Detecting Land-Use Changes in Greater Kandy Development Area

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Abstract

As urban growth became a threat to Kandy city, the Urban Development Authority (UDA) has introduced a new concept called the "Greater Kandy Development Area (GKDA)" to control and manage the rapid urban growth, as well as to minimize its' impacts towards the environment. This study examines the land use/ land cover changes in GKDA, in selected time periods using GIS and Remote Sensing techniques. Findings demonstrate that dynamic patterns of urban expansion cause progressive growth in built-ups and lowering in non-built-ups. In 2005, there were only 16.9 percent of built-up areas in GKDA but, it has increased up to 40 percent in 2020. 81.7 percent of non-built-up areas in 2005, has reduced up to 58.8 percent. As population growth happened inside the city limits, land use changes also happened within. These changes create clustered as well as sprawl development patterns.

Keywords: GKDA, LULC Changes, Urban Expansion, Sprawl Development Pattern

INTRODUCTION

The world is experiencing the most rapid urbanization it has ever seen. Much of this urbanization will occur in Africa and Asia, with enormous social, economic, and environmental consequences. The future of well-being, resource efficiency, and economic prosperity could be greatly impacted by urbanization. Cities are densely populated and have a high concentration of poverty. The rise in inequality is particularly obvious in cities, where slums and informal settlements divide rich from poor areas.

For prospective migrants from rural to urban regions, Sri Lanka's cities seem unappealing, as they are in other parts of South Asia. This is largely owing to the significant progress made in creating spatial equality between rural and urban regions in terms of the availability of essential public services and, more importantly, the overall quality of life. As a consequence, the incentives for rural migrants to travel to urban areas in search of greater income are typically lower in Sri Lanka than in other South Asian countries (Elkaduwa & Samarasinghe, 2016). According to the Ellis and Roberts (2016), Sri Lanka's cities appear to be unattractive to potential migrants from rural to urban areas. Their "messy" urbanization is represented by sprawl and ribbon development patterns, with indications of rapid expansion on the outskirts of the Colombo metropolitan zone in particular, as well as along important transportation corridors. Sri Lanka's overall urban area rose at a comparable rate to the rest of South Asia, but its urban population grew at a much slower rate than the rest of South Asia as a whole.

Colombo, Sri Lanka's main city, is experiencing rapid urbanization. In recent decades, not just Colombo, but other flourishing cities like Kandy and Galle, have started to see unstoppable fast urban expansion. Kandy's land area has decreased dramatically as a result of this and the city has begun to expand beyond its original borders in recent decades. Suburbanization has thus become more prevalent in certain places as a consequence of this development. When it comes to population, economy, administration, and other services, Kandy Metropolis is Sri Lanka's second-largest city. It has been determined that the city of Kandy, in particular, should have its growth and expansion controlled.

Sri Lanka is one of five countries in the area (the others being Bangladesh, India, the Maldives, and Pakistan) whose government estimates of the urban population share are much lower than alternative estimates. This points to mostly disguised urbanization, in which huge segments of the population live in settlements that, although having urban characteristics, are controlled as rural districts (Ellis and Roberts, 2016).

Not only Colombo, but other flourishing cities such as Kandy and Galle have begun to demonstrate unstoppable rapid growth in recent decades. Following the liberalization of economic policies in the 1970s, another phenomenon that happens as a result of urbanization is suburbanization. To

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help people in cities and towns deal with the negative effects of suburbanization, the Urban Development Authority (UDA) has started a new project called "Urban Area Development."

In Sri Lanka, the present policy scenario places a strong emphasis on metropolitan regions. The Western area Megapolis project, in particular, will primarily focus on urbanization in the Western region. Besides the Western region, the continued policy emphasis intends to develop the wider Kandy Region, which extends beyond the Kandy Municipal Council's (MC) 26.8 square kilometres and 45 Grama Niladari Divisions (GND) to almost 210 square kilometres. (Elkaduwa and Samarasinghe, 2016).

Under the UDA Law, No. 41 of 1978, the Kandy Municipality area was declared an urban development area through Extraordinary Gazette No. 26/8 of March 7, 1979, on Section 3 (1) of Section No. 8 (a) of Amendment Act No. 04 of 1982. (2019-2030 Development Plan for Kandy) Kandy is the capital of Sri Lanka's Central Province and, after the Colombo Metropolitan Area, the country's second-largest city (UDA, Central Provincial Office, 2019).

This plan caused the acceleration of the suburbanization trend in the Kandy city area and a shift in land usage in the surrounding region. The rapid expansion of built-up regions, in particular, was made possible by diverting attention away from non-built-up areas and water bodies. The primary goal of this strategy was to keep the urban sprawl inside the city limits under control by extending the growth process out into the neighbouring regions as much as possible. However, this strategy was unable to halt the expansion of Kandy city's population. Kandy city is beginning to expand beyond its physical boundaries, establishing itself as Sri Lanka's first truly unbounded metropolis.

As the last capital of the ancient monarch's reign, Kandy is well-known as a sacred Buddhist site because of the temple of the Tooth Relic. Kandy has a lot of potential in terms of financial, social, and cultural development. However, recent improper, unplanned construction has resulted in overcrowding, excessive traffic congestion, and urbanisation, pushing this ancient heritage area's historic cultural area into disaster-prone regions. This historic heritage region's townscape has not been properly protected or repaired, reducing its value and appeal and preventing the area from fulfilling its full economic potential. A project called GKUP, which means "Greater Kandy Urban Plan," has been asked to be carried out by the Japanese government. It includes a review of the Kandy Metropolitan Area's urban development vision and a plan for the Heritage Area, which includes a plan for the whole area.

Kandy is one of the most distinctive cities in Sri Lanka for several reasons. One of the primary causes is the terrain's complexity. Kandy is shaped like a triangle basin and is in the central highlands of the country. The city is situated between several mountain ranges, including the Knuckles, Bahirawa Kanda, and Hanthana mountain ranges. The Udawatta-Kale sanctuary is in the south of Kandy city. The city's ability to expand is limited because of this complicated topography.

Kandy's cultural and religious values are another prominent feature. Kandy, the last capital of Sinhala kings, is known as Sri Lanka's cultural capital because of its strong cultural worth. Kandy is important because of the combination of Sinhala and Tamil cultures. Kandy was designated a World Heritage Site in 1988 because of its cultural and historical significance. Monetary worth is another feature. Kandy is the second-largest city located outside the Colombo Metropolitan Area. As the capital of the central province and the Kandy district, there are numerous significant enterprises. It mainly includes industries like apparel, gemstones, furniture, as well as jewellery. Also, there are several agriculture research centres nearby.

