07 m^2 and a cell size of 57.488 were used to ensure the high resolution of building densities. Afterwards, the output density data of each map was categorized into four groups as low, medium, high, and very high.

2.6. Direction of Urban Expansion

The wind rose diagrams were used to illustrate the direction of urban sprawl [4,49,58]. Accordingly, the mean point in spatial statistics, ArcGIS 10.8, was calculated in each digitized building layer in 1992, 2007, 2017, and 2022 to find the center of the study area. Afterwards, a buffer zone with a 10,000 m radius and eight sectors of that zone were created, and the number of buildings was calculated sector-wise. Then, the number of buildings was converted into percentage values using Microsoft Excel.

2.7. Population Density

Studying population density is crucial for a comprehensive understanding of urban sprawl [59]. Accordingly, population density data for 2000, 2007, 2017, and 2020 were downloaded from the "Worldpop" data source [46]. Yet, population density data before 2000 were not available from this data source. The downloaded maps were extracted according to the study area using ArcGIS 10.8. On the other hand, the spatial resolution of these raster map layers is 1 km, which directly influenced the illustration of the large cells of population densities and a lack of smoothness along the boundary. In that case, some micro-level variations of population density were not captured in the study area.

2.8. Urban Sprawl with Transportation Network

Transportation networks and urban sprawl are tightly connected with each other. In particular, a well-developed transportation network encourages the distribution of residential, commercial, and industrial areas in the peripheral areas. Moreover, high connectivity and accessibility lead to a reduction in travel time and maintain the link between the Central Business District and the periphery areas due to high automobile dependency [47]. Consequently, buildings, especially commercial and service buildings, are proliferating along with the road network [60,61]. Accordingly, the multiple-ring buffer zone analysis in GIS was used to create two buffer zones with a radius of 1,000 m due to the high development pressure within this distance. These buffer zones were aligned on either side of primary and secondary roads using ArcGIS 10.8. After, the number of buildings within each buffer zone was calculated separately using a spatial statistics tool in ArcGIS 10.8 to investigate the connectivity between urban sprawl and the transportation network.

3. Results

3.1. The Geospatial Patterns and Dynamics of the Urban Sprawl

The geospatial building distributions in 1992, 2007, 2017, and 2022 were demonstrating a gradual increase in the number of buildings in the study area (**Figures 2–5**). Quantitatively, **Table 2** illustrates the total number of buildings for the respective years.

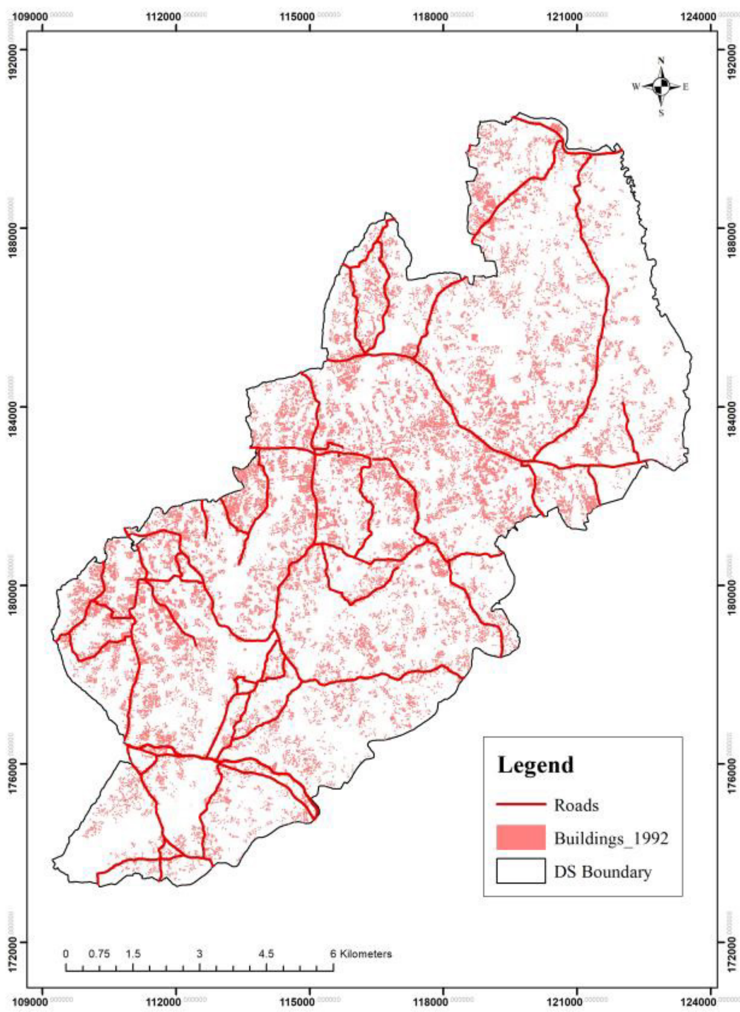

Figure 2. Distribution of the Buildings (1992).

Source: Compiled by authors, 2025.

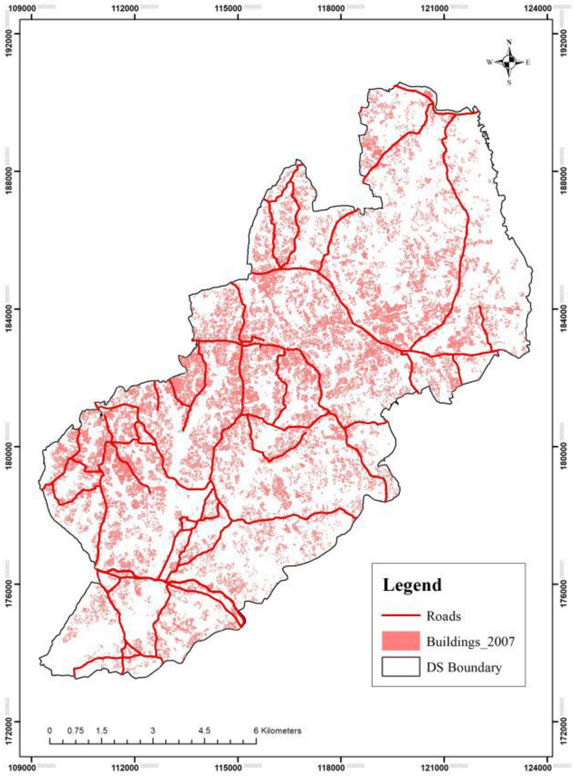

Figure 3. Distribution of the Buildings (2007).

