Spatiotemporal changes of green cover pattern in urban areas of Batticaloa, Sri Lanka

M Seevarethnam[1,2], V Selvanayagam[1] and N Rusli[3]

[1]Department of Geography, Faculty of Arts and Culture, Eastern University, Sri Lanka, Vantharumoolai, 30350, Sri Lanka
[2]Department of Urban and Regional Planning, Faculty of Built Environment and Surveying, Universiti Teknologi Malaysia, 81310 Johor Bahru, Malaysia
[3]Centre for Innovative Planning and Development (CIPD), Faculty of Built Environment and Surveying, Universiti Teknologi Malaysia, 81310 Johor Bahru, Malaysia

Corresponding author: mathanrajs@esn.ac.lk

Abstract. Sri Lanka's cities are subject to varying green cover patterns due to rapid population growth in urban areas. Over the last two decades, urbanization has driven the rampant development of built-up areas, predominantly residential development. As a developing city in Sri Lanka, Batticaloa involves rapid construction development after the civil war. This trend increases pressure on green cover, making the city population more susceptible to urban challenges. This study investigates the spatial and temporal dynamics of green cover changes in selected urban areas in Batticaloa, Sri Lanka, from 2000 to 2020. Three (3) nearby areas were selected for the study, namely Kallady, Arayamapthy, and Kattankudy. ArcGIS Normalized Difference Vegetation Index (NDVI) analysis was used to identify the green cover pattern and changes using Landsat Images. The changing patterns were detected between 2000 - 2010 and 2010 – 2020. The study reveals that the total loss of green cover was high in the first decade, approximately 44.15%, which has slightly increased about 12.58% in the second decade of the selected years. The Kattankudy zone shows a high built-up density, while the Arayampathy zone is low. This pattern has led to the further loss of green cover in the Kattankudy zone, while the other two (2) zones are significantly mixed with the green cover. A significant proportion of the green cover is occupied by the newly built-up areas, mainly residential areas throughout the period. Thus, the green cover conservation should prioritize the built-up expansion to protect the environment. The residential green cover is essential for humans' daily lives, and one of the most vital mechanisms in the urban green cover system cannot be ignored. This finding can contribute to the land use planning application and make policies to conserve the green cover in the future.

1. Introduction

Urban green areas are subject to various changes over time in the world. Green cover is considered an essential element of the ecosystem, but urbanization constraints on green spaces within cities and continues to affect them [1]. Green areas are a crucial component of the urban ecosystem with essential ecological functions [2] and benefit the environment and urban dwellers. Urban green spaces play a crucial role in maintaining the balance between the natural and built environment [3] which maintain a healthy environment in urban areas and support sustainable livelihoods. Thus, the green cover conservation is potential for the ecological connection and function of the urban area associated with the residential green cover [4]. Further, the role of urban green cover is becoming an increasingly important area, as the number of environmental problems is caused by rapid urbanization around the world [2]. Urbanization has transformed the natural landscape into a man-made structure, which has been a noteworthy feature in the last five decades [5].

Cities have diverse socio-economic opportunities that attract people like a magnet [6], who flock more to the cities in developed and developing countries. The world's urban population has grown from 751 million in 1950 to 4.2 billion in 2018 [7], with an estimate of approximately 55% of the world's population lives in cities [8]. According to the United Nations, the world's urban population is expected to almost double by 2050 [7]. The projected growth of the urban population will further affect the sustainability of green cover in urban areas of the world's cities. This trend often represents the evolution of developing countries. The rapid decline of urban green cover has been exposed in Asian developing countries, Vietnam, Pakistan, and Hanoi [9]. Developed countries are already exposed to high levels of urbanization, and much of the rapid urban growth took place over a hundred years ago. Many European countries [10], Australia, and New Zealand are the well-established processes for defining the ecological regions and mapping these zones.

On the other hand, modern urbanization is a predominant phenomenon in developing countries, mainly centred in Asia [11]. The South Asian region is the most vulnerable region to the challenges posed by the rapidly growing urban population. The urban population of South Asia is expected to double over the next two decades as the population of this region is expected to peak in this century [7]. Further, 250 million additional people are expected to live in the South Asian region over the next 15 years [12]. In this context, South Asian countries that have already lagged in development with unique socioeconomic and cultural characteristics are at greater risk.

Sri Lanka has been characterized as one of the countries in South Asia with the lowest urbanization rate, although it has several fastest-growing cities. The annual urban expansion rate in Sri Lanka is estimated at 6.42%, and the growth rate is higher than in India (4.84%), the USA (3.31%), Europe (2.5%), and Africa (4.32%) [13]. In addition, according to worldwide urbanization projections, Sri Lanka's urban population will reach 31.6 percent by 2050 [7]. The structural transformation of Sri Lanka's economy from a long-standing rural economy to a product-oriented, urban-based economy has a greater impact on this [14].