Kandy is the only colonial city that keeps its indigenous traits. Sena Sammatha Wickramabahu picked Kandy as his kingdom in 1473-1511 (Peiris, 2019). It became the capital of the Sinhalese monarchs in 1592, and they maintained their independence throughout European colonial rule except for brief Portuguese and Dutch occupations until 1815 when the British Removed Sri Wikrama Rajasingha. The Colonial era began with the insuring agreement in 1815, which was known as the Kandyan Convention. After a 150-year British ruling period, Sri Lanka became an independent nation in 1948. So, Kandy city can be called the only city in Sri Lanka that has all of the original, colonial, and post-independence Characteristics.

In recent decades, the suburbanization process has become dominant in this area. Because of the above discussed environmental barriers and historical value, the land extent of Kandy has become miniscule and, therefore, the city has grown outside its boundary. Conversely, Kandy, in particular, has been nominated as a city whose development and expansion should be regulated. Therefore, UDA introduced a concept called the Greater Kandy Development Area (GKDA) to manage and facilitate it. As a new concept and proposed concept, no proper study has been done on this topic.

Not only Kandy, but the Greater Kandy Area is also a highly environmentally sensitive area. So, as developed countries do, there is a special need for proper monitoring of the physical growth of urban areas in this area. If urban growth happens in this environmentally sensitive area, several problems can occur. But there hasn't been a proper study done before to keep track of and predict the growth of cities in this area. Therefore, the main objective of this study is to identify the spatiotemporal growth pattern of urban expansion in the GKDA.

LITERATURE REVIEW

The growth of major cities and their growing spatial effects indicate a random or organised movement of people from wide rural regions to mostly urban areas. Over the previous two centuries, this has occurred in almost every nation on the globe. This rapid and challenging process of urbanization results in the physical extension of the city spilling over into the surrounding territories, a phenomenon referred to as "urban growth." These spatial changes are only noticeable over a lengthy period, while the accompanying physical processes exhibit continuous spatial changes over time. As a consequence, urbanisation may be seen as a spatial-temporal phenomenon. Often, urban growth is uncontrolled

and dispersed, impeding long-term development (Weerakoon, 2017). They are:

1. Initial stage
2. Acceleration Stage
3. Mature Phase

There is a centrepiece for economic activity in each city; the Central Business District (CBD). Pettah, for example, is Colombo's CBD. During the day, this area is usually rather packed. However, it is not crowded or packed at night. Due to the high cost of land, this neighbourhood has less residential activity. On the other hand, it serves as the city's centre point. It is the city's business, office, and rental hub. It also serves as a hub for transportation networks. More employment is created in this region as a result of the economic activity in the CBD. Rural-urban migration occurs in this area to meet the labour shortage. Middle-class residents concentrate in the CBD's outskirts while low-income people construct their homes within city limits. Most of the time, these are just ordinary dwellings. Similarly, rural-urban migrations are important during the start of a city's development. The population density is steadily decreasing from the city centre to the city limit, where it is concentrated. The population of a city grows in lockstep with the expansion of the city, due to three causes:

1. Natural increase which happens inside a city.
2. Increasing migration due to rural-urban migration.
3. Urban expansion which happens due to expanding city boundaries.

Urban development happens when these three variables increase. Urban expansion is a rapid process in the early stages. However, at some point, the rate of expansion decreases. Environmental pollution, transportation congestion, and rising property prices are all factors that contribute to a reduction in rural-urban migration. As a result, migration from metropolitan areas to the suburbs is on the rise. People who relocate from cities begin to dwell in the suburbs. At this stage, the suburbanisation process occurs.

In general, the explanatory variables of urban growth are examined when studying urban expansion trends. Previous research has indicated that socioeconomic factors such as population and economics influence urban growth. Due to a lack of data in most situations, a qualitative approach was used to define those guiding aspects where a quantitative analysis would be more helpful.

Furthermore, not just economic considerations, but also physical elements such as elevation and proximity factors such as distance to a river or water, as well as access to important roadways, impact urban growth. According to Dissanayaka et al., (2019) when compared to other places, the Impervious Surface (IS) expanded toward the north in 2006 and 2017. Results of their study showed that IS areas expanded from 529 to 1514 ha (2.3% to 6.7% of the total land area) between 1996 and 2006, and to 5833 ha (23.9% of the total land area) in 2017, with an annual growth rate of 11.1% per year from 1996 to 2006 and 12.2% per year from 2006 to 2017. Forest cover showed a clear downward trend from 1996 to 2006, with an annual change rate of 1.6% from 1996 to 2006 and 1.8% from 2006 to 2017. During the study period, the total decrease rate was 1.7%. IS absorbed the majority of the decreased forest cover. The cropland area fluctuated between the three time-points. It increased from 5570.8 to 6486.3 ha (or 1.5% per year) from 1996 to 2006, but then decreased to 5372.6 ha in 2017, giving an average rate of change of −0.2% per year from 1996 to 2017.

As Dissanayaka (2020) explained, in the past two decades, Kandy city has experienced a substantial built-up area increase, resulting in spatiotemporal variations in the built-up area (BUA). Its size has been raised to 528.4 hectares (2.3%). For 1996, 2006, and 2017, respectively, 1513 ha (6.7%), 5377.5 ha (23.9%), and 1513 ha (6.7%). In 1996, there was a greater concentration of built-up areas in the city centre. Later, it grew north and southwest along the road, except the southern section. The mountain ranges may act as a deterrent to growth in the southern area. A linear growth trend was seen during the 14-year observation period. In 2017, a more developed pattern was also displayed.

Also, Dissanayaka (2020) had mentioned that, Kandy city has three major urban flows that flow along with three major transportation networks: Kandy-Jaffna, Kandy-Colombo, and Kandy-Mahiyanganaya. The urban flow pattern is based on the Kandy urbanization process and stresses the linear dispersion of built-up regions. A major urban form was discovered to emerge around the Katugastota growth node (D1), and it appears to be improving in the future. There is also the potential of converting Kandy city from single-core to multi-core in the future.

In 2015, Masakorala and Dayawansa generated land-use maps for 1976, 1992, 2001, and 2011 using 5 land-use classes. Those maps clearly show that the forest cover, and paddy fields in the study region demonstrate a progressive decline and there is a clear rise in built-up areas and homesteads. However, according to their study, after water bodies have expanded in size as a result of seasonal changes when they should be decreased. According to their findings, previously, Kandy's built-up area was limited to Kotugodella, the city's core. Then it extended south-west and north-east along the Peradeniya-Kandy and Kandy-Katugastota routes, respectively. The initial wave of urban expansion happened in the southwest, while subsequent phases occurred in the northeast. The radius has grown to eight kilometres along the Kandy-Peradeniya route and four kilometres north and northwest. Peradeniya, Katugastota, Ampitiya, and Kundasale are four urban centres located on the outskirts of the present urban boundaries in the southwest, northwest, southeast, and eastern directions, respectively. The population density map of Kandy city demonstrates that the population is crowded inside the city limits and that large densities can be observed outside them: northwest in the direction of Katugastota, southeast in the direction of Ampitiya, and southwest in the direction of Peradeniya (Masakorala and Dayawansa,2015).

