An Analysis of the Impact of Urbanization on Natural Character of Coastline Along Southern Suburbs of Colombo, Sri Lanka

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ABSTRACT

Coastal ecosystems, including mangroves, swamps, sand bars, and coastal vegetation, play a vital role in maintaining environmental sustainability. However, rapid urban expansion and shoreline development have disrupted these natural systems, resulting in ecosystem degradation. Achieving sustainable development in coastal zones therefore requires the careful management of natural resources alongside the conservation of ecological functions. This study investigates the impacts of shoreline constructions and urban growth along a 30 km coastal stretch from Moratuwa to Kalutara, extending 1 km inland. Temporal changes in the coastline between 2004 and 2021 were assessed using high-resolution satellite imagery from Google Earth. Shorelines were digitized and analyzed in ArcGIS to evaluate spatial variations and to determine the influence of revetments, groynes, and breakwaters on coastal stability. Built-up expansion was quantified using supervised classification with the maximum likelihood technique on geo-referenced imagery from 2004 and 2021. The results indicate notable increases in both shoreline engineering and urban development during the study period. Shoreline structures contributed to coastal stabilization and, in several areas, facilitated seaward extension of the coast. Conversely, analysis of built-up area growth revealed that relatively low-urbanized areas preserved more natural coastlines, while densely developed regions exhibited extensive shoreline modifications. Field investigations supported these findings, highlighting the progressive transformation of natural coastlines into engineered environments. The study concludes that although shoreline constructions enhance coastal stability, the accelerated expansion of the built environment threatens the persistence of natural coastal ecosystems. These findings underscore the need for balanced development strategies that integrate coastal protection with ecosystem conservation to safeguard long-term sustainability.

Keywords – built environment, coastal zone, GIS analysis, shoreline

INTRODUCTION

Background of the Study

Being an island nation in the Indian Ocean, the 1,680km long coastline of Sri Lanka is very important to the nation, in terms of environment, economy, and culture. The coastline has provided livelihood to many people in various sectors such as fisheries, tourism and recreation, port-centric logistics, and natural resource extraction. This can be identified as a major reason for the urbanization along coastal areas. Many of Sri Lanka's highly populated cities are situated along the coastline, including the commercial capital Colombo.

Problem Statement

Growth of built environment over the natural environment due to urbanization along coastal areas has resulted several environmental problems such as coastal erosion, loss of biodiversity, marine pollution, and destruction of natural ecosystems. These environmental problems cause negative impacts on the livelihood of the coastal

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community, mainly tourism and fisheries. Human settlements along the coastline are also threatened by environmental degradation. Therefore, coastal zone management is an important strategy to maintain a sustainable built environment along coastal areas.

The built environment along the Sri Lankan coastline has been increasing for several decades. Along with that, many artificial barriers have been built to protect the coastline from erosion. They have been built mainly in fishery harbor areas and recreational beach areas by respective authorities such as Coastal Conservation Department (CCD) and Ceylon Fisheries Harbour Cooperation (CFHC) of Sri Lanka.

However, the performance of these structures has to be monitored from time to time. The structures may be causing positive impacts by stopping erosion and supporting accretion. On the other side, they may react negatively causing further erosion in the same place or a nearby shoreline. Analyzing the erosion and accretion patterns around such structures is helpful to identify their performance. Therefore, coastal erosion and accretion patterns before and after the construction of these structures should be analyzed in the relevant areas.

Aim of the Study

The main objective of this study is to investigate the impact of built environment spread over natural environment along the coastlines.

Objectives

1. To identify the effects of shoreline constructions towards coastline variation and natural character of coasts

2. To analyze the performance of coastal protection measures towards the stability of coastline

Scope of the Study

1. The built-environment features considered in this study are mainly the structures that have been constructed along the coastline; mainly, within the coast, shore, and nearshore areas.