Sri Lanka's urban centres are expanding faster as the population grows. Consequently, urban areas are forced to expand rapidly, resulting in the development of new suburban areas. In certain urban areas in Sri Lanka, urban growth has resulted in a significant loss of green cover. Rapid population growth has caused pressure on agricultural land that has been converted into industrial and residential land [15]. It brings a profoundly detrimental ecological and socio-economic impact on the city [1]. Saparamadu et al. [15] found that inadequate urban planning and regulations caused a measurable decline in agricultural land and wetlands in Colombo city. The loss of ecosystem services has become a significant environmental effect of diminishing green cover. Urban green cover and city dwellers are at risk due to the development activities that have drawn the attention in the urban research arena.

Though several studies have been conducted using various methods to estimate the changes in green cover in Sri Lankan urban areas, most of these studies have been conducted in urban areas in the western province, where cities are relatively developed. However, urban areas in the Eastern Province have been studied less on the green cover changes with time and space, which is significant to conduct this study in Batticaloa. The Civil War has impacted the region for nearly three decades, forcing it to lag in the development context. Over the post-war period, physical development takes place in the region has led to a wide range of changes, particularly in land use and green cover. Thus, many urban areas, in and around, have been transformed into built-up areas. Simultaneously, residential developments are expanding in an uncontrolled manner in recent years. Thus, growing population, residential development, and other development activities in this area pose a threat to environmentally sensitive areas, such as wetlands, coastal and lagoon areas.

Moreover, the district is more prone to hydro-meteorological and geophysical hazards due to its location and other environmental factors, negatively impacting green cover. In particular, Batticaloa, being a dry zone district, prolonged droughts cause impacts on the green cover directly and indirectly. Thus, maintaining vegetation with urban development has become mandatory to cope with drought risk with minimal effects. Thus, mapping the changes and quantifying the existing green area is imperative need from the management perspective.

According to the National Physical Planning Policy and Plan - 2050, Batticaloa is expected to develop as a metropolitan region with a population of 300,000 [16]. In this context, it is essential to assess the existing green cover, value, changes, and untapped potential of green cover in this area. Moreover, modern remote sensing technology has also provided a platform to quantify the spatiotemporal patterns of urban green cover. Thus, understanding the changing pattern of the green cover in recent decades is imperative for green cover management to achieve a status of sustainable and resilient city. Therefore, this study investigates the spatiotemporal dynamics of green cover changes in Batticaloa urban areas, Sri Lanka, from 2000 to 2020.

2. Materials and Method

2.1 Description of Study Area

Batticaloa is located in the Eastern Province of Sri Lanka, which is surrounded by inland water, sea, and land. The boundaries of this area are the Kallady Bridge in the northern part, the Bay of Bengal in the eastern part, Thalankudah in the southern part, and the western part bounded by the Batticaloa lagoon. It belongs to three Divisional Secretariat Divisions (DSD) as Manmunai North (Kallady), ManmunaiPattu (Arayamapthy), and Kattankudy. Similarly, it belongs to three local authorities that are part of the Batticaloa Municipal Council area in the north; the middle part indicates the Kattankudy Urban Council and the southern part belongs to Arayampathy Pradesiya Sabha.

Batticaloa and Kattankudy are large commercial cities in the east, consisting of 24,707 and 47,125 people, respectively. High population density is a key feature of the town of Kattankudy. This area's total extent is approximately 2,579.67 hectares. The study area belongs to the dry zone, and the temperature varies between 25ºC and 36ºC. The mean annual rainfall in the study area is 1200 mm and ranges from 864mm to 3081mm [17]. The area is almost flat and is enriched by lagoon systems, coastal and related landforms. The land is utilized for various purposes linked to different sectors such as commercial, small industries, agriculture, and fishing. Each area has a cluster of development in all sectors, such as residential, commercial, and leisure activities. The most important land use in this area is residential, and the next is commercial land use. One of the low extents of the land-use class is agriculture compared to other major land uses. Moreover, this area consists of several natural lands, including water bodies, wetlands, and scrublands at a smaller proportion. Thus, it is more significant to understand the green cover changes in this area for selected years.