The expansion of the built-up area is a necessary effect of urban growth, and Kandy city has done so as well. The "None built-up" category, which reflects the dense vegetation in the city, is the most impacted in this relation. It has dropped by 10% in a short period, from 28% in 2003 to 10% in 2007. (18%). It is clear that the city's built-up area has grown significantly in the previous two decades, and as a result, the city has lost a significant percentage of its dense plant cover (Uduporuwa and Manawadu, 2015).

Geographic Information Systems are made up of two primary components: GIS and Remote Sensing. (Hapner et al, 2005). The urban application of remote sensing has grown in popularity as a result of recent developments in remote sensing data, technology, and theories in wide-earth observations (Ju-Yang et al., 2021). The application of remote sensing to the urban environment, on the other hand, varies depending on the application's purpose. Remote sensing has various advantages for urban studies in general. Mainly, satellite photos can provide a synoptic view of a broad region at a given moment, which is impossible to do using traditional surveying approaches.

Recent improvements in remote sensing have provided greater information for urban area mapping using high-resolution satellite data (0.6m-2.5m; Quick-Bird, IKONOS, SPOT, and ALOS) and medium resolution (15m-30m; ASTER, IRS, and LANDSAT) (Guindon et al., 2004). Due to a lack of data and a high cost, studies employing high-resolution hyperspectral pictures in an urban context are still limited (Chengqi et al., 2003). The medium-resolution photos have been frequently used in urban applications. (Xian, 2015) Because of their great availability, Landsat pictures are routinely utilized to offer high-quality, regularly updated information on land surface habitats. They've been accessible regularly since 1972, and they've helped to characterise historical changes in urban regions at all scales, from local to global (Sohl and Sleeter, 2011).

The word "land cover" refers to the cover of characteristics that exist on the Earth's surface and near underground, such as biodiversity, geology, terrain, ground and surface liquid, and anthropogenic structure (Lambin et al., 2001). The phrase "land usage" refers to how people use the land cover. (Turner and Meyer, 1994) Land-use change is influenced by socioeconomic and biophysical factors and geographical location, size, and previous land use (Lambin et al., 2001). Changes in land use based on the built-up area are more rational and assist in compressively defining the urban process (Wu and Zhang, 2012). As a result of the increased population and urbanization in a particular region, the land would be under a lot of stress, and the land cover would change rapidly. As a result, examining land-use changes was another method of determining urban expansion (Masakorala and Dayawansa, 2015).

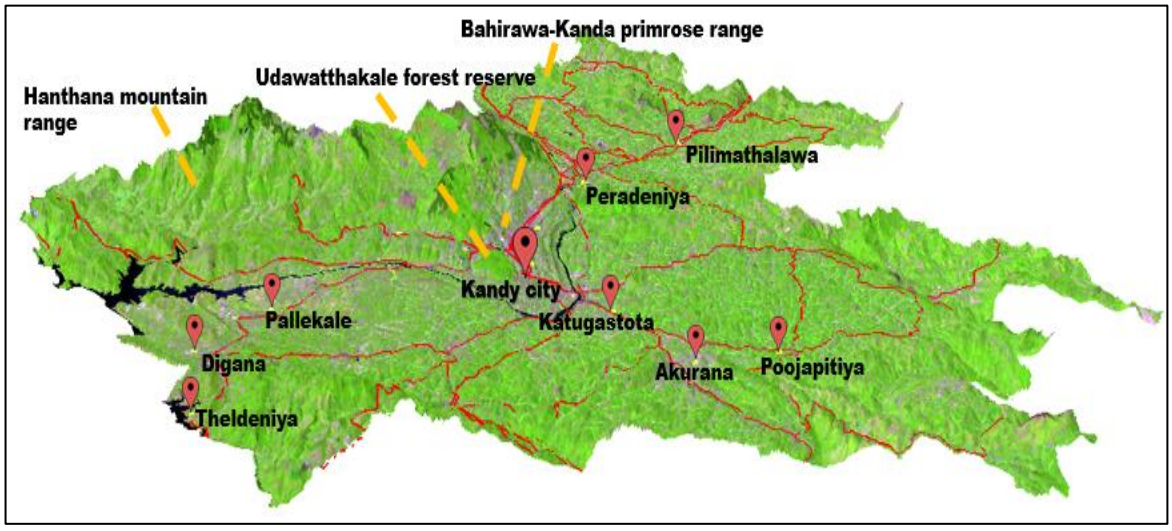
The traditional methodological approach, according to Dissanayaka (2020), is inconvenient for detecting land-use change in wide geographical regions. As a result, he used the same strategy as earlier studies. To begin, three time points were chosen (1996, 2006, 2017). After that, the United States Geological Survey (USGS) produced radiometrically corrected and atmospherically accurate Landsat level 2 data files were downloaded. A cloud-free picture with the bare minimum of cloud cover during the data download step was carefully selected. Due to cloud disturbance, which is a typical problem with RS data in the tropical region, it was difficult to locate the same day and time image. Thousands of successful LULC applications are still based on pixel-based categorisation (Blaschke, 2010). However, because of its technological and conceptual constraints, such as the "salt and pepper effect," the use of PB categorisation confronts significant obstacles (Blaschke, 2010).

MATERIALS AND METHOD

Study area

Kandy is the major city in central Sri Lanka, which is located 120km from Colombo. Kandy by the moniker “Maha Nuwara (“Great city”)”, is situated at the height of 1640 feet (500 meters). In ancient times, it was known as Kanda Pas Rata (Place on five hills) partly owing to the surrounding steep terrain. Kandy is located in a steep and thick woodland environment. The Kandy Municipal Council (KMC) area has a land area of 26.45 square kilometres or 2645 hectares. It is a triangle location that is virtually fully bounded on the west, north, and east by the Mahaweli River's main course, and the south half reaches a height of 1337 meters in the Hanthana mountain range. This municipality is situated at 70 21' North Latitude and 80 45' East Longitude. The inner city of Kandy is located in a 0.4 square-mile basin at a height of 1600 feet, created by the convergence of three valleys lying between the foothills encircling the northern extremity of the Hanthana range, the Primrose-Bahirawakanda range.