2. The impact of urbanization is measured in terms of spatio-temporal variations caused by potential human activities.

3. Special consideration is given to the coastline changes that occurred during the period from 2004 to 2022 along the Kalutara - Moratuwa coastal stretch.

LITERATURE REVIEW

The world's coastline extends for about 440,000 km and nearly half of the world's population lives within 100 km of the shoreline (Kusky, 2008). There are five factors namely; climate, coastal process, sea level, human activities, and sediment budget interact to influence erosion and accretion in the coastal regions (Williams, 2001). The land use and land cover in the coastal areas are extremely experiencing substantial transformation due to waves, wind, tide, saltwater, saltation, sea level rise, storm surge, cyclones, and human interference (Weismiller & Momin, 1977). At present, coastal erosion is one of the most serious environmental issues being faced by coastal ecosystems worldwide (Toimil, et al., 2017). Coastal erosion is already identified as a longstanding problem in Sri Lanka which continues (Lakmali, et al., 2017).

Coastal Zone Management Issues: Case Studies from Sri Lanka

When considering Sri Lanka, informal flood-controlling measures have caused severe coastal erosion in Kalutara at the Kalu Ganga river outlet in 2017. According to Gunasinghe, et al., (2019) the area was significantly changed after the collapse of the natural sand barrier where the famous Calido beach was located. Kalutara town area was threatened by erosion as it was exposed to sea waves thereafter. The area is now conserved by an artificial sand barrier constructed by CCD.

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A similar incident happened in the Navaladi area, Batticaloa in 2010, after opening a new bar mouth between the lagoon and the sea with the involvement of politicians (in addition to the natural bar mouth existing), to control the floods that occurred during that period. This caused significant damage to the surrounding environment afterwards in terms of coastal erosion and land degradation. The lack of an integrated and coordinated decision-making system for coastal zone management was highlighted in the study by Kiruparajah (2018) for the above scenario.

A study by Senevirathna et al. (2017) has found the causes and impacts of coastal erosion and environmental degradation in the Unawatuna area on the southern coast of Sri Lanka. Reasons for coastal erosion include the destruction of coral reefs (due to tourist activities, motor boat rides, water pollution, and harmful fishing methods), sand removal from the coast, construction of a breakwater, and unplanned infrastructure development. Many of the reasons mentioned above were found interrelated to each other and caused by tourism development in the area. Coastal erosion had badly affected the rich biodiversity and natural beauty in the surrounding area, damaging turtle habitats, fish species, sandy beach, and coral reefs. That had resulted in a decrease in tourist arrivals to the area, according to further investigations carried out.

Another important study had been carried out by Samarasekara, et al. (2018) for the Marawila beach area to investigate historical changes in the shoreline and management since 1980. The investigation was done by studying the area and livelihood of residents, GIS analysis of satellite images, field observations with interviews, and a bathymetric survey. The GIS analysis highlights erosion and accretion rates of the shoreline in several consecutive time frames starting from 2002 to 2017. Several structures including revetments, detached breakwaters, submerged breakwaters, and groyne fields had been built together with beach nourishment during that period. The resulting graphs clearly indicated how the erosion and accretion patterns vary with the establishment of shoreline stabilization projects. The outcomes of bathymetric surveys also reveal that significant erosion had taken place during 2007-2017. Cross-shore profiles and DEMs created using survey data have been used to indicate the erosion in Marawila beach. Furthermore, the study highlights the effectiveness of coastal conservation structures with respect to shoreline length protection and construction cost involved.