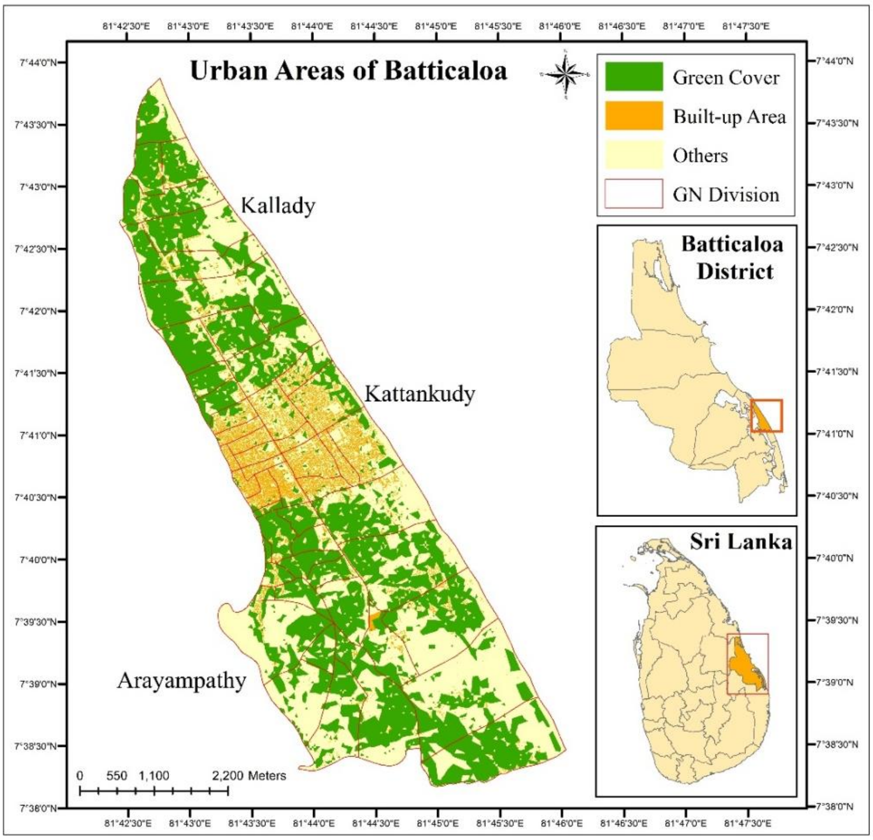

Figure 1. The Study Area – Batticaloa Urban Area.

2.2 Data Collection – Source of Data

The data for this study were mainly derived from maps and other secondary and primary data sources. Direct observation and key informant interviews were accommodated to obtain the primary data. Key informant interviews have been conducted with land use and urban planning officials of the Batticaloa district. Local people (5) were also interviewed to understand the causes and critical changes in the past on green cover. Direct observation has been done to gather information about the existing green cover and land use pattern. Secondary information was gathered from Batticaloa District Secretariat, Satellite images, and web collections of the related documents. The satellite images such as Landsat ETM+ (28-SEP-2000), Landsat TM (24-SEP-2010), and Landsat 8 (03-MAR-2020), which are 30m resolution, were downloaded from Earth Explorer, United States Geological Survey that utilized to produce the green cover maps.

2.3 Data Analysis

Landsat images for 2000, 2010, and 2020 were geo-referenced and projected to the Kandawala coordinate system, Sri Lanka. Image enhancement tools such as sharpen, blur, and smoothing were used to improve the quality of the images. The demarcation of the Batticaloa urban area was digitized as a shapefile using the existing Divisional Secretariats division map. This Divisional Secretariats division map was used to clip the satellite images to the study area.

The integration of several greening indicators is applied in many city models. The most common indicators, such as the green cover area and green cover ratio were used to evaluate the spatial distribution of green cover. Normalized Difference Vegetation Index (NDVI) was calculated to get the green cover area [18]. The NDVI classification method is commonly used to extract the green cover pattern from the satellite images. The green cover for the Batticaloa urban area was derived for 2000, 2010, and 2020 to understand the spatial pattern and the temporal changes using ArcGIS 10.6.1.

NDVI depends on the chlorophyll content of plants, which is simplified to observe the vegetation changes. Vegetation strongly absorbs sunlight's red wavelength and reflects the near-infrared wavelength, which differs from the other surface elements. The Spatial distribution of vegetation density and the condition of plant growth are indicated using this analysis. It is a measure of different reflection between the wavelength ranges; values lie between -0.1 and +0.1. The higher values (0.5) show a greater, greener cover area [9], and the lower values (< 0) indicate no vegetation cover. NDVI index is calculated as (see Formula 1):

$$NDVI = (NIR - R) / (NIR + R) \tag{1}$$

Where *NIR* denotes the reflectivity value of the near-infrared band, and *R* mentions the reflectivity value of the red band [18, 19]. Further, the green cover ratio (GCR) illustrates the percentage of all green cover in the study area as a percentage of total land area, and the green cover ratio is calculated as (see Formula 2):

