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Dynamics of Urban Sprawl Growth Using Shannon's Entropy Model: Special Reference to Couple Cities in Sri Lanka

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ABSTRACT

Urban sprawl is a remarkable phenomenon in the developing cities and megacities of the world. As a spatial pattern, it has increased in recent decades thanks to urbanisation and rapid population growth. The spatial and temporal changes of urban sprawl have been thoroughly studied in cities around the world. However, few studies on urban sprawl were conducted in Sri Lanka, such as Kandy and Colombo. Batticaloa and Kurunegala are rapidly growing cities in Sri Lanka. Batticaloa has been severly affected by the Civil War for three decades. At the end of the Civil War in 2009, many development opportunities started in Batticaloa as well as Kurunegala because of a calm situation. This rapid development increased further spatial changes in the municipalities. This study aims to identify the dynamics of urban sprawl growth in Batticaloa and Kurunegala city for 2000, 2010 and 2020. Landsat satellite images for 2000, 2010 and 2020 were employed with the Normalized Difference Built-up Index (NDBI) in ArcGIS. The built-up images were calculated using Shannon's entropy model to comprehend the urban sprawl intensity. The findings indicate that urban sprawl growth gradually increased from 2000 to 2020 based on the entropy and relative entropy in Batticaloa and Kurunegala city. It showed extreme sprawling growth, which was exceeded the halfway mark of Log(n) 0.97295 and very close to the Log(n) value of 1.94591. This growth occurred in the municipality due to individual homeownership, which increased a residential sprawl. Therefore, the government should introduce more housing schemes and implement a mandatory approval system for housing development in the municipality. These findings can contribute to formulating policies related to built-up development in the municipality to reduce the sprawling growth in future.

Keywords: urbanization, urban sprawl, land use, population growth.

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1. INTRODUCTION

Rapid population growth and the expansion of urban areas constitute urbanisation. Human activity has had a devastating effect on the planet's natural resources, which have been taxed to the limit by the ever-increasing world population (Hamad, 2019). Sometimes the rapid expansion of metropolitan regions can be attributed to the high population density in the area (Jain, Dimri, & Niyogi, 2016). Despite its many advantages, the development process in a country sometimes results in uncontrolled and unsustainable growth of the urban centres (Wolny, Dawidowicz, & Źróbek, 2017). More than half of the global population now lives in the city, a statistic reached in the first decade of the 21st century (Grigorescu, Kucsicsa, & Mitrică, 2015). The rate of urbanisation is accelerating not only in the west but also in emerging economies like China, India, and Bangladesh. Large cities in Asian countries have also been expanding in recent decades, and this trend is predicted to peak around 2050.

The term "urban sprawl" refers to an expansion pattern characterised by a low population density in built-up regions such as commercial, residential, and administrative hubs, as well as a lack of viable alternative transportation corridors and centres of economic and social activity. The "urban sprawl" phenomenon happens when the demand for land exceeds the available land, leading to an ever-increasing city (Yue, Liu, & Fan, 2013). Urban areas with a greater average population density can be considered urban sprawl if they occupy a broad land area with a low population density. This phenomenon illustrates the fragmented, decentralised development that characterises big, isolated sections of cities, where the vast majority of the world's population now resides (OECD, 2018). There are obvious features of urban sprawl, such as massively dispersed forms and activities, linear growth of highways, urban regions spread over large open spaces, and shapeless housing developments affecting urban fringes (Polyzos, Minetos, & Niavis, 2013). Multiple dimensions of urban sprawl are prevalent in the United States, Canada, Slovenia, and Austria, among other nations. This development pattern must be continuously monitored to prevent expansion. From 1990 to 2014, most dimensions were measured, justifying further monitoring in cities such as Poland, France, the Czech Republic, Slovakia, and Denmark (OECD, 2018).

Rapid urbanisation has led to the emergence of a global problem with personal consequences: urban sprawl. Over the past few decades, sprawl has been increasingly noticeable in megacities and developing cities worldwide (Aburas, Ahamad, & Omar, 2019). This spatial pattern has grown over the past few decades as cities and populations have expanded. Population density is lower in developed world cities than in developing countries like Sri Lanka. As people move to cities, new neighbourhoods are built outside to accommodate them, which forms an irregular residential pattern. These patterns, such as leapfrog development, low-density development, scattered development, and commercial ribbon growth, are visible in the urban areas of both industrialised and developing nations. Such development patterns are referred to as urban sprawl development, leading to a wide range of issues in urban areas. The number of dwellings is a straightforward indicator of urban sprawl (Ottensmann, 2018). Hence, studies of urban sprawl focus primarily on spatial and temporal patterns.

In cities across the globe, the spatial and temporal changes of urban sprawl have been intensively investigated (Chettry & Surawar, 2020; Hamad, 2019; Sahana, Hong, & Sajjad, 2018). However, only a few studies have been undertaken on urban sprawl changes in Sri Lanka, such as Kandy (Masakorala & Dayawansa, 2015) and Colombo (Antalyn & Weerasinghe, 2020). Batticaloa is one of the expanding cities in Sri Lanka that was severely affected by the Civil War from 1983 to 2009. After the end of the Civil War, people were able to live in peace. In the meantime, many development opportunities arise due to the tranquillity of this area, and this rapid development exacerbates urban spatial transformations. It is also vital to examine the historical evolution of urban sprawl in order to appreciate contemporary and past tendencies.