Source: Compiled by authors, 2025.

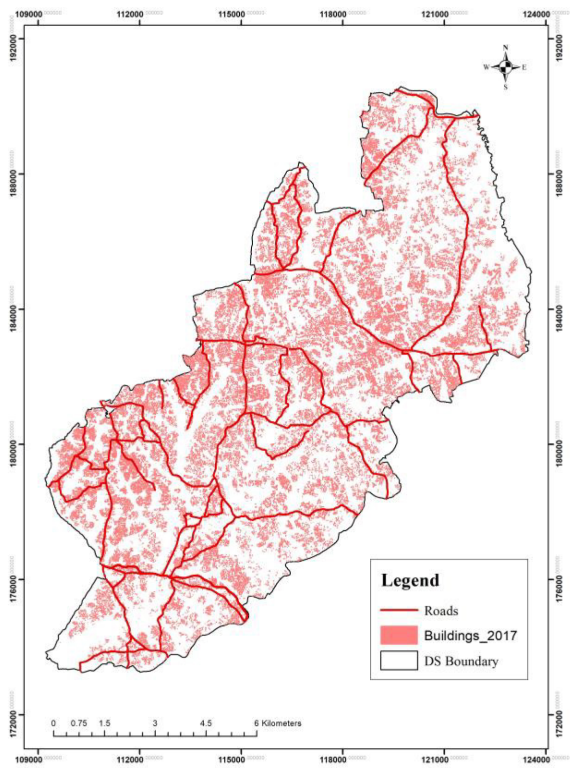

Figure 4. Distribution of the Buildings (2017).

Source: Compiled by authors, 2025.

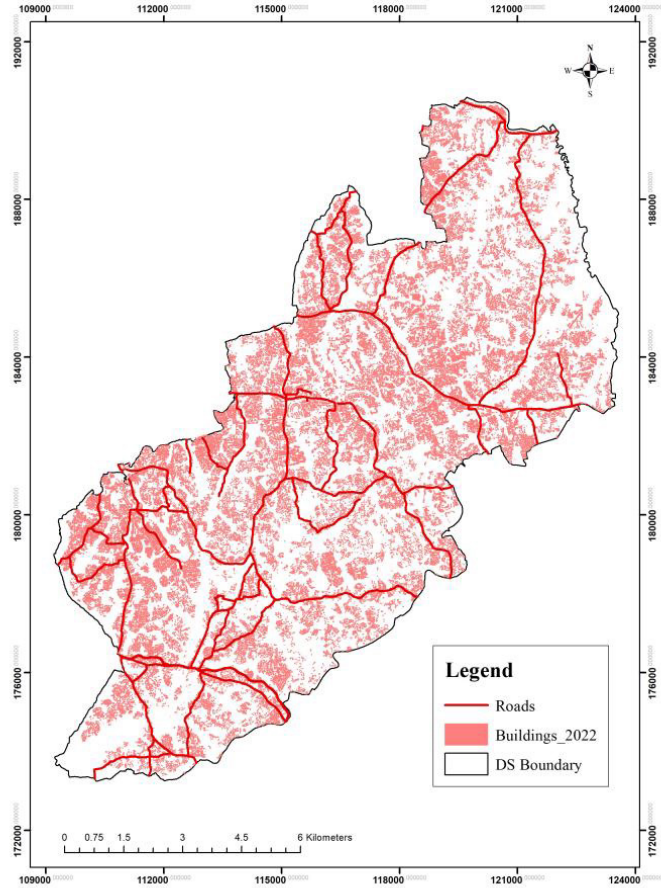

Figure 5. Distribution of the Buildings (2022).

Source: Compiled by authors, 2025.

Table 2. Total Number of buildings (1992–2022).

Year	Number of Buildings
1992	43,202
2007	58,770
2017	82,091
2022	95,291

Source: Compiled by authors, 2025.

Table 3. Shannon's Entropy Calculation (1992–2022).

Year	Shannon's Entropy Model	
	Absolute Value	Relative Value
1992	0.5495	0.3414
2007	0.6884	0.4277
2017	0.8105	0.5036
2022	0.8568	0.5324

Source: Compiled by authors, 2025.

Table 3 presents Shannon's Entropy calculations, including absolute and relative values. In particular, absolute values exceeded the midpoint of log (n). Absolute values were recorded as 0.5495 in 1992, 0.6884 in 2007, 0.8105 in 2017, and 0.8568 in 2022, respectively. On the other hand, the relative entropy values were 0.3414 in 1992, 0.4277 in 2007, 0.5036 in 2017, and 0.5324 in 2022. In particular, the threshold value (0.5) was exceeded in 2017 and 2022. Accordingly, both absolute and relative values in Shannon's Entropy calculations have exhibited a transformation of compact building patterns to a dispersed pattern.

The intensity index (**Table 4**) serves as another indicator depicting the geospatial patterns and trends of urban sprawl. Based on the results of the UEII for the studied period, all values remained below 0.28, indicating a threshold for slow urban sprawl. Consequently, the study area experienced a slow concentration of urban growth during the considered time. The main reasons were environmental conservation and urban green space practices like the Homagama Urban Forest Initiative and Sustainable Landscape Design [62,63].

Table 4. Intensity Index of Urban Sprawl.

Year	Urban Expansion Intensity Index (UEII)	Intensity
1992–2007	0.1156	Slow
2007–2017	0.2468	Slow
2017–2022	0.1762	Slow

Source: Compiled by authors, 2025.