$$GCR = S_{Green\ area} / S_{Land\ area} \tag{2}$$

Where *GCR* is the ratio of green cover, $S_{\text{Green area}}$ is the area of green spaces, and $S_{\text{Land area}}$ is the total land area of the selected zone [9, 20]. Buildings in the Batticaloa urban area were digitized using Google Earth Pro in 2020, which was downloaded as a .kml file and converted to a layer file in ArcGIS. After converting the layer to a feature file, each building feature was converted into points using the feature-to-point tool. Point density analysis was employed to generate the built-up density. Based on the Jenks natural breaks method, the density is categorized into five (5) classes: very high, high, moderate, low, and very low. The built-up density changes in the study area were recognized using the developed map.

3. Results and Discussion

The ecological sustainability of an urban area is measured based on the green space[1], which has played an essential role in the quality of life and health. The increase of urban development has concerned the studies of the spatiotemporal dynamics of green cover [9]. Monitoring green cover in this area is vital because rapid economic growth and building constructions diminish the green cover.

3.1 Green Cover Pattern in Batticaloa

Figure 2 illustrates the green coverage pattern of the Batticaloa urban area for the years 2000, 2010, and 2020. The total green area in 2000 was 1485.34 hectares, which was diminished to 1030.40 hectares in 2010. The amount in 2020 is 1178.72 hectares, which is slightly increased from 2010. The reduction of green space led to a corresponding decline in vegetation cover. Thus, a vegetation restoration process implemented in the coastal and riverbank areas by the government and non-governmental organizations after the tsunami and flooding disasters and that is one of the reasons for the green cover growth after 2010. During these periods, the rapid development of building construction increases the decline of green cover in many areas such as Kattankudy, Kallady, and Arayampathy. This finding is parallel to Chen et al. [2] in Shanghai, China. Accordingly, rapid urbanisation and human activities on the land mainly affect the vegetation cover, including Batticaloa.