Numerous studies have successfully defined this phenomenon using a mathematical relationship in the context of urban sprawl (Chatterjee, Chatterjee, & Khan, 2016; Jain et al., 2016; Ozturk, 2017; Polyzos et al., 2013; Yue et al., 2013). Simultaneously, for nearly three decades, major research activities have utilised remotely sensed images for the spatial and temporal investigation of urban sprawl change (Bhat, ul Shafiq, Mir, & Ahmed, 2017; Gumma, Mohammad, Nedumaran, Whitbread, & Lagerkvist, 2017; Hamad, 2019; Liu, Liu, Qi, & Jin, 2018; Ozturk, 2017; Padmanaban et al., 2017; Sahana et al., 2018). Although Masakorala and Dayawansa (2015) investigated the spatial and temporal patterns of urbanisation, urban expansion, and urban sprawl in Kandy, Sri Lanka, urban sprawl was not a major emphasis of their research. Manesha and Jayasinghe (2021) analysed urban sprawl in several small and medium-sized cities in Sri Lanka, excluding Batticaloa. The study focused solely on quantifying urban sprawl and determining its drivers, such as population, income, and accessibility. However, spatial patterns were not taken into account, which is essential for comprehending the distribution of sprawl. Simultaneously, Manesha, Jayasinghe, and Kalpana (2021) examined spatio-temporal patterns of urban sprawl in multiple Sri Lankan cities, which were restricted to two (2) periods of change. However, Batticaloa was excluded from the study. Consequently, as a growing city, Batticaloa should measure the spatial and temporal patterns of urban sprawl in Sri Lanka.

2. MATERIALS AND METHODS

2.1. Study Area

Batticaloa Municipal Council (BMC) is located in the eastern part of Batticaloa District in Sri Lanka's Eastern Province. It lies between the latitudes 7°39′53″ and 7°44′36″ to the north and 81°39′17″ and 81°41′54″ to the east. Being a prominent coastal city in Sri Lanka, it is renowned for its physical and social structures. It is bounded on two sides by natural features: the Batticaloa lagoon on the west and the Bay of Bengal on the east. Land separates by the north of Eravur Pattu Pradeshiya Saba and the south of Kattankudy town. Its elevation ranges between 1.2 and 4.0 meters above mean sea level, making the topography flat and low-lying. The city has a total extent of 4195.18 hectares divided into 48 Grama Nniladhari Divisions (GND).

The natural significance of Batticaloa is enhanced by its geographic location, sandy beaches, lagoons, various ecosystems, and associated natural resources. It lies on a peninsula comprised of a lagoon-formed number of islands and a plain coastal strip. These small islands in the lagoon that run through the district and the spit of land that separates it from the mainland are two key features that make the city more attractive in terms of morphology. The largest island, Pulliyanthivu, is a core and more dynamic area in the city.

BMC experiences a dry climate due to its geographical location on Sri Lanka's eastern coast, where it receives rainfall between 864 mm to 3081 mm annually and average temperatures between 28°C and 34°C (Statistic-Office, 2015). The area typically experiences rainfall from the North-East monsoon and second inter-monsoon, and a dry climate prevails from May to September. As a result of these climatic factors and its location, the study area is at risk from several natural hazards such as floods, cyclones, and drought. One of the key contributing factors to this growing risk is the changing land use pattern. Thus, this scenario challenges the city's ability to create a livable and conducive environment for urban dwellers.

BMC is a multi-ethnic area with a total population of 94,785, and the majority of people in the area are Tamils, accounting for 89.89% of the total population. Muslims (5%), Burgers (4.13%), and Sinhalese (0.23%) take a minor proportion of the population (Statistic-Office, 2021). With the end of a 30-year conflict, there has been a significant change in the characteristics of the urban population and its associated structure. In 1971, 36,696 people lived in the BMC area, which increased to 94,785 in 2021. Despite an uneven population distribution throughout the BMC, the population density is 1394 persons per square kilometre (Statistic-Office, 2021).

The land use pattern of the BMC demonstrates how the city's land use is distributed based on its various economic activities. Agriculture, tourism, fishing, and industry are the key drivers of the urban economy, which is reflected in these economic activities centred in the city. The most prominent land use is residential, followed by agricultural and other land use types. The majority of the population works in the public sector. In recent years, the city has attracted more economically active people. Thus, 71% of the male population and 29% of the female population in the city contribute to the urban economy (BMC, 2022).

In addition, the spatial and temporal growth pattern is consistent with several distinctive characteristics that the city encountered during its origin and evolution. Since the area was severely affected by civil war for three decades and the tsunami in 2004, its development shows a varied trend. Moreover, the area has witnessed some significant changes that have expedited its development in the post-war period. It is indicative of the spatial pattern of the city, which is portrayed by its changing land use pattern, which is influenced by various elements such as physical, cultural, and historical considerations. Therefore, this area is significant for identifying urban sprawl growth spatially and temporally.

Kurunegala city is the capital of the North Western Province of Sri Lanka, located between 7°28'59.99"N and 80°21'59.99"E. Relatively, the city is bordered by six other districts: Anuradhapura in the north, Matale and Kandy in the east, Gampaha and Kegalle in the south, and Puttalam in the west. The city's terrain can be characterized as a plain area bordered by rock outcrops, with the northern part of the city being slightly higher than the southern part, with the mean elevation of about 76 meters above sea level.

The city's climate is hot throughout the year, which is an impact of the surrounding rock outcrops since they trap heat during the day. 26.82°C was recorded as the highest mean monthly temperature of Kurunegala. Around 2000 mm of rainfall is recorded in Kurunegala on average each year, where the monsoon rains are experienced from May to August and October to January (UN-Habitat, 2020). The city is subject to socio-spatial climate vulnerabilities, with the most important being extremely hot weather, flooding spells, public health emergencies associated with disasters, a decline in drinking water supplies, and groundwater pollution.