When considering this geospatial pattern and trend descriptively, the current study observed a strong association between the location of road networks and the augmented nature of buildings. In contrast, most of the buildings in 1992 and 2007 were constructed based on the road networks for easy accessibility to the Central Business District (CBD). In 1992, urban sprawl showed a low level because most people were primarily concentrated in major cities such as Colombo, despite peripheral areas such as Horana, Homagama, Waththala, and Kasbewa [10].

Additionally, middle-income individuals in developed countries often migrate towards peripheral regions for their permanent settlements. Moreover, this trend is intensified by several reasons, such as polluted environments, high land prices, busy lifestyles, and high living costs in core areas [40,64,65]. In Sri Lanka, the economic context directly influences the intensification of this pattern, especially the high cost of living and land prices [10]. Significantly, barren lands in the Homagama DS Division have been subdivided and prepared for sale, particularly in Maththegoda, Hidigala, and Godagama. Moreover, the establishment of development infrastructure projects such as the "Gaminipura – Third Lane Road development" and "Divisional Secretariat Office building" in Homagama has created a feasible environment for people's permanent residences [66,67]. Additionally, the "Mega Development Projects for Homagama" launched in 2021 was another crucial economic and infrastructure development project implemented in Meegoda, Godagama, Diyagama, Homagama, Barawa, Ingiriya-Godagama, and Kahathuduwa GNDs [68]. In particular, the Urban Development Authority, integrated with the Ministry of Local Government, Housing, and Construction, formulated a housing development plan (1986–2001) in the Homagama area for the economic and social development [62].

Accordingly, these initiatives facilitated a favourable socio-economic background for increasing the number of buildings and people's migration over 31 years in the Homagama DS Division [40].

3.2. The Temporal Patterns and Dynamics of Urban Sprawl

The building density from 1992 to 2022 (**Figures 6–9**) revealed the temporal patterns/dynamics of urban sprawl in the Homagama DS Division. Accordingly, in 1992, very high building densities were identified in Mattegoda Central A and Henawatta GNDs, surrounded by high-density zones. Middle-density patches expanded mainly toward the southwest and north. But the few middle-density patches were more limited in the north. Low-density areas were widely distributed across the study area.

A complex building density pattern emerged in 2007, illustrating five very high-density patches. They are located in the Mattegoda, Gehenuwala, Henawatta, Kuruduwatta, and Siddamulla GNDs. Moreover, middle-density patches have grown towards the north and southeast direction within the DSD boundary. Low-density patches were distributed in smaller numbers. Building density in 2017 demonstrated a strong decline of very high-density patches. They were limited to Mattegoda Central A, Hiripitiya, and Siddamulla South GNDs. Additionally, the number of high-density patches was decreased, and their diameters shrank from 3,407.41 m^2 in 1992 to 282.85 m^2 in 2017. Yet, middle-density patches significantly expanded, particularly in the Kahathuduwa South, Meegoda South, Gehenuwala, and Magammana West GNDs. The number of low-density areas has reduced in the study area. In 2022, very high-density patches were limited to three patches located in the Mattegoda Central A and Henawatta GNDs. However, their size and diameters have increased compared with those in 2017. While middle-density areas have spread toward the north, low-density areas have gone down gradually.

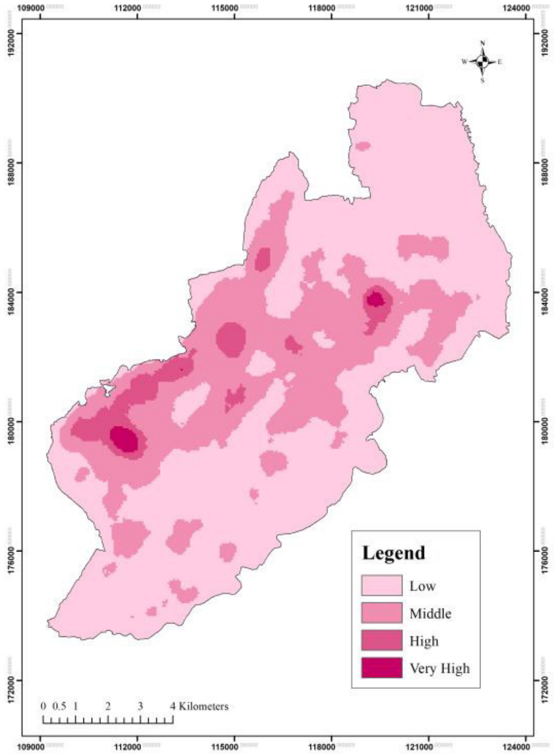

Figure 6. The building density in 1992.

Source: Compiled by authors, 2025.

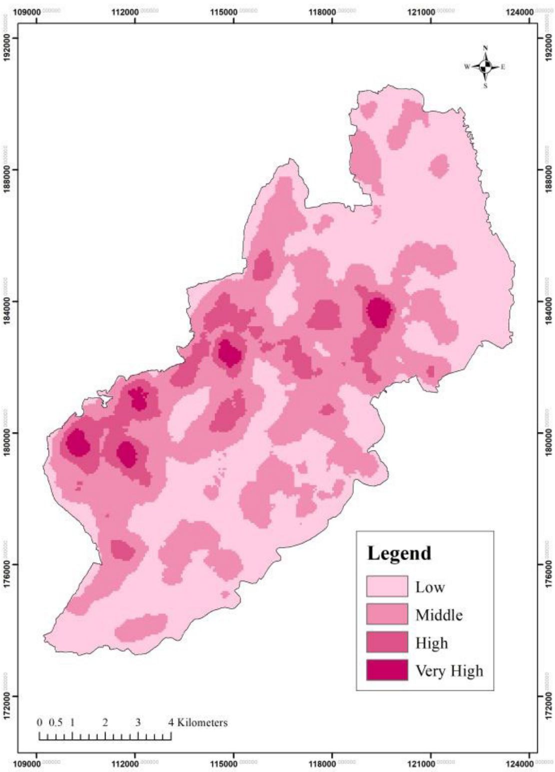

Figure 7. The building density in 2007.