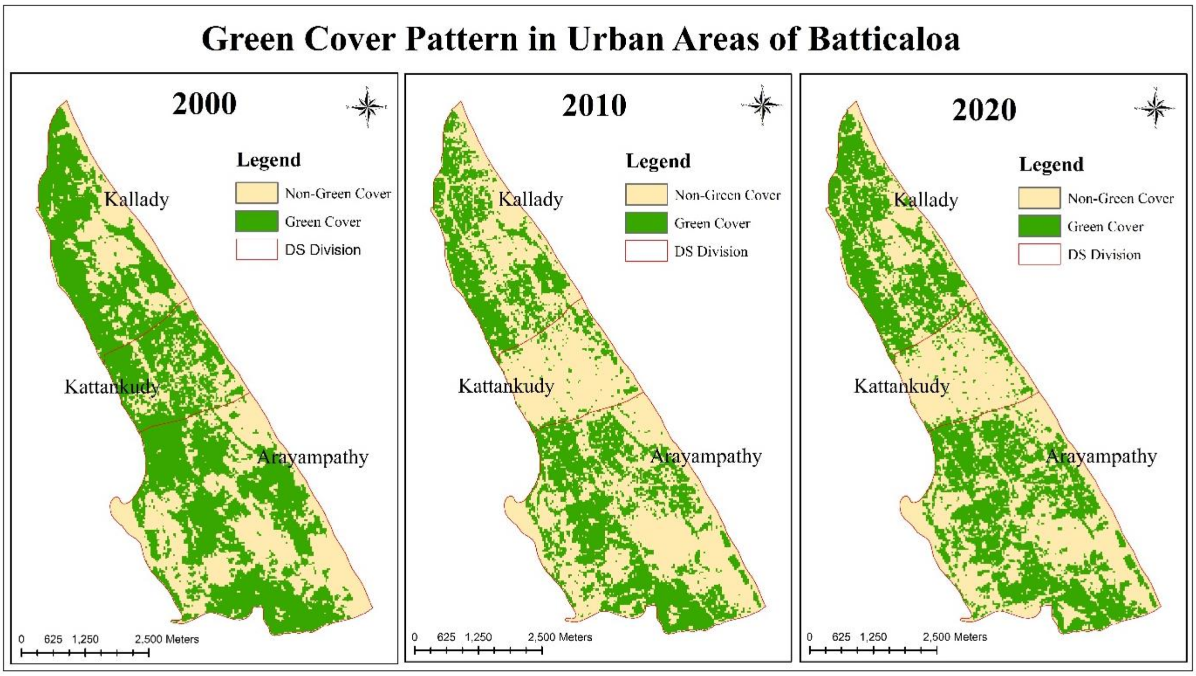

Figure 2. The green cover pattern in Batticaloa urban area from 2000 to 2020

The overall green cover ratios show a variation of 57.58% in 2000, 39.94% in 2010, and 45.69% in 2020, which is the percentage of green cover in the total land area. Figure 3(b) illustrates the green cover ratio by three zones as Kallady, Kattankudy, and Arayampathy. The Kallady zone displays a gradual increase of 30.21% in 2000, 34.12% in 2010, and 36.44% in 2020, while the Kattankudy zone illustrates a drastic decline of 18.36% in 2000, 4.73% in 2010, and 4.63% in 2020 in the total green cover area. Nonetheless, the Arayampathy zone indicates a fluctuation of green cover change at 51.43% in 2000, 61.15% in 2010, and 58.93% in 2020. The comparison revealed that Kallady and Arayamapthy zones display minimum green cover changes, but the Kattankudy zone loses a significant area of green cover. Thus, this zone made a considerable change in the overall green cover patterns of the study area. Kattankudy is an emerging town in Batticaloa with commercial and small industries, which has affected the green cover pattern due to the rapid construction development. Increasing needs for commercial land, residential property, and transportation land have led to the conversion of more and more green cover areas and farmed land into construction land. This finding is consistent with Deng et al. [21] in Hangzhou city, China.

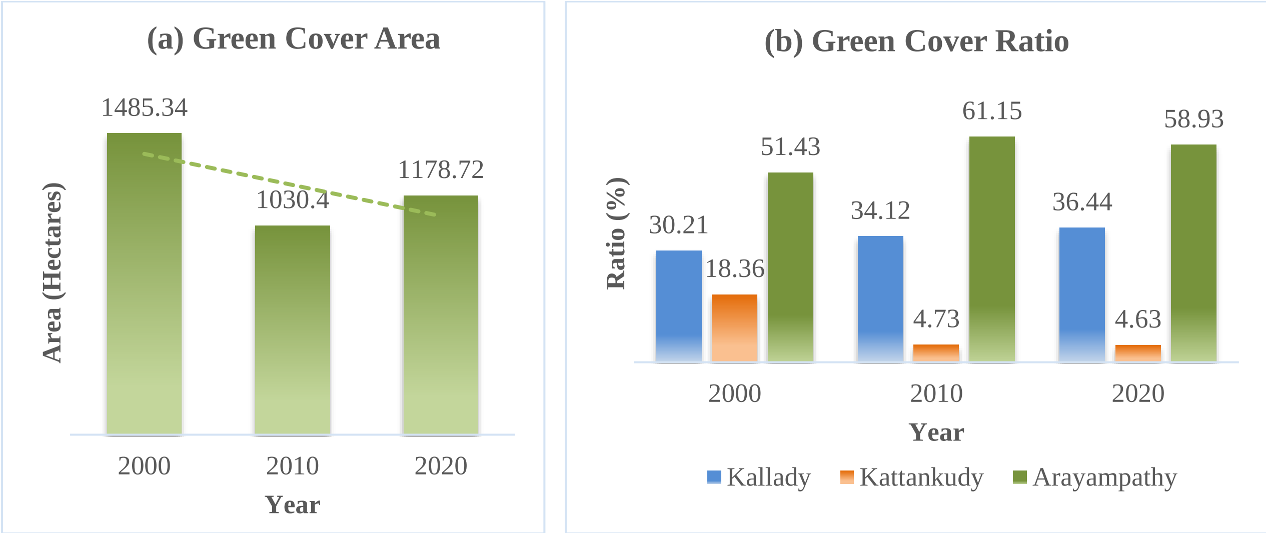

Figure 3. (a) Green cover area, **(b)** Green cover ratio in Batticaloa Urban area from 2000 - 2020

3.2 Built-up Density in Batticaloa Urban Area

The built-up growth in the urban area varies in each place. The density was achieved in five categories, showing a significant variation between the zones. The built-up map (see Figure 4) presents the density with the DS Division zones, Kallady, Kattankudy, and Arayampathy. Kallady zone shows below the moderate density level, while the Kattankudy zone shows above the moderate density level. The Arayampathy area displays below the low level of density. It means that the Arayampathy area has a high level of green cover compared to those other areas such as Kattankudy and Kallady.