The majority of the population in Kurunegala is Sinhalese (73.3%), followed by Sri Lanka Moor (16.8%), Tamil (8.1%), and other groups (1.8%) (Statistics, 2011). The estimated population of the city is 25,857 (Resource Profile: Kurunegala Municipal Council, 2021). The city's demographic dynamics indicate that the growth rate is continuing to decline. The population growth rates were 0.317 in 2021, 0.278 in 2022, 0.238 in 2023, and expected to be 0.207 in 2024, respectively.

In the urban economy, Kurunegala's land use pattern is clearly significant. Kurunegala is renowned as a service town for a 25-kilometer radius. A significant growth in commercial use was noticed between 2001 and 2017 in the Kurunegala Town Limit, compared to a very small amount of residential construction (UDA, 2019). There are 3,694 industries with 11,618 employees functioning within municipality limits, ranging from large-scale to cottage industries. Thus, as evident from the aforementioned, it is clear that there is a trend toward decreasing industrial and residential land use while there is a high demand for commercial land use. As a result, urban sprawl is reportedly occurring along the edge of the municipality area to meet the expanding demand.

2.2. Data Source

Landsat images with all bands for 2000, 2010 and 2020 were retrieved using the USGS Earth Explorer. The images were projected in the Kandawala coordinate system used in Sri Lanka. These Landsat imageries were processed for study by clipping along the Batticaloa municipality boundary, which was digitised based on the existing municipality boundary.

Table 1. Details of satellite data.

Satellite Name	Path/Row	Image Resolution	Date Acquired	Band used
Batticaloa				
Landsat 7 ETM+	140/055	30m	2000/09/28	Band 4, 5
Landsat 7 ETM+	140/055	30m	2010/09/24	Band 4, 5
Landsat 8 OLI	140/055	30m	2020/09/27	Band 5, 6
Kurunegala				
Landsat 7 ETM+	141/055	30m	2000/12/11	Band 4, 5
Landsat 7 ETM+	141/055	30m	2010/05/13	Band 4, 5
Landsat 8 OLI/TIRS	141/055	30m	2020/10/23	Band 5, 6

2.3. Data Analysis

The following analyses were intended to evaluate the results and findings using Landsat imageries for the Batticaloa municipality area.

2.3.1. Normalised Difference Built-Up Index (NDBI).

Normalised Difference Built-Up Index (NDBI) was applied to extract built-up features from Landsat images. NDBI have values between -1 and 1. The value of built-up land can be positive, whereas the value of other land uses can be negative (Sahana et al., 2018). This calculation method is utilised to improve the individual spectral responses of different forms of land cover, including built-up areas and other land uses. NDBI is computed with Equation 1 (Viana, Oliveira, Oliveira, & Rocha, 2019).

$$NDBI = (SWIR - NIR)/ (SWIR + NIR) \quad (1)$$

Where NDBI mentions the normalised difference built-up index, SWIR indicates the shortwave infrared band, while NIR indicates the near-infrared band of the Landsat images.

To comprehend the expansion of urban sprawl in the Batticaloa municipality, the built pattern for 2000, 2010 and 2020 were retrieved using the Landsat imageries. Since the beginning, the built-up area has risen gradually because of the expansion in construction development as the municipality became an urban region. This building expansion occurred within the last three decades. Thus, 2000 (earlier) and 2020 (later) built-up patterns were utilised in ArcGIS 10.8.1 for change analysis. Using this tool, maps for built-up changes were obtained to illustrate the expansion of urban sprawl during the specified years above.

2.3.2. Shannon's Entropy Model

The entropy model is a tried-and-true technique for detecting and measuring the quantity of urban sprawl using spatial data sets of GIS and remote sensing technology (Chettry & Surawar, 2021; Das & Angadi, 2021). Shannon's entropy and the relative entropy index were determined to understand the intensity of urban sprawl in Batticaloa municipality. Shannon's entropy is a metric computation method based on information theory that measures spatial concentration or dispersion and temporal variations of spatial zones. That is referred to as a robust amount of urbanisation process (Chatterjee et al., 2016; Das & Angadi, 2021; Sahana et al., 2018). Consequently, this method is the most reliable of the currently available urban sprawl indexes.

Shannon's and relative entropy were calculated using Batticaloa municipality's built-up areas. The quantity of entropy values was utilised to determine if the urban area was concentrated or dispersed. The entropy values range from 0 to $\log_e$ (n), indicating that the value 0 represents a maximum concentration of built-up regions, whereas the value $\log_e$ (n) shows a maximum dispersion of the built-up area. However, the threshold value is typically the halfway mark for $\log_e$ (n).

The city that exceeds this barrier is termed sprawling (Amarawickrama, Singhapathirana, & Rajapaksha, 2015; Chatterjee et al., 2016; Chettry & Surawar, 2020). The entropy (*H*) was computed with equation 2 (Das & Angadi, 2021):

$$H_n = \sum_{i=1}^{n} Pi * \log_e(1/Pi) \qquad (2)$$

Where *Pi* value indicates the proportion of a phenomenon (built-up areas) occurring in the *i*th zone $x_i / \sum_{i=1}^{n} x_i$ and *xi* represents the density of built-up area, which equals the extent of built-up areas divided by the total extent of built-up areas in the *i*th of *n* total zones.