Source: Compiled by authors, 2025.

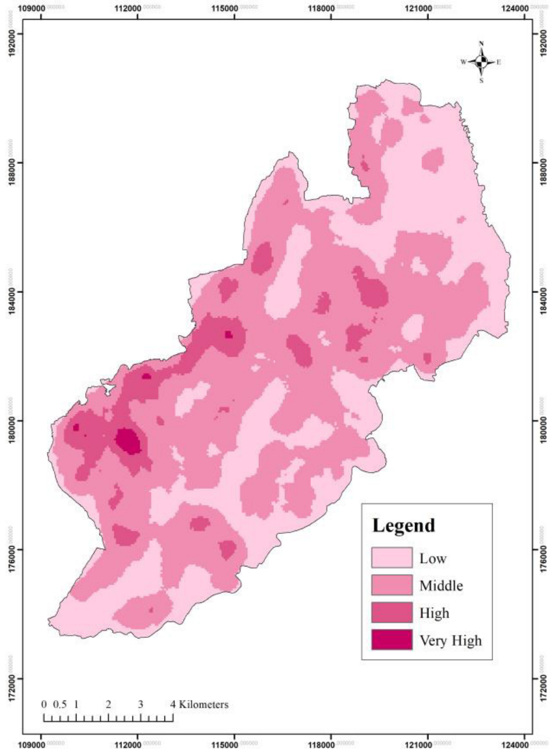

Figure 8. The building density in 2017.

Source: Compiled by authors, 2025.

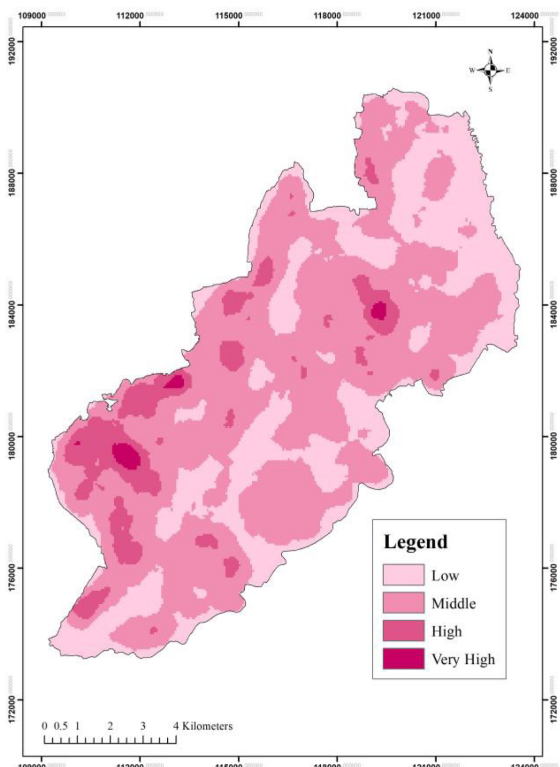

Figure 9. The building density in 2022.

Source: Compiled by authors, 2025.

Under the directional analysis of urban sprawl, **Figure 10** illustrates two primary trends in 1992. They were an expansion of the buildings towards the north and southwest. Approximately 15% of buildings were spread northward along with the narrow sector. On the other hand, around 25% of buildings expanded widely to the southwest. Furthermore, smaller proportions of buildings, such as less than 10% distributed towards the northwest, southward, and east.

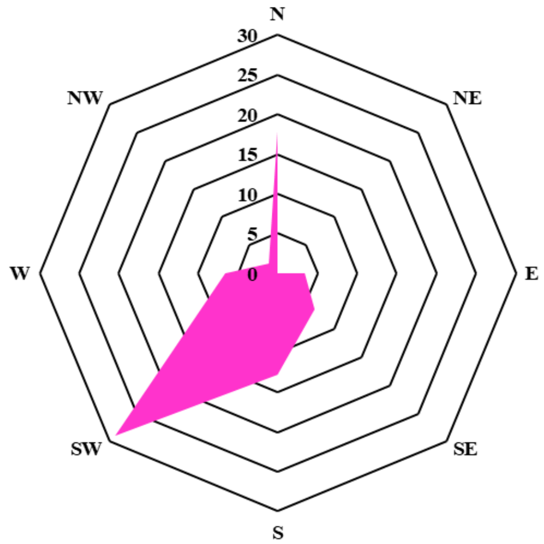

Figure 10. Direction of urban sprawl in 1992.

Source: Compiled by authors, 2025.

Figure 11 shows the directions of building expansion in 2007. While more than 25% of buildings expanded towards the southwest, and about 16% of buildings spread to the north. In particular, the development of the road network located in the north, such as Batawala Road, Etabagahalanda Road, and Kanda Road, significantly facilitated the enhancement of the number of buildings in the north due to increasing accessibility and connectivity. Another noticeable pattern was that approximately 17% of buildings and more than 15% of buildings expanded towards the northwest and south, respectively, reporting a high building percentage compared with 1992. Additionally, more than 10% of buildings expanded to the southeast. In particular, buildings in 2007 illustrated a significant pattern of expansion towards the northern and northeastern areas, especially in the Nawalamulla, Megasmulla, and Meegoda South GNDs. Accordingly, the development of the transportation network, proximity to the Central Business District, and availability of vacant lands are determining factors in the distribution of buildings towards the different directions.

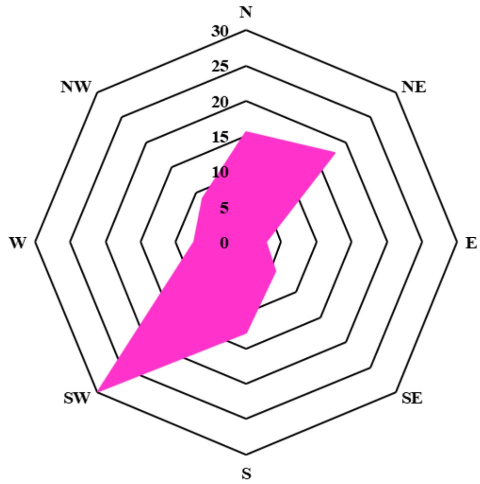

Figure 11. Direction of urban sprawl in 2007.