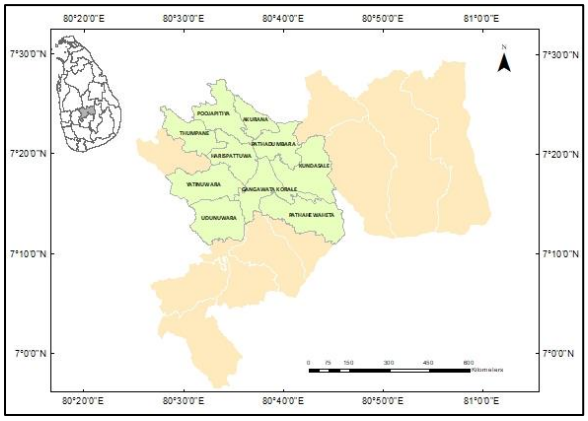
Figure 1: Topography of study area



Source: Developed by author; based on 1:50,000 digital data of survey, Department of Sri Lanka, 1996

With the rising demand for urban space, urban development in the KMC area, which was practically solely restricted to this narrow basin until the late nineteenth century, has extended outwards since then, across valley bottoms and adjoining lower hill slopes. KMC was classified as an urban development area in 1979. In terms of economic, social, and cultural development, Kandy has a lot of potential. However, the recent poorly planned building has led to overpopulation, excessive traffic congestion, and urbanisation pushing towards disaster-prone parts of the historic cultural area. Additionally, the townscape of the historical heritage region has not been adequately protected or restored, detracting from its value and appeal and hindering the area from realising its full economic potential. In this backdrop, the Government of Sri Lanka (GOS) has commissioned the Government of Japan (GOJ) to carry out the project for the Formulation of the Greater Kandy Urban Plan (GKUP), which comprises a revision of the Kandy Metropolitan Area's urban development vision and a comprehensive plan for the Heritage Area.

Figure 2: Study area



Source: Developed by author; based on 1:50,000 digital data of Survey, Department of Sri Lanka, 1996

Though the Kandy Development Plan was conducted in the Kandy municipal zone, the 10 divisional secretariat areas of Thumpane, Pathadumbara, Kundasale, Gangawata Koralaya, Haripatthuwa, Yatinuwara, and Udunuwara, with a total size of 608 square kilometres were evaluated and researched. There were 13 local government areas in this region, including a municipality, two urban councils, and 11 Pradeshiya Sabhas (UDA, Central Provincial Office, 2019).

Data collection

This study used secondary data gathered from websites (Table 1). Landsat images were mainly used for urban land use mapping. Landsat images of three selected time points were mainly used namely 2005, 2011, and 2020. In addition to Landsat imageries, Google Earth imageries were employed to develop urban land-use maps. To detect the urban land-use changes in GKDA, Landsat imageries and Google Earth images were mainly used.

Table 1: Information about data used to detect the land use in GKDA

Data type	Data source	Years
Landsat data	Official website of United States Geological Survey. (https://earthexplorer.usgs.gov/)	2005, 2011 and 2020
Google earth images	Google earth pro	2005, 2011 and 2020

Source: Prepared by authors, 2023

Three Landsat TM/ETM imageries of selected years (2005, 2011 and 2020) from the United States Geological Survey website were acquired (Table 2). All these images are with 30m resolution and cloud-free or minimum cloud cover. The basic information of those three images can be provided as below.

Table 2: Information about Landsat data

Acquisition date	Satellite/ sensor	Path	Row	Waveband		Spectral range(mm)		Spatial resolution
				SWIR	NIR	SWIR	NIR	
2005-03-17	Landsat-5TM	141	055	7	4	2.09-2.35	0.76-0.90	30
2011-03-14	Landsat-5TM	141	055	7	4	2.09-2.35	0.76-0.90	30
2020-03-10	Landsat -08	141	055	7	5	2.11-2.29	0.85-0.88	30

Source: Developed by author; based on Landsat images 2005-2011 and 2020

Data analysis

Land Use/Land Cover (LU/LC) mapping

Land cover mapping is the process of categorising and classifying human activities and natural features on the terrain across time. LULC mapping is the most extensively utilized method for studying changes in remote sensing.

Classification of Landsat imageries

The maximum-likelihood classification algorithm is used in this pixel-based supervised classification technique. This technique involves three main steps: training sites/sample preparation, signature development, and classification. Mainly, this was used to generate three maps (2005, 2011, and 2020) of land-use changes with three classes (Table 3 and Table 4). Namely, water, non-built-up, and built-up. Human-made constructions such as houses, roads, and other surfaces are included in built-up areas. Agricultural areas, woods, meadows, and barren lands are all examples of non-built terrain. Rivers, lakes, and other bodies of water are taken as water. Classification has been completed, with at least 100 samples in each class, each year.

Land Use /Land Cover classification scheme

Table 3: Land use land cover classification scheme

LU/LC classes	Description
Water areas	Natural and man-made bodies of water such as lakes, rivers, ponds
Built-up Area	All the manmade structures including buildings and roads
Agriculture lands	All croplands
Bare lands	Barren lands and other open spaces
Forest cover	All the forest areas

Source: Prepared by authors, 2023

Table 4: Land use classes

Old class name	New class name (reclassify)
Water areas	Water
Built-up Area	Built-up-areas
Agriculture lands	Non-built-up-areas
Bare lands	Non-built-up-areas
Forest cover	Non-built-up-areas

Source: Prepared by authors, 2023

Change matrix

By reclassifying land use maps of three years (2005,2011 and 2020) using the reclassify tool, those maps were combined as 2005-2011, 2011-2020, and 2005-2020 to identify the land-use changes. To analyse land-use changes, change Metrix was used. (Equation 1)

$$\left(\frac{t_2 - t_1}{t_1}\right) \times 100 \quad (1)$$

Where t1 refers to Period 1 and t2, refers to Period 2.

Annual change was calculated by using Equation 2

$$(t_2 - t_1) \div Y \quad (2)$$

Where t1 refers to Period 1, t2 refers to Period 2, and Y refers to the number of years.

Assessing the accuracy

The accuracy of the land-use classification was checked with 100 random sample points for each year (2005, 2011 and 2020) using create random points data management tool in ArcMap 10.4 software. Overall accuracy was calculated separately from each time point. All the random points generated for accuracy assessment were visually assessed by using Google Earth images. The data obtained from the comparison between reference and actual points on pixel-based classification land-use maps were then used to calculate the accuracy of the LULC map using overall accuracy (Congalton, 1991). To calculate overall accuracy first, calculate producer accuracy (Equation 3) and user accuracy (Equation 4).

$$\mathrm{PA} = \mathrm{CLU} \div \mathrm{TLU} \quad (3)$$

Where PA is Producer's Accuracy, CLU refers to Correct Land Use Pixel and TLU is Total Land Use pixel.

$$\mathrm{UA} = \mathrm{CLU} \div (\mathrm{CP} + \mathrm{MP}) \quad (4)$$

Where, UA refers to User's Accuracy, CLU Correct Land Use Pixel, CP refers to Correct Pixels and MP is Misclassify pixels.