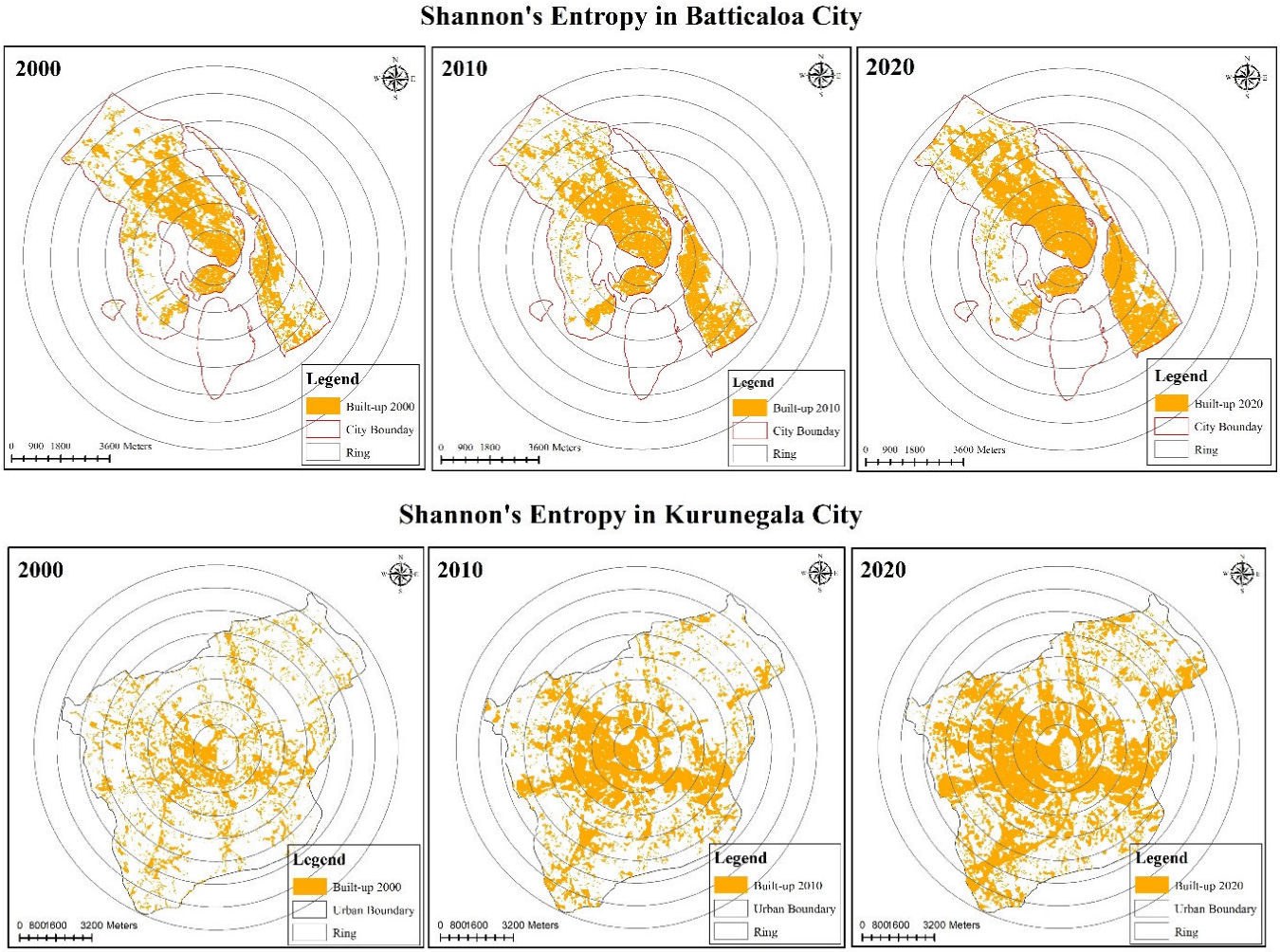

Figure 1. Shannon entropy in Batticaloa and Kurunegala City.

Using the multiple ring buffer technique in ArcGIS, eight (8) rings or zones were formed for each built-up map (2000, 2010, and 2020) encompassing all parts of Batticaloa municipality at 1km intervals from the city centre (see Figure 1). To calculate the entropy and the relative entropy value of each ring, the built-up areas were intersected with the rings in vector format to extract the total built-up regions of each ring. Relative entropy is a measure of the similarity between two time periods. Using equation 3, the relative entropy was computed (Chatterjee et al., 2016):

$$H'_n = {}^{H_n}/_{\log_e(n)} \quad (3)$$

Where H'_n represents the relative entropy value, *Hn* indicates the entropy of a specific year divided by the $\log_e$ (n). In this case, the relative entropy values range from 0 to 1, and this value exceeded 0.5, which is the threshold value that mentions sprawled growth in the city (Antalyn & Weerasinghe, 2020; Chatterjee et al., 2016; Das & Angadi, 2021).

3. RESULTS AND DISCUSSION

The built-up pattern is the key measure of urban sprawl expansion. In Batticaloa municipality, the built-up area is the most prominent land use type. As a result, the built-up areas for the specified years were derived from the land use/land cover patterns (see Table 2). Figure 2 depicts the municipality of Batticaloa's built-up pattern over time (2000, 2010, and 2020).

Table 2. Extent of built-up land in Batticaloa municipality.

Class Name	2000	%	2010	%	2020	%
Batticaloa						
Built-up	1237.86	29.51	1367.10	32.59	1774.44	42.30
Non-built-up	2957.32	70.49	2828.08	67.41	2420.74	57.70
Total	**4195.18**	**100**	**4195.18**	**100**	**4195.18**	**100**
Kurunegala						
Built-up	2045.77	19.08	3378.01	31.50	4699.76	43.82
Non-built-up	8678.80	80.92	7346.56	68.50	6024.81	56.18
Total	**10724.57**	**100**	**10724.57**	**100**	**10724.57**	**100**