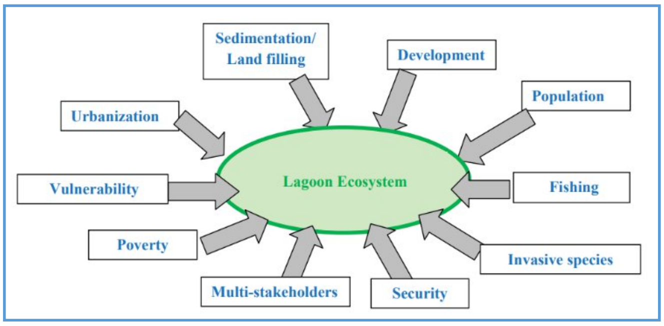

Figure 2.1: Several key threats on lagoon ecosystems in Sri Lanka (Silva, et al., 2013)

Figure 2.1 illustrates diverse impacts on lagoon ecosystems in Sri Lanka causing threats to environmental sustainability as identified by Silva, et al., 2013. Many of them are inter-related to each other and directly or indirectly linked with the spread of built environment.

Coastal Zone Management: Case Studies from Other Countries

Some examples of coastal zone management that have adopted nature friendly solutions which have been effective in other countries are described here onwards.

Mangrove Restoration in Bangladesh and the Philippines

Other than coastal engineering, conservation and restoration of mangrove forests are practiced in Bangladesh and the Philippines, as a more sustainable option as recognized by Marois & Mitsch, (2015). Both countries are highly vulnerable to cyclones and the Philippines to tsunamis. The damage caused by such natural disasters

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becomes more disastrous with sea level rise and coastal erosion (Nicholls & Cazenave, 2010). Bangladesh Forest Department initiated a program of planting mangroves along the country's coastline in response to a series of severe cyclones that hit the country in the early 1960s. Planting mangroves in those coastal areas was found to reduce erosion, causing the land to stabilize and expand enough to support agriculture (Saenger & Siddiqi, 1993).

In the Philippines, Banacon Island had become a national display of sustainable, community-based mangrove management area, as the residents had been cultivating new mangroves while harvesting existing mangroves for their timber since the 1940s (Walters, 2003). The Philippine government had started a 'comprehensive program of environmental protection' including the establishment of 'no-build zones' in coastal areas and restoration of mangroves after the devastating typhoon 'Haiyan' hit the Philippines in 2013 (Straits Times, 2013).

New Zealand

Waikato region in New Zealand has about 1,150 km of open coast and estuarine shoreline. There has been considerable urban development in the Coromandel Peninsula much closer to the shoreline. This means there is not enough space left between the development and the ocean to protect against coastal erosion or the effects of predicted sea level rise. Shoreline protection structures are more likely to be built in areas where private property is exposed to coastal hazards. This means more highly developed beaches tend to have a greater number of protection structures and such structures can affect the coastline's natural character and make access to beaches difficult (Waikato Regional Council, 2019).

Shoreline protection structures affect;

1. Natural character: Natural qualities of the coastal environment are called natural character. These include natural processes and spiritual, cultural, scientific, and visual values of coasts. The natural character of beaches is recognized as a matter of national importance in the New Zealand Coastal Policy Statement. Adding foreign material to coastal areas and preventing altering natural landforms and processes can degrade the natural character.

2. Natural processes: People build shoreline protection structures to stop the erosion of the land. While groynes can protect dunes by holding sediment in place, they can increase erosion elsewhere if trapped sediment is unable to reach neighboring beaches. Seawalls can stop dune erosion, but often at the expense of lowering the level of the beach in front of it, so the dry sandy beach is lost at high tide. There can be increased erosion at either end of the seawall where increases in turbulence occur near the ends of the wall ('end effects').

3. Public values: The effects of structures on natural processes and landforms can make access to the beach and along the beach difficult. Large, poorly designed, or unstable structures can be unsafe (particularly for young children and the elderly). Often alternative public access needs to be created.

It is therefore important that shoreline protection structures are: only built where necessary, and managed so that their adverse effects can be avoided or reduced. Waikato Regional Council (WRC) therefore has a well-organized coastal monitoring and reporting program to know where shoreline protection structures have been erected and how they affect the region's beaches and coastline areas. In addition to shoreline protection structures, indicators such as coastline ownership, the extent of coastal habitats, protected coastal areas, coastal developments at risk, and shoreline changes are regularly monitored and reported by WRC.