Then overall accuracy was calculated using the values that are gained from producer accuracy (Equation 5).

$$OA = PC_1 + PC_2 + PC_3 \div TC \quad (5)$$

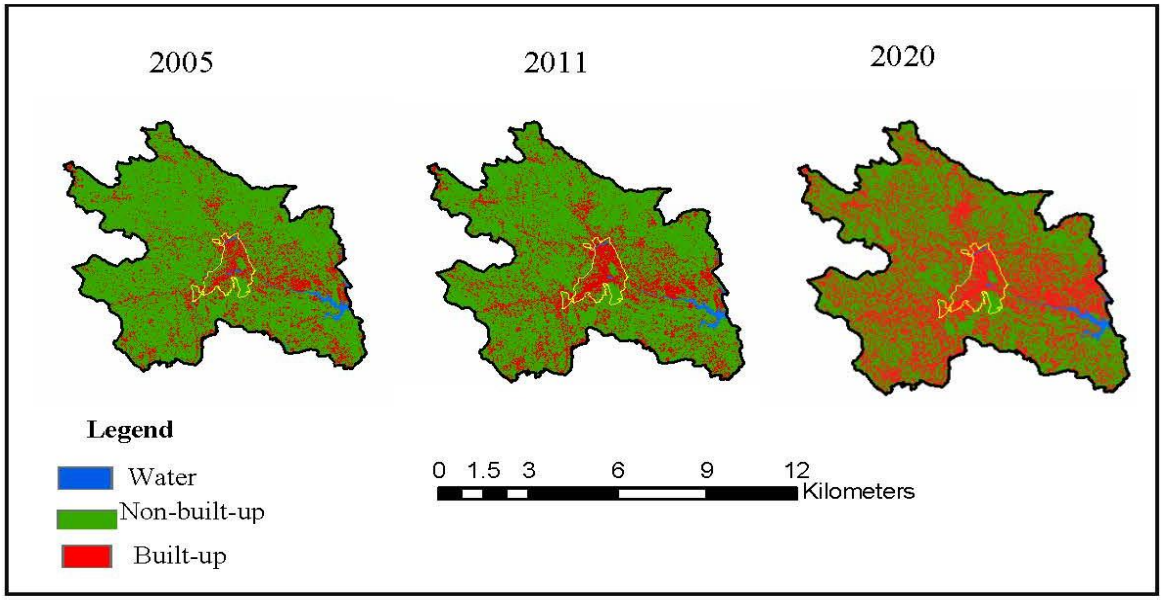
Where OA refers to overall accuracy, PC1 refers to producer's accuracy of class 1, PC2 refers to producer's accuracy of class 2, PC3 refers to producer's accuracy of class 3 and TC refers to the number of classes.

RESULTS AND DISCUSSION

Analysis of urban Land Use changes in greater Kandy development area

Figure 3 illustrates three classified maps for the GKDA for 2005, 2011, and 2020. It clearly shows the increase of built-up areas in GKDA and the areas that changed from non-built-up to built-up during the 2005-2020 period. It clearly shows the increase of built-up areas in GKDA and the changes from non-built-up to built-up areas during the 2005-2020 period. In 2005, built-up areas were widely distributed and enclosed by the Mahaweli river. The city centre is mainly comprised of built-up land compared to other areas. In 2011, a gradual rise in built-up areas outside of city boundaries was seen, especially on the city's outskirts. The east part of the city

Figure 3: LULC maps of year 2005, 2011 and 2020



Source: Developed by author; based on LULC classification of Landsat TM/ETM imageries-2005, 2011,2020

sees the start of the development of built-up areas. After 9 years, in 2020, built-up areas have expanded in the whole study area, more than in previous years.

With the growth of the city, demand for land has increased. Therefore, some urban-related problems like traffic congestion, air pollution, lack of land, and an unaffordable cost of land occur. On the other hand, as a UNESCO-designated world heritage site, old archaeological buildings cannot be eliminated. Sensible environmental sites, including mountains and forests, cause the city to limit the space in which it can grow. These limitations cause the suburbanisation process of Kandy to accelerate. According to Uduporuwa (2015), after 2011, the suburbanization process of Kandy became more visible in Kandy. Figure 3 justifies the growth of suburbs after 2011.

The Greater Kandy Development Plan, which ran from 2008 to 2020, sought to alleviate urban congestion while simultaneously enhancing Kandy as a world heritage site. Governmental activities, academic institutions, medical facilities, Singhe regiment headquarters, the prison system, and local council facilities such as the Bogambara outer bus stand have already been relocated within the city limits, and UDA will begin moving them to areas outside of the city borders, such as Kundasale, Peradeniya, Katugastota, and Digana under this plan. When this plan is implemented, it will result in the urbanisation of Kandy expanding outwards to the Kandy city border. As a result, there can be an increase in built-up areas outside Kandy city in the 2011 and 2020 LULC maps. Under this plan, Kandy town has been designated as a cluster area for culture and tourism, Peradeniya as a clustered area for higher education, Katugastota as a clustered area for trade and commercial operations, and Kundasale and Digana as clustered areas for industrial and associated activities. Those areas show a high concentration of built-up areas in LULC maps.

LULC maps, clearly show how the city centre is growing as a cluster. Another cluster that can be identified is Peradeniya.

A large number of educational centres are located in the Peradeniya area. As a result, Peradeniya starts to grow as a cluster. The Pallekale area is another main cluster. Due to the industrial zone, this area is starting to grow. Currently, one can see a high concentration of built-up areas in this area. As shown in Table 5, according to the LULC changes in GKDA in 2005, the built-up area was 99.84 thousand hectares, covering 16.97% of the entire landscape. By 2011, it had grown to 127.6 hectares or 21.37% of the landscape. In 2020, it rose further, reaching 6.99 thousand hectares, or 40.04% of the total area. There was a net change in the built-up area of 27.77 thousand hectares in 2005–2011 (Table 5). The net change in a built-up area in GKA during the period 2011–2020 (Table 4) was a record of 111.41 thousand hectares. The average net change in the built-up area between the 15 years from 2005-2020 is 139.18 thousand hectares (Table 5). However, there is a decline in the number of water bodies. In 2005, it had an area of 7.08 thousand hectares or 1.3% of the land area covered by water. The amount has been reduced to 7.03 thousand hectares. The percentage reached 1.18 percent. By 2020, water bodies represented only 6.99 thousand hectares of lands or 1.17% of the total area. Due to the decrease in water bodies, the net change in water bodies reached -0.79 thousand hectares in 2005–2011. From 2011 to 2020, the net variation in water bodies was -0.04 thousand hectares. Consequently, the average net change in water bodies from 2005 to 2020 was -0.8 hectares. Water bodies change mostly as a result of encroachment in water body locations. Natural encroachments, as well as human encroachments, are both possible. Human encroachments, on the other hand, have a greater influence than natural encroachments. As a result, flash floods have taken over several parts of GKDA. Flash floods are widespread in the Yatinuwara, Akurana, and Poojapitiya DSDs due to the obstruction of the Mahaweli River and the building of unlawful structures together with adjacent land areas of water sources.