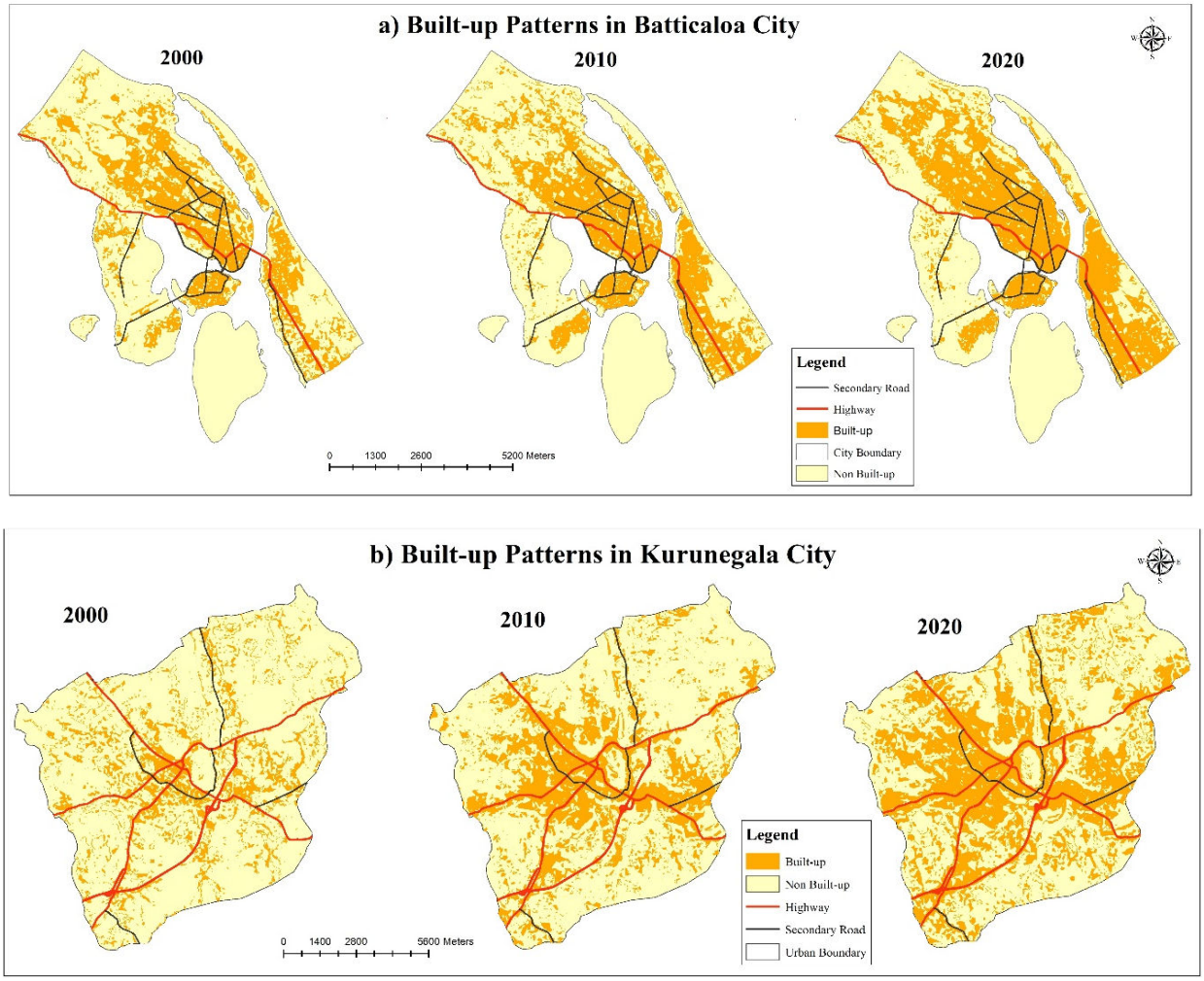

Figure 2. Built-up pattern in the Batticaloa municipality.

The built-up growth rate increased from 1.04% between 2000 and 2010 to 2.98% between 2010 and 2020, which was the most remarkable built-up development rate in the Batticaloa municipality within the examined time periods (see Table 3). Rapid constructions in the Batticaloa region predominantly contributed to the built-up growth during these time periods. In this instance, citizens contributed considerably to the sprawling development of the city. The entropy was computed based on the built-up patterns of the selected years to determine the sprawl intensity in the city.

In contrast, the built-up growth rate of Kurunegala between 2010 and 2020 has decreased to 3.91% compared with the previous analyzed period of study, 2000- 2010, where it was 6.51% (see Table 3). TheLimitationssuch as the proportion of land which could not be utilized due to the geographic attribute (outcrops), existence of historical places as well as the lands belonging to religious institutions and regulatory factors of land development, such as restrictions on filling paddy lands has added a subsistence contribution to the above pattern.

Table 3. Urban growth rate in the Batticaloa municipality.

Urban Area (built-up growth)				
Period	**Batticaloa**		**Kurunegala**	
	Net Increase (Ha)	**Growth Rate**	**Net Increase (Ha)**	**Growth Rate**
2000 – 2010	129.24	1.04%	1332.24	6.51%
2010 – 2020	407.34	2.98%	1321.75	3.91%

Shannon's entropy model has been utilised to measure urban sprawl in the municipality of Batticaloa. The entropy value closest to zero (0) suggests that the city's built-up growth is more concentrated, whereas a value greater than the halfway mark for $\log_e n$ shows that the city is undergoing urban sprawl development. According to Paul and Dasgupta (2012), Shannon's entropy theory is a widely accepted technique for comprehending urban sprawl in a metropolis. In this instance, the degree of urban sprawl is determined by analysing the built-up patterns of 2000, 2010 and 2020. To compute the entropy value, eight (8) rings (1 km each ring) were generated for each time interval (see Figure 1). The results identify a continuing urban sprawl expansion trend in the built-up area.