Source: Compiled by authors, 2025.

Figure 12 demonstrated a further consistent building expansion pattern in 2017. Accordingly, more than 25% of buildings and approximately 15% of buildings have spread toward the southwest and south, respectively. Buildings expanded to the north have increased from 3% compared to 2007. Approximately 16% of buildings spread towards the northeast gradually shifted to the east. Additionally, more than 10% of buildings are spread to the southeast, reporting an increase compared with previous years.

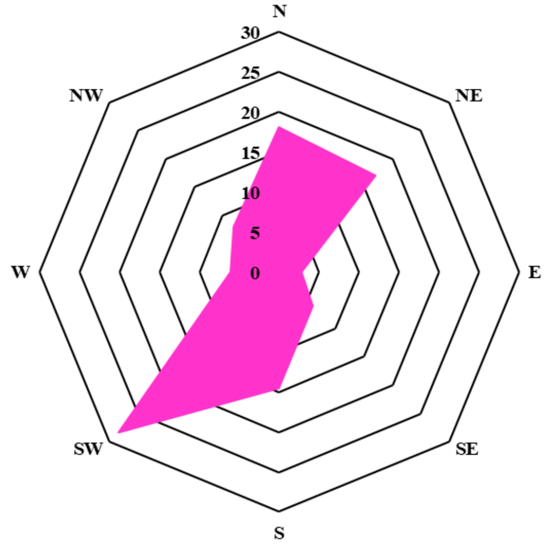

Figure 12. Direction of urban sprawl in 2017.

Source: Compiled by authors, 2025.

Figure 13 revealed the directions of building expansions. Accordingly, approximately 28% of buildings are spread towards the southwest. Building expansion towards the south and southeast increased by 2% and 1%, respectively, compared to 2017. On the other hand, approximately 23% of buildings are spread northward, reporting the highest distribution value compared to the previous years. About 16% of buildings sprawled towards the northeast, and it was gradually shifting to the east.

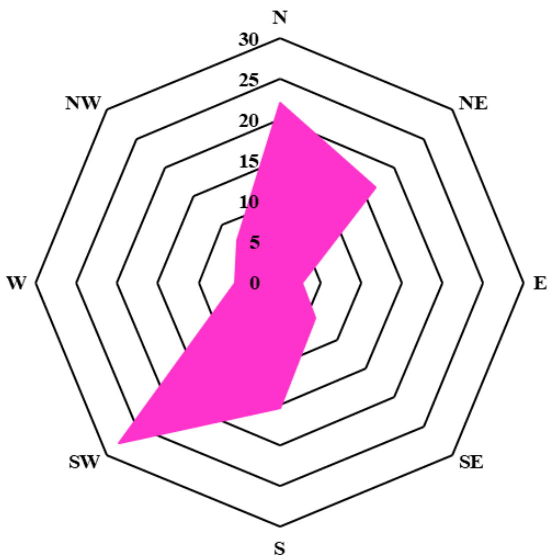

Figure 13. Direction of urban sprawl in 2022.
Source: Compiled by authors, 2025.

The above-discussed temporal patterns and trends illustrated a multidirectional spreading pattern (1992–2022) like a transformation of a "uniplex" city to a "multiplex" city based on socio-economic development and demographic composition [69]. In particular, the building densities can be computed using different geographic units, such as GNDs, DSDs, or political boundaries. Then, different types of outputs will emerge in the building densities. Thus, this problem is called the modifiable area unit problem, introduced by Openshaw in 1984 [70]. Hence, the GNDs can be utilized for calculating the building densities because outputs are crucial for establishing regional development projects. Accordingly, Mattegoda Central A, Mattegoda West, and Mattegoda Central B revealed the highest density patches. It realized a trend, most individuals are purchasing land for their residential purposes and maintaining connectivity with the CBD. This trend is driven by establishing developed socio-economic and environmental conditions around these GNDs. For instance, about 20 acres were acquired to establish the technological city project in Homagama, 2018, in collaboration with the Ministry of Megalopolis and Western Development [10,53,54]. As a result, these development projects and migration of middle-income people lead to the elimination of rural characteristics in the areas and the emergence of modern urbanized socio-economic characteristics.

Furthermore, most middle-income people were aggregated in the high building density patches due to the establishment of developed infrastructure facilities. Especially, the transportation network takes a crucial place by facilitating quick accessibility and connectivity for their daily mobility with the CBD [53]. Moreover, these areas with the highest building density were located westward due to their proximity to the CBD.

Another noticeable trend is that isolated middle building density patches in 1992 and 2007 have been distributed towards the north and southwest, illustrating a large space for their home gardens. Additionally, rapid urbanization and population pressure lead to the relocation of people to areas located farther away from the CBD, especially considering the land price. Hence, there is a high probability of spreading building to the north, south, southwest, and northeast. On the other hand, low building density patches were gradually converting to the middle building density areas [4].

Furthermore, the building densities, from low to very high, exhibited an irregular temporal pattern of urban sprawl from 1992 to 2022. This illustrates an unplanned urban development procedure in the study area. Accordingly, demographic pressure, land availability, and socio-economic context directly influence the formation of heterogeneous spatial patterns in the study area.

3.3. The Causative Factors of the Urban Sprawl

Figures 14 and **15** demonstrate the population density (people/km^2) of the Homagama DSD for the years 2000, 2007, 2017, and 2020. These maps comprehensively represented an upward trend in population growth. Accordingly, the highest population density in 2000 was approximately 3,789.37 per km^2, while the lowest population density was about 428 per km^2. Moreover, the population density in

2007 revealed that the highest and lowest population densities were approximately 4,546 per km^2 and 504 per km^2, respectively. Accordingly, the population density in 2007 emphasized a population growth compared to 2000.