In 2005, 489.34 thousand hectares of land was non-built-up, and that fell to 462.36 thousand hectares or 77.5% in 2011. In 2020, it will continue to decline to 350.99 thousand hectares or 58.8% of the total area. It has been reduced up to 111.41 thousand hectares between 2011 and 2020. The net change of the non-built-up areas in 2005-2011 was -26.98 thousand hectares, and in 2011-2020 the net change was -111.4 thousand hectares. The net change in non-built-up area over the 15 years 2005–2020 is -139.2 thousand hectares.

Table 5: LULC changes in GKDA, 2005-2011

Land use categories	2005		2011		Net change		Annual change
	Hectares '000	Percent of total	Hectares '000	Percent of total	Hectares '000	Percent of 2005	
Water	7.8	1.3	7.03	1.2	-0.8	10.1	1.7
Non-built	489.3	81.7	462.4	77.5	-26.9	5.52	0.9
Built-up	99.8	16.9	127.6	21.4	27.8	27.8	4.6
Total	597	100	597	100			

Source: Based on 2005 and 2011 LULC maps

Table 6: LULC changes in GKDA (2011-2020)

Land use categories	2011		2020		Net change		Annual change
	Hectares '000	Percent of total	Hectares '000	Percent of total	Hectares '000	Percent of 2011	
Water	7.0	1.2	6. 9	1.2	-0.04	0.5	0.6
Non-built	462.4	77.5	350.9	58.8	-111.4	24.1	2.7
Built-up	127.6	21.4	239.0	40.0	111.4	87.3	9.7
Total	597	100	597	100			

Source: Based on 2011 and 2020 LULC maps

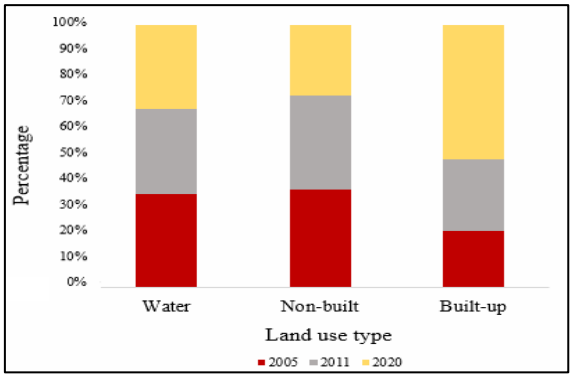
Table 7: LULC changes in GKDA (2005-2020)

Land use categories	2005		2020		Net change		Annual change
	Hectares '000	Percent of total	Hectares '000	Percent of total	Hectares '000	Percent of 2011	
Water	7.8	1.3	6.9	1.2	-0.8	10.6	0.8
Non-built	489.3	81.7	350.9	58.8	-138.4	28.3	1.9
Built-up	99.8	16.9	239.0	40.0	139.2	139.4	9.2
Total	597	100	597	100			

Source: Based on 2005 and 2020 LULC map

According to Figure 4, the percentage change in water bodies in the GKDA is not significantly verified. But there is a gradual decrease in non-built-up areas in GKDA. In 2005 and 2011, non-built-up areas covered a comparatively larger land extent. However, when compared with the other two classes, non-built-up areas cover the smallest land extent in 2020. The lowest percentage of built-up area can be observed in 2005. There is a gradual increase in the expansion of the built-up area, and by 2020, close to 50% of the increase in the built-up area is visible. When population growth happens in the city boundary areas, changes in land cover and land usage can be seen. These changes are visible in the LULC maps (Figure 3).

Figure 4: Land use changes of GKDA as a percentage in 2005, 2011 and 2020



Source: Developed by author; based on 2005, 2011 and 2020 LULC maps

As Masakorala and Dayawansa (2015) mentioned in 2015, LULC maps clearly demonstrate GKDA's great growth in the built-up areas and reduction of non-built-up areas. The extent of non-built-up areas has been replaced by the expansion of built-up areas. Non-built-up regions, for example, have decreased from 81.7% in 2005 to 58.79% in 2020. The increase in built-up from 16.97% in 2005 to 40.04% has replaced that reduction of non-built-up in 2020.

Change matrix

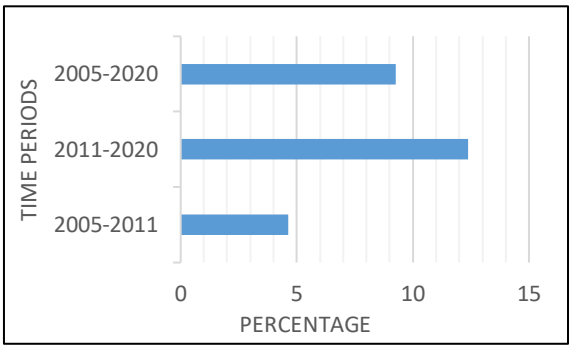


Figure 5: Increment of built-up area

Source: Developed by author; based on 2005, 2011 and 2020 LULC maps

Table 8 shows that 6.98 thousand hectares of land area occupied by water bodies in 2005 remained till 2011. In 2005, 0.34 thousand hectares of water bodies were converted to non-built-up areas. Among them in 2011, 0.49 thousand hectares of water bodies were converted to built-up areas or urban areas. In 2005, 0.01 thousand hectares of non-built-up areas were converted to aquatic areas. In 2011, 0.01 thousand hectares of non-built-up areas were turned into water bodies. 450.33 thousand hectares of non-built-up areas in the year 2005 remained the same till 2011. 38.99 thousand hectares of built-up area or urban land in 2011 were non-built-up areas in 2005. 0.03 thousand hectares of built-up land in 2005 became water bodies in 2011, while 11.69 thousand hectares of built-up land became non-built-up land in 2011. In 2005, 88.11 thousand hectares of land were built-up lands, and in 2011, 88.11 thousand hectares of land remained built-up.

Table 8: Change matrix of 2005-2011

2005	2011		
	Water ('000 ha)	**Non-built ('000 ha)**	**Built-up ('000 ha)**
Water	6.98	0.34	0.49
Non-built	0.01	450.33	38.99
Built-up	0.03	11.69	88.11

Source: Based on 2005 and 2011 LULC maps

Between 2011 and 2020, 6.68 thousand hectares of land that was water bodies in 2011 had remained as water bodies in 2020. However, according to Table 9, 0.03 thousand hectares of non-built-up land area and 0.03 thousand hectares of water bodies in 2011 were converted to built-up areas in 2020. 346.83 thousand hectares of non-built-up areas in 2011 remained non-built-up areas in 2020. Conversely, in 2020, 0.03 thousand hectares of land have become water bodies, and 115.23 thousand hectares have become built-up areas. Only 4.12 thousand hectares of built-up land are converted to non-built-up land by 2020, while 123.48 thousand hectares of land stays built up. In the period 2011–2020, no portion of the built environment changed to aquatic bodies.