Table 1. The range of built-up density in Batticaloa Urban Area

Built-up	**Range**
Very Low	0 - 15,222,299.2
Low	15,222,299.21 - 30,444,598.4
Moderate	30,444,598.41 - 45,666,897.6
High	45,666,897.61 - 60,889,196.8
Very High	60,889,196.81 - 76,111,496

Buildings occupy a high proportion of land in the Kattankudy area, and the rest is mixed up with the green cover. The built-up area enormously grew between 2000 and 2010 in the Kattankudy area. The main reason is population growth [22], 39,569 persons in 2000 increased to 48,914 persons in 2010. The population change showed a massive increase nearly 9,345 persons in a smaller area, which raised the need for predominantly residential buildings. Increasing the population density is a challenge to maintain a high level of per-capita green cover in this area. The people are interested in growing the home garden in the backyard and the terrace of their home. However, the quantity of the plant is low due to the less space at their home. Therefore, effective green cover conservation methods are essential to sustain the green cover in future.

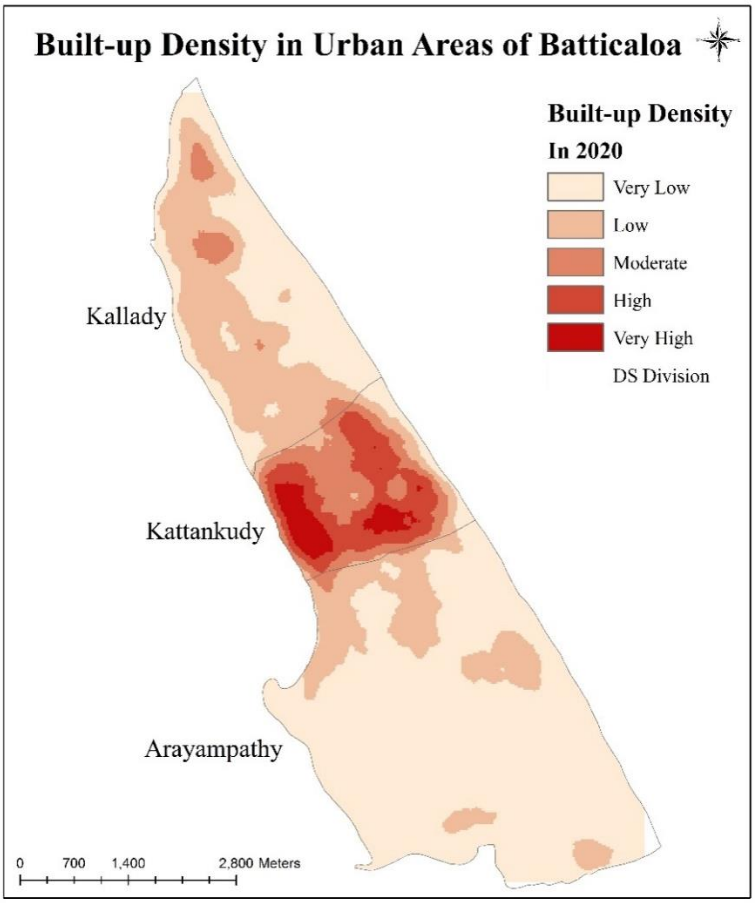

Figure 4. Built-up density in Batticaloa urban areas in 2020

As a rapidly-growing city in Sri Lanka, Batticaloa urban areas have had more population in recent decades. The population growth was 82,687 in 2002 [23], which increased to 99,456 in 2019 [17]. The internal migration from the neighbouring areas due to the civil war, education, job opportunities and standard of living are some causes for population growth. Besides, rapid urban development in post-war period increases housing schemes, highway development, minor road constructions and other infrastructure developments [24].

3.3 Green Cover Changes in Batticaloa

The change intensities between 2000 - 2010 and 2010 - 2020 were detected to understand the loss and gain of green cover (see Figure 5). The detection shows the overall decline in the green cover area around 306.62 hectares between 2000 and 2020. The green cover area declined from 1485.34 hectares in 2000 to 1178.72 hectares in 2020, indicating a 20.6 percent reduction in green cover. Between 2000 and 2010, 454.94 hectares of green cover were lost, which is a significant amount of green cover (see Table 2). However, between 2020 and 2010, the green cover area increased slightly to 148.32 hectares.

Table 2. The changes of green cover in Batticaloa urban areas

Category	Time span	Changes (+/-)
Green cover	2010 – 2000	- 454.94 Hectares
	2020 – 2010	+148.32 Hectares
	2020 - 2000	-306.62 Hectares