Table 4 displays the Shannon entropy values that were used to conclude that urban sprawl in Batticaloa municipality accelerated after 2000. By measuring the entropy, the results show that urban sprawl growth increased from 1.7137 in 2000 to 1.8078 in 2020. However, in 2010, the entropy value was dropped to 1.7050. In this study, the Shannon entropy ranged from 0 to 1.94591 (log (n) value), hence, the entropy values for all the years were greater than half of the threshold value, which was set at 0.97295. In general, the entropy value for each time period increased to near its maximum, pointing to a period of rapid sprawling development in the Batticaloa municipality between 2000 and 2020. However, the most unsustainable, sprawling growth was found to occur in 2020.

According to the Shannon entropy values, the urban sprawl in Kurunegala shows changes over time. In 2000 it was 1.9014 and decreased to 1.8905 in 2010. Again, in 2020 it has increased to 1. 9015 (see Table 4). With reference to Kurunegala, the Shannon entropy ranged from 0 to 2.0794 (log (n) value), and as a result, the entropy values for all the years were higher than the threshold value, which was defined at 1.0397. Overall, in Kurunegala, too, each time period's entropy value has surged to almost its maximum, resulting in urban sprawl where the highest in 2020.

Table 4. Shannon's and relative entropy in Batticaloa MC.

Name of the City	Year	Entropy Value	Relative Entropy	Relative Entropy Change (+/-)
Batticaloa (Log 1.9459 and Halfway mark of Log(n) 0.9730)	2000	1.7137	0.8807	-
	2010	1.7050	0.8762	-0.005
	2020	1.8078	0.9290	0.053
Kurunegala (Log 2.0794 and Halfway mark of Log(n) 1.0397)	2000	1.9014	0.9143	-
	2010	1.8905	0.9091	-0.005
	2020	1.9015	0.9144	0.005

In addition, the relative entropy value in Batticaloa revealed an upward tendency of urban sprawl from 2000 onwards. In 2000, the relative entropy value had climbed to 0.8807. It was then declined to 0.8762 in 2010 and jumped to 0.9290 by 2020. Accordingly, the selected period's relative entropy value exceeded the threshold value of 0.5, indicating an increase in urban sprawl. Thus, Batticaloa municipality has experienced continual urban sprawl since 2000, as evidenced by these growths. Changes in relative entropy values were higher in 2010-2020 than in 2000-2010, confirming that the municipality had a high degree of urban sprawl. It has been proved that the growth in building construction in Thiraimadu, Kokkuvil, Oorani, Sinna Oorani, and Saththurukkondan caused the urban sprawl expansion in the city.

Further, the relative entropy value in Kurunegala also showed an increased trend in urban sprawl beginning in 2000. The relative entropy was 0.9143 in 2000; by 2010, it had dropped to 0.9091, and it had risen back to 0.9144 in 2020. As a result, the relative entropy value for the chosen time period was higher than the threshold of 0.5, indicating an increase in urban sprawl. As a result, urban sprawl in Kurunegala town has been proceeding since 2000s. Relative entropy levels changed more dramatically between 2010 and 2020, supporting the municipality's high level of urban sprawl. It has been revealed that Malkaduwawa, North Malkaduwawa, South Malkaduwawa, and South Wilgoda have seen an increase in building construction.

Furthermore, change detection for urban built-up areas in Batticaloa city has been found to comprehend urban expansion from 2000 to 2010, and 2010 to 2020 (see Table 3). This trend indicates an increase in built-up patterns from one time to the subsequent. Approximately 129.24 hectares were added to the built-up area between 2000 and 2010. However, the built-up area climbed by 407.34 hectares between 2010 and 2020 (see Table 3), the most rise among the selected decades. From 2000 to 2020, the built-up area grew by around 536.58 hectares, indicating a significant built-up expansion during these decades. This expansion is primarily due to easy access to amenities, including transportation, education, and employment. However, this accelerated urbanization eventually led to the city's sprawling growth.

In the mean time, Kurunegala city showed the changes of urban built-up areas is a comprehensive example for urban expansion from 2000 to 2010, and 2010 to 2020. This trend indicates an increase in built-up patterns from one time to the subsequent. Approximately 1332.24 hectares were added to the built-up area between 2000 to 2010. However, from 2010 to 2020, this growth decreased to 1321.75 hectares. However, the built-up area rose by 407.34 hectares between 2010 and 2020 (see Table 3), the most rise among the selected decades. From 2000 to 2020, the built-up area grew by around 2653.99 hectares, indicating a significant built-up expansion during these decades. This expansion is primarily due to easy access to amenities, including transportation, education, and employment. However, this accelerated urbanization eventually led to the city's sprawling growth.

The Batticaloa municipality observed a rise in population of 1.0% from 2001 to 2011 and 0.9% from 2011 to 2020 (Statistic-Office, 2021). The municipality of Batticaloa in Sri Lanka expanded due to the highest population growth between 2001 and 2011, which is one of the causes of sprawling growth. Although the city's population and built-up area have expanded, the density of population growth has shown a falling trend since 2001, indicating the presence of low-density horizontal development. This is also noticed in the Indian cities of Ranchi, Patna, and Srinagar (Chettry & Surawar, 2021). However, the projected population growth rate for 2030 is between 2.5% and 3.0%. Batticaloa municipality is estimated to have a minimum population of approximately 127,291 residents in 2030, and a maximum population of approximately 170,714 residents (UDA, 2015). Therefore, sprawling development may increase in the future if the municipality is not stringent with its regulations. The policy restrictions can make the city sustainable in the future and slow the expansion of urban sprawl.