Use of Remote Sensing and GIS in Coastal Zone Management

Remote sensing and GIS can be identified as essential components in data collection, analysis, and presentation of outcomes in coastal zone management. Most of the studies related to coastal research have been using data extracted from satellite imagery and aerial photography which are remotely sensed data. GIS provides an advanced platform to analyze and visualize spatial data.

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Image classification and change detection are some important techniques used in remote sensing. A study was directed by Weismiller & Momin, (1977) to develop and evaluate different techniques to detect a change in coastal environments, based upon computer-aided analysis of Landsat data. The Matagorda Bay estuaries on the Texas coast were the study area which consisted of land use types divided principally among agriculture, rangeland, urban, industry, recreation, and large marsh-covered tracts.

Study Area

Geography of the Study Area

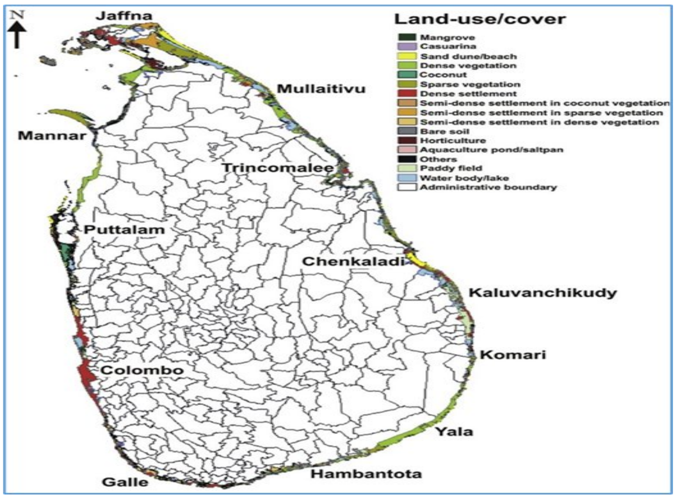

Figure 3.1 : Land cover classification of Sri Lanka's coastline (Satyanarayana, et al., 2017)

According to a study done by Satyanarayana, et al., (2017), the Sri Lankan coastline has been classified considering its land cover/use as shown in Figure 3.1. Coastal areas in and southwards of Colombo have been classified under the 'dense settlement' category. Being situated just south of Colombo metropolitan region, the study area is highly urbanized, especially alongside the Colombo-Galle main road.

The coastline stretch chosen as the study area lies between Kalutara and Moratuwa on the western coast of Sri Lanka (Figure 3.2). The northernmost limit is the outlet of Lunawa lagoon in Angulana, Moratuwa in Colombo District while the southernmost limit is Katukurunda village in Kalutara District. The length of the selected coastline is approximately 30km.

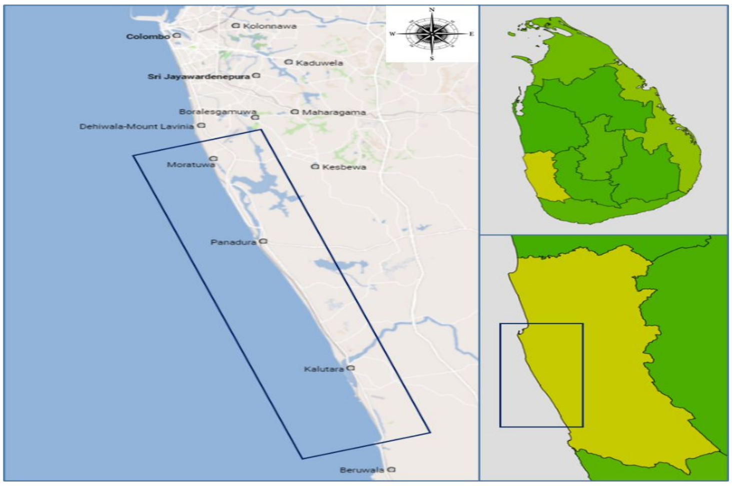

Figure 3.2: Coastal zone stretch chosen as the study area

This coastline experiences severe coastal erosion during the southwest monsoon from May to September (Lakmali, et al., 2017). However, this is not a permanent feature as the coastline is accreted during northeast monsoon due to calm weather conditions making the coastline fairly stable.