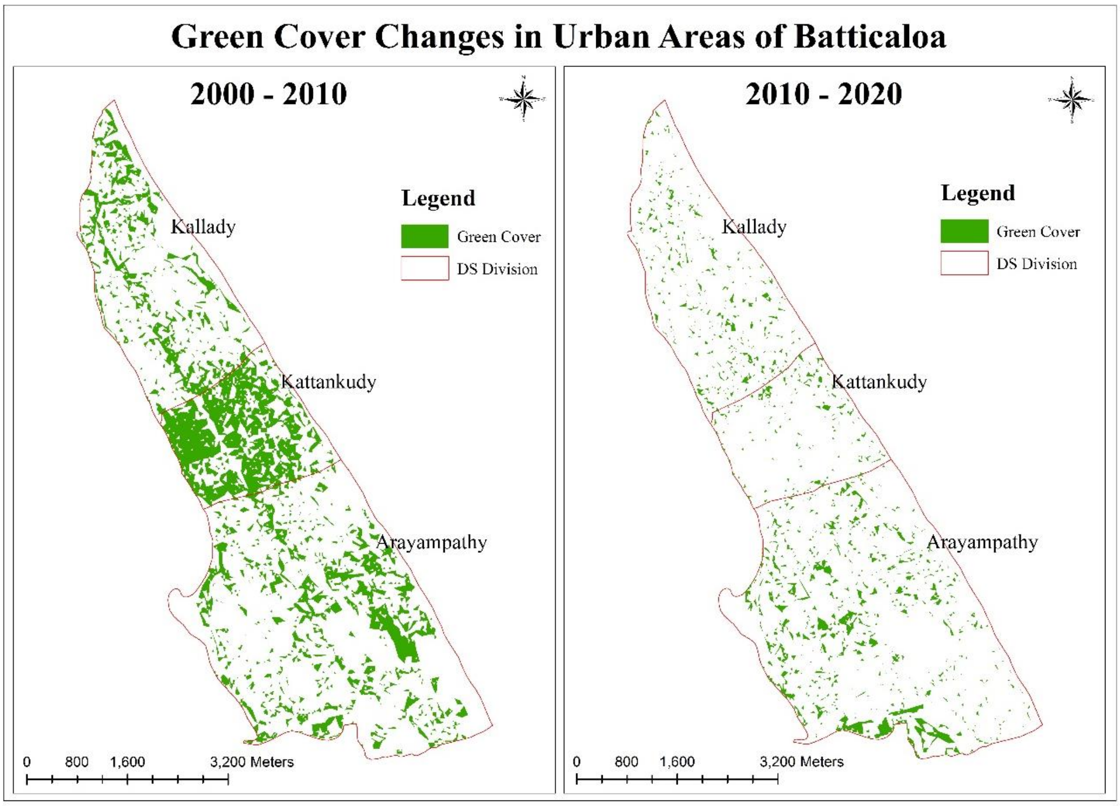

Figure 5. Green cover changes in Batticaloa urban area from 2000 - 2020

The loss of urban green cover can be attributed, in large part, to the physical development of the built-up area and the density of the town, as shown by the Figure 4 and 5. High-density urbanisation is widely acknowledged as a significant factor in changing the biosphere because of its propensity to transform natural areas into the built environment. Therefore, urban green cover can be regarded as a response to independent variables like the physical expansion of built-up areas and the densification of inner cities [25].

4. Conclusion

The NDVI analysis shows that the green cover of the Batticaloa urban area has changed significantly during the last 20 years. Compared to the year 2000, the amount of green cover in 2010 was substantially lower. However, there was a slight increase in 2020 compared to 2010, but the growth did not exceed 2000 in green cover. Moreover, the built-up growth accelerates the loss of green cover, which was observed in the Kattankudy zone between the years studied. However, the built-up development is visible in other zones, such as Kallady and Arayampathy, where the green cover is maintained rather than dwindling. The key strategies for increasing the green cover in the urban area include an urban green space management system, public participation in planning, strengthening proper development, and planning the implementation capacity. Green cover conservation should be prioritized in urban planning and management to protect the environment of the study area. On the other hand, the residential green cover has a significant impact on daily lives that cannot be neglected by urban dwellers. It becomes one of their essential mechanisms of the urban green cover system. The study demonstrates that it is critical to comprehend green cover changes, which are rapidly diminishing due to increased urbanization, and that the findings of this study can be used to mitigate potential green cover losses in this area.

The vegetation cover extracted using the NDVI method based on the satellite images, which are in a resolution of 30m not enough to categorize the green cover such as the park, garden, and street trees. This low resolution is a barrier to understanding the ecosystem's qualitative characteristics of plants; therefore, future studies should examine the loss of green cover using high-resolution satellite images, focusing on the qualitative perspective. High-resolution images provide precise land cover information that should be used in future studies affording more reliable information.