Table 9: Change matrix of 2011-2020

2011	2020		
	Water ('000 ha)	**Non-built ('000 ha)**	**Built-up ('000 ha)**
Water	6.68	0.03	0.03
Non-built	0.3	346.83	115.23
Built-up	0	4.12	112.48

Source: Based on 2011 and 2020 LULC maps

When taking the 15 years of GKDA, there is a huge change in land-use. According to the change matrix in Table 10, 6.64 thousand hectares of water bodies of 2005 will remain as water bodies in 2020. However, 0.37 thousand hectares of water bodies in 2005 were converted into non-built-up areas by 2020. In 2020, 0.8 thousand hectares of water body areas will be converted to built-up areas. 334.79 thousand hectares of non-built-up areas in 2005 remained non-built-up in 2020, while 0.31 thousand hectares of non-built-up area converted to water areas and 154.23 thousand hectares converted to built-up areas. 0.03 thousand hectares of built-up areas in 2005 were converted into water bodies, and 15.82 thousand hectares of built-up areas were non-built-up in 2020. As of 2005, 83.98 thousand hectares of built-up areas remained built-up in 2020.

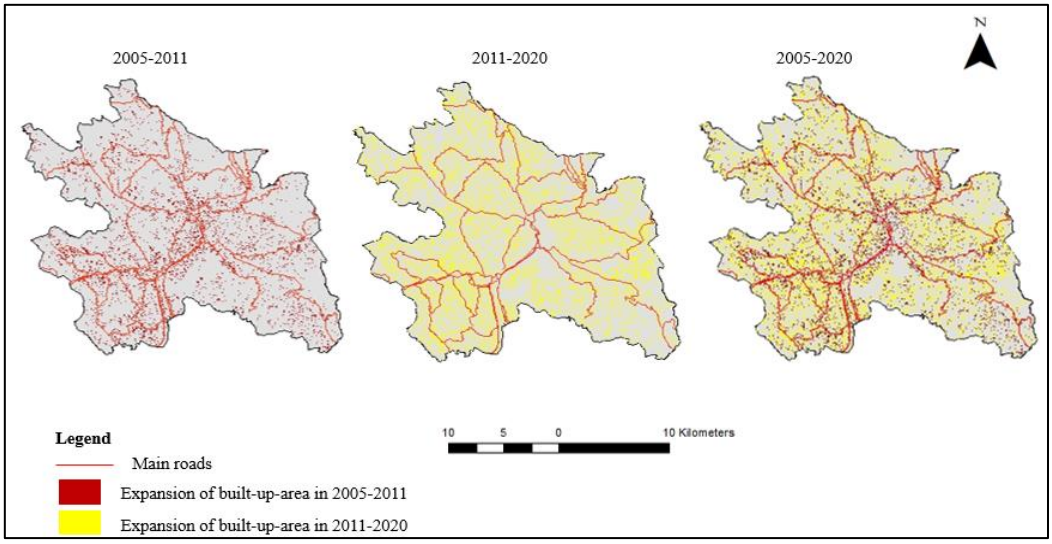
Table 10: Change matrix of 2005-2020

2005	2020		
	Water ('000 ha)	**Non-built ('000 ha)**	**Built-up ('000 ha)**
Water	6.64	0.37	0.8
Non-built	0.31	334.79	154.23
Built-up	0.03	15.82	83.98

Source: Based on 2005 and 2020 LULC maps

Figure 6 clearly shows that between 2005 and 2011 built-ups are spread along the main roads. Then after 2011 they started to further grow inwards. Therefore, as usual, in many Sri Lankan cities, GKDA also shows a linear growth pattern. Due to the obvious great need for development activities on both sides of main roads, there is a large concentration of built-up areas along main roads. A9 (Kandy-Jaffna), A26 (Kandy-Mahiyanganaya), A1 (Katugastota-Kurunegala), and B413 (Katugastota-Kurunegala) (Raja Mawatha) in particular. Along the Kandy-Digana, Kandy-Peradeniya, and Akurana-Alawathugoda routes, the most noticeable expansion can be seen. The high density of built-up areas can be seen along the Kandy-Peradeniya Road due to the presence of most educational, health, and administrative facilities. The Kandy-Katugastota route has seen a significant increase in trade business operations and, therefore, increasing built-up areas along that road. This pattern can be identified especially within the Mahaiyawa area.

Figure 6: Pattern of urban expansion in GKDA area



Source: Developed by author; based on LULC classification of Landsat TM/ETM imageries

Results of accuracy assessment

The accuracy assessment of each year is presented in Table 9, Table 10, and Table 11. The overall accuracy of 88.16percent, 90.34 percent, and 92.69 percent in 2005, 2011 and 2020 respectively. Thus, resultant images were employed for further analysis.

Table 11: Error matrix for the classification 2005 LULC map

Classified data	Reference data			Total	User's accuracy
	Built	**Non-built**	**Water**		
Built	12	5	0	17	70.58 %
Non-built	5	77	0	82	93.90 %
Water	0	0	1	1	100 %
Total	17	82	1	100	
Producer's Accuracy	70.58 %	93.90 %	100 %		

Overall accuracy: 88.16 percent

Source: Developed by author; based on LULC classification of Landsat TM/ETM imageries

Table 12: Error matrix for the classification 2011 LULC map

Classified data	Reference data			Total	User's Accuracy
	Built	Non-built	Water		
Built	18	5	0	23	78.82 %
Non-built	5	70	0	75	92.20 %
Water	0	0	2	2	100 %
Total	23	75	2	100	
Producer's Accuracy	78.82%	92.20%	100%		

Overall accuracy: 90.34%

Source: Source: Developed by author; based on LULC Classification of Landsat TM/ETM imageries

Table 13: Error matrix for the classification 2020 LULC map

Classified data	Reference data			Total	User's Accuracy
	Built	Non-built	Water		
Built	22	13	0	35	62.85 %
Non-built	1	61	0	62	98.38 %
Water	0	0	3	3	100 %
Total	23	74	3	100	
Producer's Accuracy	95.65 %	82.43 %	100 %		

Overall accuracy: 92.69%

Source: Developed by author; based on LULC classification of Landsat TM/ETM imageries

CONCLUSION

As a result of population growth occurring inside the city limits, changes in land cover and land-use may be seen. These modifications may be seen on the LULC maps. It reflects GKDA's tremendous expansion in the urbanized region. Because of the rise of urbanization, the amount of non-built-up land has been replaced by the extension of developed land. As an example, the proportion of non-built-up areas has declined from 81.7% to 58.79% in 2020. By 2020, the increase in built-up area from 16.97% to 40.04% will have completely compensated for the decline in 2005 to 20%.

When the British started to govern the Kandyan kingdom, forests covered a quarter of the present Kandy city area, a figure that has now dropped to 52% after the country's independence from Britain. In 2019, forests cover just 11% area of the city. At the start of the twentieth century, forests, shrublands, lake conservation, barren lands, wetlands, and agricultural regions, including rice fields, occupied about 75% of the land area in the Kandy Municipal area.