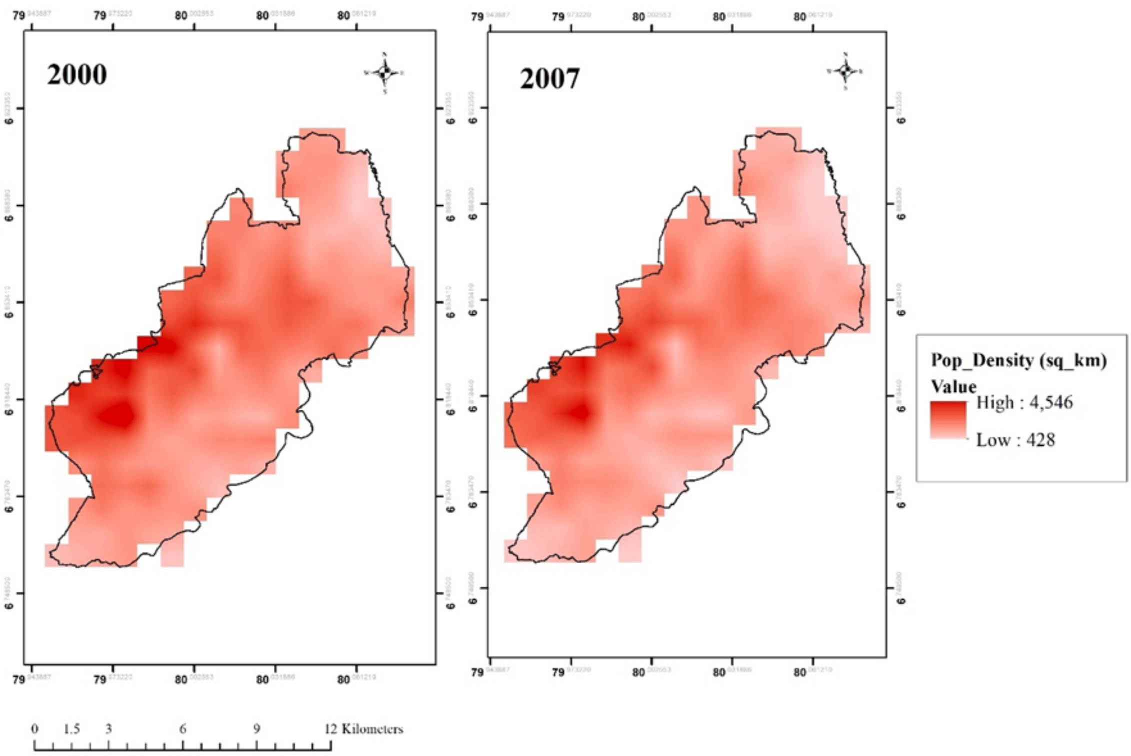

Figure 14. Population Density in 2000 and 2007.

Source: Compiled by authors, 2025.

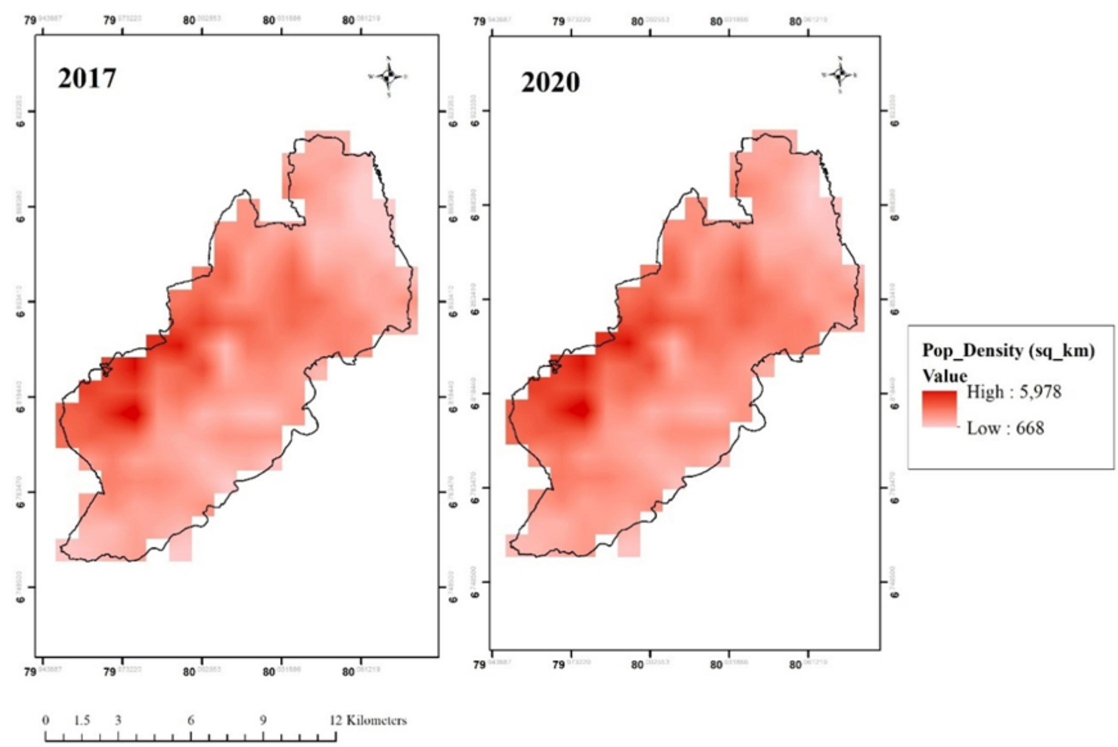

Figure 15. Population Density in 2017 and 2020.

Source: Compiled by authors, 2025.