In the mean time, according to the Statistics (2011) and UDA (2019), since 1971 the population of Kurunegala has continued to expand rapidly. The population growth rate was 0.34% from 2001 to 2011, and it showed 0.31% beween 2011 and 2021. The fast population growth in the last decade of the 20th century is one of the major causes for the urban sprawl in Kurunegala. During the time, residential land use was the most prevalent. In terms of the percentage of developed land that is used for residential purposes, it is 56%, or 36.57% of the total land area. The west and south-west of the city possessed the highest overall distribution of residential usage, which is impacted by the availability of more land for residential development along with preferred facilities.

Further, arbitrary development is one of the causes of sprawling development in Batticaloa, which detracts from the aesthetic appeal of the city. This development pattern has an effect on sustainable land use and contributes to the growth of urban sprawl. This pattern has an immediate impact on the development of the city, including its services and infrastructure. Therefore, this type of development pattern in the municipality is an extreme example of urban sprawl. In addition, Undeveloped area, particularly in periurban areas, has fewer buildings and a lower population density. The areas of Panichalady, Kokkuvil, Thiraimadu, Navalady, and Paalameenmadu, for instance, contain numerous vacant lots that contribute to urban sprawl. Undeveloped terrain and limited access to utilities such as water, electricity, and public transportation contribute to poor population growth in these regions. Although the majority of the houses are small, consisting of one- or two-bedroom brick or clay buildings, the majority of the land utilised for their residences is three or four times the size of the houses. Low-income individuals occupy the majority of the land in these places, resulting in sprawling development. In addition, people's desires and preferences expand the houses with large land in these places, for example, Puliyanthivu, Arasady, Thandavanveli, and Kottamunai.

The families living in the city are largely nuclear families, with gradually more single or solitary residences. The absence of large families in the metropolis contributes to a rise in sprawling construction. Therefore, residents must adjust to extended family living in low-rise or high-rise buildings. Similarly, the municipality should consider incorporating this technique into its policy laws in order to make the city more compact and limit future sprawling growth.

On the other hand, being an inter connective town and nationwide provider for some renowned services in Sri Lanka (Eg: Foreign employment, Spare parts) had generated the demand for buildup land, which has been a major influencing force for urban sprawl in Kurunegala city. According to Kurunegala (UDA, 2019), over 100,000 people visit the Town on weekends for tuition, out of the 5/6 school student population comes from outside the town. In the meantime, individuals from nearly every region of Sri Lanka secure the services from reputed foreign employment agencies. The majority of commercial expansion has occurred along roadways and byways. Even though the city's commercial land usage is obvious, it is done so in a concentrated manner using ribbon development. Even if there is an increase in the conversion of residential land use into commercial land, it is not being centralized, owing to the presence of state-owned land. The construction of homes along the major roadways results from the suppression of cluster commercial growth.

In addition, Kurunegala, being the primary administrative center under British Rule, 10% of the town's total commercial area has been set aside for uses like schools and government buildings. Due to the presence of single-story structures there, it has been determined that lands with higher economic value have not been productively utilized. Further, approximately 90% of the slots in the triangle-shaped area of the CBD bounded by Main Street, Parakumba Street, and Bodhiraja Mawatha have mostly 2 to 3 perches or fewer than 6 perches. There are commercial buildings in the form of 3 to 4 storeys where only the ground floor can be utilized to its full potential.

Urban sprawl is the homogenous and the less mixed land use pattern in the city (Galster et al., 2001), which exacerbates sprawling growth, particularly in the areas of Thiraimadu, Panichalady, Iruthayapuram, Mamangam, and Koolavadi. These patterns of growth have an impact on residents who should travel long distances to access services. According to Amarawickrama et al. (2015), this inefficient land use is a result of the Sri Lankan tradition of associating one's home with land. In addition, the cost of land and building a house in urban core areas such as Puliyanthivu, Thandavanvely, Arasady, Koddamunai, Bharathipuram, Thamaraikeny, and Kallady forces citizens to settle in urban fringe areas such as Thirupperunthurai, Thiraimadu, Palameenmadu, Kokkuvil, and Saththurukkondan in order to pay an own home. This increase in housing in these fringe locations is indicative of the city's extensive housing expansion. It indicates that individual homeownership contributes to the urban sprawl of Batticaloa. This finding is comparable to that of Antalyn and Weerasinghe (2020) in Colombo, Sri Lanka.

On the other hand, according to Manesha et al. (2021), Patch Density and Edge Density have risen in Kurunegala towns between 2001 and 2012. The significant urban spread and irregular creation of isolated urban areas are reflected in such large increases. This pattern could be clearly seen in areas like Wilgoda, Polaththapitiya, Wew Gala, Gettuwana, and Dambulla Road. Majority of the population of these areas belongs to laborers who work for daily wages in the city. Although the population density is higher in these areas, the privileges for a healthy living are lacking in these areas. Nearly 500 families living in these areas lack pipe borne water. The settlements are poor, without basic facilities for a living.

Moreover, these areas are subjected to urban flooding at least once per year. However, there are peri urban areas with low population density and fewer buildings, which can be seen around areas like Theliyagonna, Mallawapitiya, and Muththettugala. There are nuclear families residing in these houses, and the surrounding land along with the house are minimum twice higher. If the municipality considers land subdivisions in future in its policy laws, it would be an efficient way of managing urban sprawl. In the meantime, there are developable lands around the town area. It is estimated that 5748.11 hectares of land (UDA, 2019) has been found around Kurunegala Local Government administrative area. The majority of the coconut lands in Kurunegala's northern region are infertile, however, there is possibility to partition those lands for residential use.