The majority of changes in water bodies occur as a consequence of encroachment on their boundaries. Both natural and human encroachments are conceivable, and both are detrimental. Human encroachments, on the other hand, have a higher impact on the environment than natural encroachments do. As a consequence, flash floods have engulfed various areas of the GKDA. Flash floods are widespread in the Yatinuwara, Akurana, and Poojapitiya DSDs, mostly due to the blocking of the Mahaweli river and the building of unlawful structures in parallel land areas with water sources.

The demand for land has grown as a result of the city's expansion. As a result, several urban-related issues, such as traffic congestion, air pollution, a scarcity of land, and an exorbitant cost of land, might arise. Examples include: on the other hand, ancient archaeological monuments cannot be demolished since the city has been designated as a UNESCO World Heritage Site. According to the World Heritage Committee, out of 490 historical structures, 79% of heritage buildings are located in the city centre. Sensible environmental features, such as mountains and woods, force the city to restrict the amount of territory that it may expand into. As a result of these restrictions, the suburbanization of Kandy is speeding up rapidly. Several researchers, including Uduporuwa (2014), have noted that the suburbanization trend in Kandy has been increasingly noticeable in the city since 2011.

According to the Greater Kandy Development Plan, which was created for the years 2008–2020, it was intended to reduce urban congestion while simultaneously promoting Kandy as a UNESCO World Heritage site. As mentioned above, administrative offices, educational centres, hospitals, Singhe regiment headquarters, Bogambara prisons, and municipal facilities such as the Bogambara outer bus stand are already located within the city limits, and under this plan, the Urban Development Authority (UDA) will begin relocating them outside the city limits to sub-towns such as Kundasale, Peradeniya, Katugastota, and Digana, among others. As a result of the execution of this plan, the urbanisation of Kandy will continue to spread outwards until it reaches the city border. As a consequence, you will notice a rise in the number of built-up regions outside of Kandy city on the LULC maps between 2011 and 2020. The changes that have occurred in the eastern section of the study region

have received considerable attention. This is mostly occurring as a result of the industrial zone's geographic position in Pallekale.

Due to the high demand for development activities on both sides of major roads, there is a significant concentration of built-up regions along major roads, particularly in urban areas. Particularly popular routes are the A9 (Kandy-Jaffna), the A26 (Kandy-Mahiyanganaya), the A1 (Katugastota-Kurunegala), and the B413 (Katugastota-Kurunegala) (Raja Mawatha). The most significant increase may be observed along the Kandy-Digana, Kandy-Peradeniya, and Akurana-Alawathugoda roads, which are all in the province of Kandy. Because of the presence of the majority of educational, health, and administrative institutions along the Kandy-Peradeniya route, there is a high density of built-up regions along this stretch of road. As a result of this expansion, trade and business activities along the Kandy–Katugastota route have increased significantly, resulting in an expansion of the built-up regions along that route. This pattern can be seen in the Mahaiyawa region in particular.

It is also possible to detect certain clustering tendencies in some places. The GKDP anticipated a development plan with a clustered pattern of development (2008–2020). Kandy town has been designated as a clustered development area for culture and tourism, while Peradeniya has been designated as a clustered development area for higher education, Katugastota has been designated as a clustered development area for trade and commercial operations, and Kundasale and Digana have been designated as clustered development areas for industrial and related activities, respectively. As a consequence, certain places have a high concentration of built-up areas as a result of their location. The development of Kandy city as a cluster may be seen on the land use map and the urban level map, which are both available online. The LULC maps clearly demonstrate how the city core is developing as a concentration of businesses. Peradeniya is another cluster that may be recognized on the map. Peradeniya has a great number of educational facilities, which are spread around the city. As a consequence, the city of Peradeniya begins to develop into a cluster. Another important cluster is located in the Pallekale region. This region is beginning to develop as a result of the presence of an industrial zone. This region currently has a high concentration of built-up areas, which can be seen across the city.

Due to the rapid urbanization of the GKDA, several social and environmental difficulties have arisen, including excessive traffic congestion, land mismanagement, and air pollution, which is a consequence of poorly built structures. GKDA is situated in a region that is described as "The Central Fragile Region" in the national physical plan 2030 and has been included in the protected area network to stress the significance of the region in maintaining the country's water supplies. Certain towns will continue to exist in this land, but the development and extension of these settlements will be strictly regulated. It has been acknowledged that Kandy, in particular, has grown into a metropolis whose growth and development should be overseen and governed. The future pattern of urban development, however, may dictate that urban expansion will prevail outside of the city limits, which might include extending the city's boundaries or growing the city outside of the city limits.

The terrain of the Greater Kandy Development Area determines the form of urbanisation in the area since it is designed to discourage urban expansion. The bulk of KMC's urbanized areas is concentrated in the city's central business district. The steep terrain that surrounds the city centre has been increasingly urbanized in recent years. A variety of structures, including hotels and residences, may be found scattered around the hills.

A long and thin pattern of development arises along major highways and in the area of suburban centres, resembling the typical sprawl pattern. In recent years, the spread of urban sprawl and ribbon development along vital transportation corridors has resulted in a slew of urban challenges, including mismanagement of land use.

As a result, the city centre of Kandy has a high concentration of socio-economic activity, which results in traffic congestion and pollution. Rural economies, on the other hand, are experiencing economic stagnation as a result of the underutilisation of their natural resources. It is necessary to decentralise some urban functions in the city centre to the cluster cities of Katugastota, Peradeniya, and Kundasale-Digana, and to relocate some urban functions in the city centre to the cluster cities of Peradeniya, Peradeniya, and Kundasale-Digana to the city centre and promote economic activities in Greater Kandy by linking them to local industries.

As part of the national physical plan 2030, GKDA is situated in a region referred to as "The Central Fragile Region." As a result, it has been designated as a protected area to stress its significance in maintaining the country's water supplies. Certain towns will continue to exist on this land, but the development and extension of these settlements will be strictly supervised. It has been noted that Kandy, in particular, has grown and developed in a way that has to be monitored and managed. However, if the present growth is continuous, shortly, Kandy can be identified as the second unbound city in Sri Lanka. There is a high potential for Kandy city to grow exceeding its boundary. Therefore, there is a special need for a new policy to further control the growth of the city.

It is critical to correctly define the environmentally sensitive regions and to improve the rules in place to prevent encroachment and development activities. Among other things, the upper Mahaweli river catchment region in the Akurana area has become a severely degraded environment, with urban flooding being the predominant hazard in this area. A major contributing factor to this phenomenon is the presence of unlawful encroachments on riverbanks.

Another crucial task is to keep track of the development of cities. Sri Lanka, like the vast majority of nations throughout the globe, lacks adequate monitoring of urban expansion. It may be possible to solve a variety of urban-related challenges by keeping track of even big cities' development for at least once in 10-year period in the future.

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