The population density in 2017 showed a population growth, further illustrating the highest population density as approximately 5,602 per km^2. On the other hand, the low population density was recorded at about 668.53 per km^2. However, the highest population density in 2020 reached approximately 5,977.08 per km^2. It exceeded the highest population density values in 2000, 2007, and 2017. Significantly, the lowest value was about 705.43 per km^2. Furthermore, the disparity of the highest population density between 2000 and 2020 was approximately 2,187.71 per km^2, ensuring a population increase in the Homagama DS Division. Accordingly, the population is one of the causative factors for urban sprawl in this study area, facilitating large geographical spaces for people's accommodations.

In particular, people's migration to suburban areas rather than natural population growth was the main driver of population growth in this area. Unaffordable land prices in the CBD intensified these migration patterns of middle-income people to the Homagama DS Division [40]. As a result of this, new occupational opportunities and a developed socio-economic background are gradually created within this area, such as providing a more luxurious lifestyle for people. On the other hand, the Urban Development Authority has initiated the "Middle Income Housing Program" to fulfill middle-income individuals' housing needs in this suburban area [71]. Additionally, the Homagama DS Division has been selected for the infrastructure development under the zoning development plan in the Urban Development Authority (UDA), Sri Lanka.

Another critical perspective is people's vertical distribution. In particular, there is a significant trend, which is that people often choose to buy apartments rather than land, based on their financial backgrounds. Different apartment complexes are mostly located in Panagoda, Homagama, and Kahathuduwa areas [72]. Thus, people's vertical distribution was not calculated in this study.

On the other hand, the road network is another significant causative factor for the expansion of buildings associated with connectivity and accessibility. In particular, five primary roads are in this area. They are High-level Road, Avissawella Road, Colombo–Horana Road, Malabe–Godagama Road, and Colombo–Hanwella Low-level Road, with the Southern Highway. Additionally, the study area consists of nine secondary roads. They are Kottawa–Thalagala Road, Homagama–Diyagama Road, Godagama–Padukka Road, Station Road, Homagama–Athurugiriya Road, Panagoda–Ambulgama Road, Piliyandala–Kottawa Road, Pitipana–Thalagala Road, and Habarakada–Ranala Road. Hence, **Figure 16** provides evidence of an increase in the number of buildings along the primary and secondary roads.

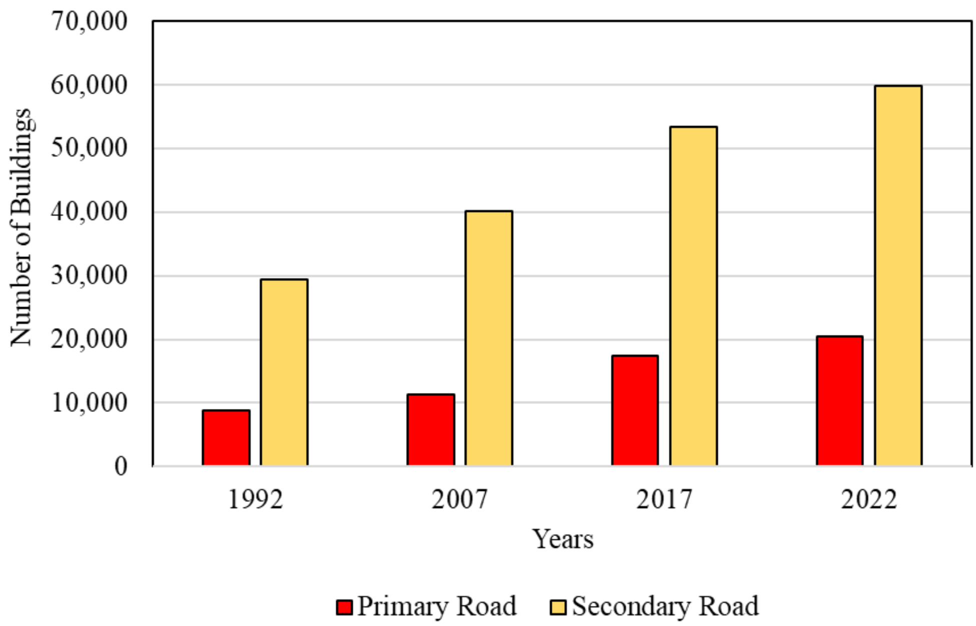

Figure 16. Urban Sprawl with Primary and Secondary Roads.

Source: Compiled by authors, 2025.

Less than 10,000 buildings in 1992 were located around the primary roads. Yet, the number of buildings located around the primary roads was gradually increased in 2007 and 2017 within the buffer zone. Accordingly, they reported approximately 11,296 in 2007 and 17,449 in 2017, respectively. In particular, this pattern went upward, further reporting 20,419 buildings in 2022. On the other hand, the number of buildings along secondary roads also illustrated an upward trend. Accordingly, approximately 8,761 buildings in 1992 were located within the buffer zone associated with secondary roads. Furthermore, approximately 40,066 buildings in 2007 and 53,318 buildings in 2017 were underlaid in the zone, a result of developed connectivity and accessibility. Approximately 59,805 buildings were reported in 2022, ensuring this trend. In particular, this phenomenon exemplified a linear growth pattern and ribbon development of buildings along primary and secondary roads [51,52,73,74]. Additionally, this pattern clearly provided evidence of the growth of commercial and residential buildings associated with the transportation network from 1992 to 2022 [75].

Moreover, **Figure 17** shows the growth of the transportation network from 1992 to 2022. Approximately 60.56% of the growth rate can be recognized in the considered period. Quantitatively, the transportation network expanded from approximately 6.228 km^2 in 1992 to 10 km^2 in 2022. On the other hand, several transportation development projects, such as the Homagama Bypass Construction, Rural Road Improvement Program, and the development of “C” type roads in Homagama, Godagama, and Kahathuduwa have contributed to enhancing accessibility and connectivity [62,73]. On the one hand, these development processes directly lead to traffic congestion, increased taxes, environmental pollution, high automobile dependency, and socio-cultural conflicts [10,20,74,76].