Figure 3.3: Typical natural vegetation along beaches in the study area

Hydrology of the Study Area

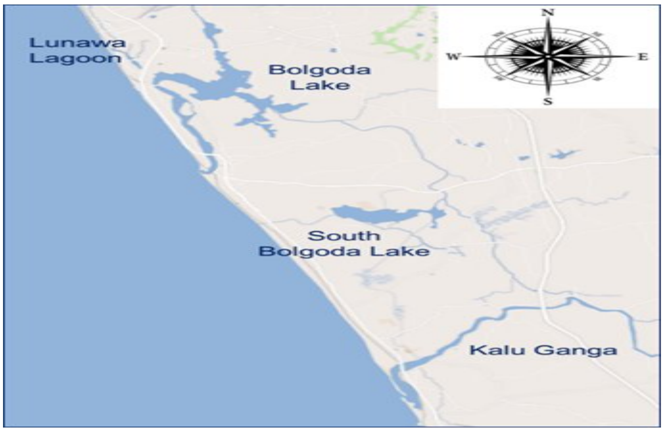

Figure 3.4 : Hydrology features within the study area

Furthermore, the study area consists of several major inland water bodies that outflow to the sea from several locations as shown in the map in Figure 3.4. They are Lunawa Lagoon, Bolgoda River, South Bolgoda River, and Kalu Ganga River which outflow to the sea at Angulana, Panadura, Pinwatta, and Kalutara areas respectively.

Administrative Status and Demographics

The study area consists of three major administrative divisions namely,

1. Moratuwa DS division
2. Panadura DS division
3. Kalutara DS division

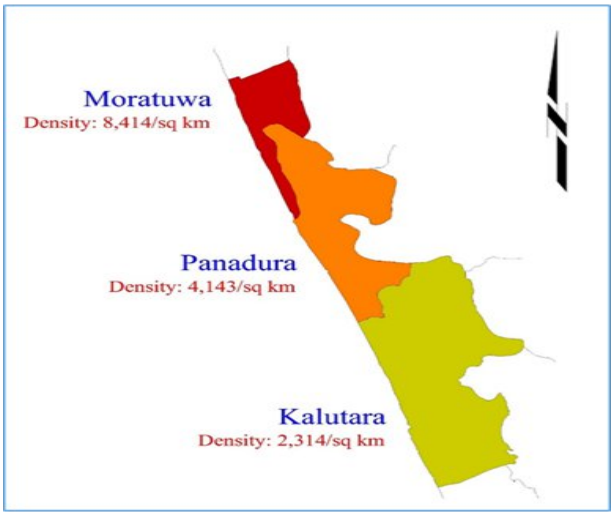

Figure 3.5 : Population density of DS divisions (2012 census)

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The population density of these three DS divisions is illustrated in Figure 3.5 with reference to the 2012 census. According to the details, the Panadura division has a population density nearly twice the figure of the Kalutara division. Interestingly, the population density of Moratuwa is also nearly two times higher than the density of Panadura. In general, the density of built environment in a particular area can also be assumed to be proportional to the population density within that area. Thereby, the population density pattern of these divisions provides an ideal opportunity to contrast the impact of the built environment among DS divisions.

The major towns of the study area are also Moratuwa, Panadura, and Kalutara. The local government details of them are shown in Table 3.2.