References

[1] Kong F and N Nakagoshi 2006 Spatial-temporal gradient analysis of urban green spaces in Jinan, China. *Landscape and urban Planning*, 2006. **78(3)**: p. 147-164.
[2] Chen C, N Tabssum, and Nguyen H P 2019 Study on Ancient Chu Town Urban Green Space Evolution and Ecological and Environmental Benefits. *Nature Environment & Pollution Technology*, 2019. **18**(5).
[3] Pervaiz S et al. 2019 Spatial analysis of vegetation cover in urban green space under new government agenda of clean and green Pakistan to tackle climate change. *Journal of Ecological Engineering*, 2019. **20**(4).
[4] Nor A N M and Abdullah S A2019 Developing Urban Green Space Classification System Using Multi-Criteria: The Case of Kuala Lumpur City, Malaysia. *Journal of Landscape Ecology*, 2019. **12**(1): p. 16-36.
[5] Ranagalage M et al. 2020 Spatiotemporal Variation of Urban Heat Islands for Implementing Nature-Based Solutions: A Case Study of Kurunegala, Sri Lanka. *ISPRS International Journal of Geo-Information*, 2020. **9**(7): p. 461.
[6] Fonseka H et al. 2019 Urbanization and its impacts on land surface temperature in Colombo metropolitan area, Sri Lanka, from 1988 to 2016. *Remote Sensing*, 2019. **11**(8): p. 957.
[7] UNDESA, World Urbanization Prospects 2018, in UN Department of Economic and Social Affairs: Population Dynamics. 2018.
[8] World-Bank, Urban Development. 2020, The World Bank Group: Sri Lanka.
[9] Wu Z et al. 2019 Changing urban green spaces in Shanghai: trends, drivers and policy implications. *Land Use Policy*, 2019. **87**: p. 104080.
[10] Baycan-Levent T and Nijkamp P 2009 Planning and management of urban green spaces in Europe: Comparative analysis. *Journal of Urban Planning and Development*, 2009. **135**(1): p. 1-12.
[11] Roberts B and Kanaley T 2006 Urbanization and sustainability in Asia: Case studies of good practice. 2006: Asian Development Bank.
[12] Ellis P and Roberts M 2016 Leveraging urbanization in South Asia: Managing spatial transformation for prosperity and livability. 2016: The World Bank.
[13] UN-Habitat, The State of Sri Lankan Cities 2018. 2018, Government of the Democratic Socialist Republic of Sri Lanka: Colombo.
[14] World-Bank, The World Bank in Sri Lanka. 2020, The World Bank Group: Sri Lanka.
[15] Saparamadu S, Z Yi, and Zongping Z 2018 Temporal Changes of Land Use Land Cover and Environmental Impacts: A Case Study in Colombo, Sri Lanka. *International Journal of Earth & Environmental Sciences***2018**.
[16] NPPD, National Physical Planning Policy & The Plan — 2017 - 2050, N.P.P. Department, Editor. 2019: 5th Floor, Sethsiripaya, Battaramulla, Sri Lanka.
[17] Statistic-Office, Statistical Hand Book, in Population and Housing. 2021: District Secretariat, Batticaloa, Sri Lanka.
[18] Sun C et al. 2019 Spatial pattern of urban green spaces in a long-term compact urbanization process—A case study in China. *Ecological indicators*, 2019. **96**: p. 111-119.
[19] Song Y, Chen B, and Kwan M P 2020 How does urban expansion impact people's exposure to green environments? A comparative study of 290 Chinese cities. *Journal of Cleaner Production*, 2020. **246**: p. 119018.

[20] Wickramasinghe L, Subasinghe S, and Ranwala S, Spatial and temporal changes of the green cover of Colombo city in Sri Lanka from 1956 to 2010. *Journal of Environmental Professionals Sri Lanka*, 2016. **5**(1): p. 53-66.

[21] Deng J et al. 2019 A Methodology to Monitor Urban Expansion and Green Space Change Using a Time Series of Multi-Sensor SPOT and Sentinel-2A Images. *Remote Sensing*, 2019. **11**(10): p. 1230.

[22] Sharifi A and Hosseingholizadeh M 2019 The effect of rapid population growth on urban expansion and destruction of green space in Tehran from 1972 to 2017. *Journal of the Indian Society of Remote Sensing*, 2019. **47**(6): p. 1063-1071.

[23] Statistic-Office, Statistical Hand Book, in Population and Housing. 2002: District Secretariat, Batticaloa, Sri Lanka.

[24] Seevarethnam M et al. 2021 A Geo-Spatial Analysis for Characterising Urban Sprawl Patterns in the Batticaloa Municipal Council, Sri Lanka. *Land*, 2021. **10**(6): p. 636.

[25] Girma Y et al. 2019 Urban green spaces supply in rapidly urbanizing countries: The case of Sebeta Town, Ethiopia. *Remote Sensing Applications: Society and Environment*, 2019. **13**: p. 138-149.