According to the above discussion, the transportation network plays a crucial role in the expansion of buildings throughout the study area.

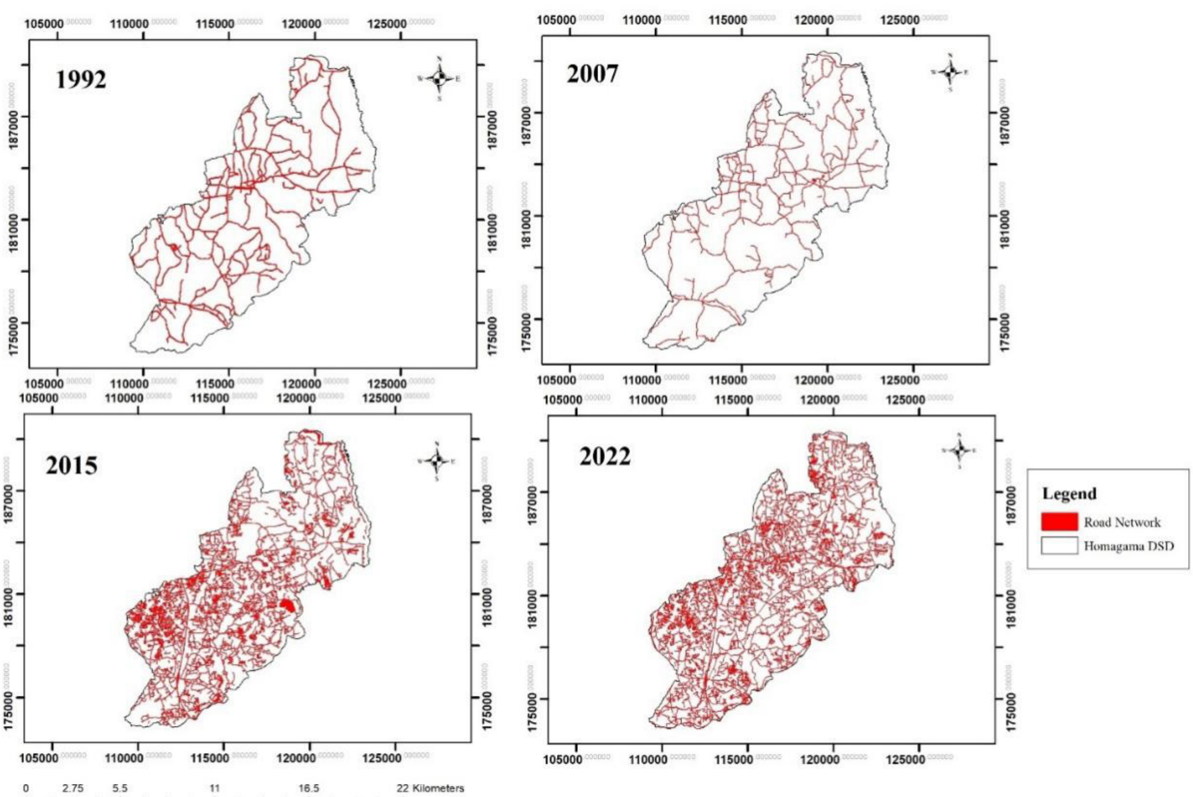

Figure 17. Road network in the Homagama DSD.

Source: Compiled by authors, 2025.

4. Conclusions

The principal contribution and implication of this study were a comprehensive analysis of trends and dynamics of urban sprawl using Geographic Information Systems and Remote Sensing technologies, focusing on the number of buildings. Accordingly, the spatial patterns and trends of buildings from 1992 to 2022 revealed a transformation from the compact distribution pattern to the dispersed distribution pattern. It indicated a massive urban sprawl with a slow, steady intensity rate in the Homagama DS Division.

In the examination of temporal patterns and dynamics of urban sprawl, a rapid growth of middle and high building densities is observed in the study area. On the other hand, the low-density areas have gradually declined over the considered period. In particular, the expansion of building density was heading/spreading towards the north and southwest directions, which was further emphasized by the directional analysis of urban sprawl. Moreover, population density and transportation network in the Homagama DS Division were primary drivers in shaping the spatial and temporal landscape of urban sprawl from 1992 to 2022. More importantly, this study revealed irregular geo-spatial and temporal patterns of urban expansion in the suburban area from 1992 to 2022. This expansion is further intensified by land acquisition competitions, urban pressure, developed infrastructure facilities, and high automobile dependency.

As a consequence, the environmental balance (e.g., the balance of nature) and community well-being have been dramatically disrupted by this urban sprawl. Hence, the findings suggest that an optimized land use plan should be initiated in order to control unplanned building distribution to ensure a sustainable urban trajectory. Furthermore, enhancing walkable neighbourhoods and green spaces will mitigate the urban heat island effect (UHI) and eliminate people's heat stress by spending time in a green environment. Additionally, policies and regulations for encouraging buildings' vertical growth will directly influence the conservation of mixed land use development procedures. Introducing a proper public transportation network will contribute to reducing environmental pollution, decreasing automobile dependency, and eliminating traffic congestion. On the other hand, equal resource utilization and social equality in the establishment of urban sustainability in the suburban area can be identified/considered as influential remedies controlling unplanned urban sprawl.

Thus, this study exemplifies the necessity of an urban master plan and urban policies to establish a sustainable city in the Homagama DS Division. Accordingly, a land use zoning plan with environmental conservation is essential to organize the city structure regularly and achieve effective city management. On the other hand, introducing a green infrastructure policy and a land use regulation policy are other crucial urban policies to control unplanned urban expansion, such as creating a green belt. Moreover, people should be encouraged to move towards the northern part of the study area to keep a balance between building development and green-blue infrastructure development.

Author Contributions

Conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing—original draft preparation, G.E.K.; writing—review and editing, visualization, supervision, A.K. Both authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare that no potential conflict of interest is found regarding this study.

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