Furthermore, Amarawickrama et al. (2015) noted that individual preferences in developing nations, such as Sri Lanka, are the leading cause of urban sprawl. Instead, peripheral urban expansion happened as a result of pollution and high population density in urban areas, which prompted middle-class migration to urban margins in developed nations. The comparison reveals that this growth pattern is not observed in the municipality of Batticaloa, which is a developing city since the end of the Sri Lankan civil war. People migrate to the city from different parts of the Batticaloa district. These individuals created more built-up growth in regions such as Thiraimadu, Thirupperunthurai, Panichaldy, and Puthunagar than long-term municipal residents. The paucity of land and the high value of land, around LKR 3 to 4.5 million (1 USD = 302 LKR) per perch in the city centre, attracts people to the periphery of the municipality, where there are many lands of cheap value, ranging from LKR 100,000 to LKR200,000 (1 USD = 302 LKR) per perch. Some city-centre and suburban homeowners purchase land within the city limits for future investments or to build a new home.

In addition, after the tsunami in 2004, a number of areas, including Thiraimadu and Thirupperunthurai, were identified as having new housing developments in Batticaloa. The recent designation of the Thiraimadu area as the city's administrative district has accelerated the construction boom in recent years. Some people prefer to build their homes in this area, resulting in the progressive rise of residential structures. This population activity generates sprawling development in this region. In comparison to other locations, Thiraimadu and Navalady have low land values (about 100,000 per perch), which encourages individuals to purchase land there (UDA, 2015). These regions are frequently impacted by flood disasters, resulting in low land values (Suthakaran, Withanage, Gunawardhane, & Gunatilake, 2018). People of low and middle income can afford land in these locations to build homes. The municipality encourages the construction of residences in these protected areas. In addition, the high land value in and around the city centre, such as in the Puliyanthivu, Kallady, Thanavanveli, and Arasady areas, is the key reason for picking these areas, such as Thiraimadu and Navalady, to build the homes. Thus, these places were selected as having less urban sprawl. In addition, areas such as Puliyanthivu, Kallady, Thandavanveli, and Arasady are primarily served by banks, hospitals, commercial facilities, and other infrastructure amenities, and are linked by highways, which greatly contributes to the low sprawl. This rapid growth has altered the built-up patterns of the municipality of Batticaloa.

Compared to the core town area, the peripheral areas have not been developed with services in Kurunegala. The areas included, Wellawa, Maspotha, Mathawa, Kiriwawla, are good examples for this. In order to enjoy the privileges of urban life, people settle in fringe areas where the cost of land and possibilities to establish settlements are favored for their economic status.

People are drawn to the municipality's periphery, where there are numerous lands of inexpensive value, ranging from LKR 50,000 to LKR 75,000 per perch, due to the municipality's lack of land and the high value of land, which is around LKR 3 to 5 million per perch in the city center. This is a factor contributing to the urban sprawl of Kurunegala. To ensure the smooth functioning of the CBD and to extend the development to outside places, the forthcoming developments should be introduced to periphery areas. Here aims to lessen the burden in central town areas by transferring that demand to outlying places and luring developments. A good zoning plan for sustainable development is also to be introduced here.

In addition, several divisions, such as Sinna Oorani and Nochchimunai, have conflicts with landowners associated with the local communities in the municipality of Batticaloa. The Punnaicholai, Kallady Uppodai, Mamangam, Puliyanthivu South, Karuvappankeny, Kokkuvil, and Amirthakali regions were also noted as having landlord issues connected to low-income individuals. These factors are responsible for the subdivision and abandonment of land in the municipality. Landowners illegally subdivide low-value areas, such as Uppukarachi and Saththurukondan, for sale purposes (UDA, 2015). This illegal property subdivision produces a low-density sprawl. Consequently, the municipality should create a prior approval system that is distributed to all inhabitants. Therefore, residents can obtain municipal approval prior to subdividing their land. Once the municipality has granted the application, residents can divide the land for sale or other uses; otherwise, they cannot. This technique can decrease future sprawling growth by reducing illegal land subdivisions and land disputes with local communities.

4. CONCLUSION

Increasing urban sprawl is a result of the Batticaloa and Kurunegala municipality's rapid built-up expansion, which is driven primarily by residential development. From 2000 to 2020, the built-up area grew gradually. Consequently, using Shannon's entropy model, urban sprawl was detected for the years 2000, 2010, and 2020, confirming that a pattern of high sprawl growth has been observed since 2000. The year 2020 was regarded as having the greatest built-up expansion among the studied time periods, whereas this year demonstrated the largest sprawl among the study years. Thus, it was established that urban sprawl had spread over the entire municipality without becoming more compact.

The housing policies of the city can be created with the input of residents and housing professionals. These opinions can provide a good picture of the income levels and preferences of the various populations in this city. The reactions of the inhabitants are vital to the proper implementation of the policy; thus, the decisions should then be displayed. When people's thoughts are incorporated into these conclusions, the policy can become immediately recognisable and adaptable without difficulty. Thus, the residents may be noted for the quality of their home construction. In addition, they can make prudent selections while constructing a home or keeping a plot of land, amongst other activities. Further, the National Housing Development Authority of Sri Lanka should offer more new housing programmes for low-income residents. Additionally, the municipality encourages developers to construct high-rise buildings. These actions can reduce sprawling development at the city's edge. Also, the municipality should conduct programmes to educate the public about the implications of sprawling urban development. Residents' comprehension of this growth can limit sprawling growth and bring a future sustainable municipality.

Further, building types and locations can be defined while a building code is provided for every residential and commercial building in the municipalities. This coding system can be used to identify a specific building in the event of construction issues. It implies that some structures may be constructed illegally or contrary to municipal norms. Furthermore, the municipality should establish a monitoring unit to ensure compliance with housing policy, building laws, and construction strategies. Simultaneously, the municipality should provide an online forum for residents to debate or interact with the municipality over future building construction. Therefore, this surveillance system can aid in limiting both municipality's sprawling growth.

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