Table 3.2: Population of major towns (source: 2012 census)

Town	Status	Population
1. Moratuwa	MC	168,280
2. Panadura	UC	30,069
3. Kalutara	UC	32,417

METHODOLOGY

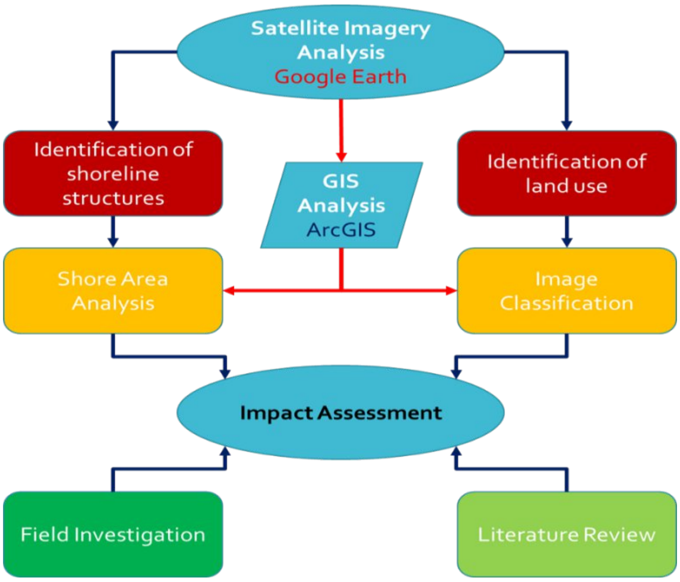

Figure 4.1 : Flow of methodology

The key procedures of the study and the basic flow of methodology are highlighted in the Figure 4.1. The main data source was Google Earth and it was helpful by being a platform for data analysis as well. The two major tasks of the analysis were shore area analysis and image classification which were carried out using various facilities available in ArcGIS 10.7.1 software. The outcomes of both of these analyses were considered along with field observations and reviews of past studies for the impact assessment of built environment growth.

Data Collection

The primary data source for this study was historical satellite imagery available on Google Earth. The resolution of images since 2004 (which is around 40cm) was satisfactory enough to detect temporal changes along the coastline. But the main constraint here was that the imagery available in Google Earth have to be used by the analyst despite whatever the conditions. For example, imagery cannot be obtained with respect to the required conditions sometimes due to the cloud coverage. Another option was to download satellite imagery that satisfy the user requirements (such as time period taken, cloud-free weather conditions, etc.) from

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online sources such as USGS. However, the resolution in freely available image sources was found to be not sufficient, especially in the case of coastline variation analysis. Purchasing high-resolution imagery was not considered as it was a much costlier option at the moment.

Secondary data were gathered from a field investigation by making observations of the places of interest and making discussions with people who live nearby. Findings of previous studies (which were carried out, especially on Sri Lankan coasts) were also helpful as a secondary data source in several instances.

Data Analyzing

Data extracted from satellite imagery and GPS surveys can be analyzed in ArcGIS environment which enables spatial and temporal analysis using various types of geo-processing tools. Also, ArcGIS software is ideal for representing geographic information using many different layers of data, which makes the analysis very precise and accurate. The image classification process will be helpful to identify different land covers in the study area and their changes over different periods.

Shoreline Change Analysis

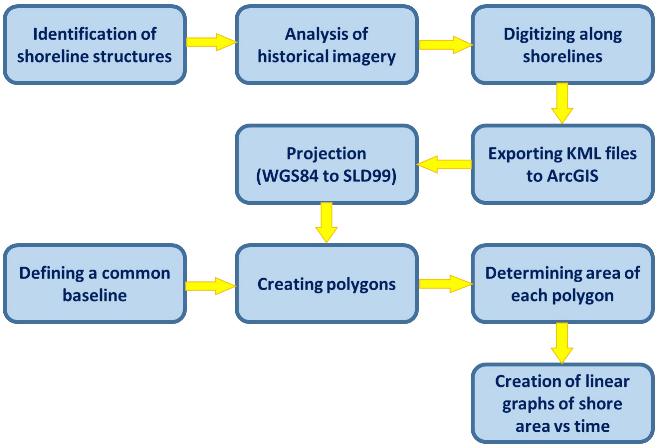

Figure 4.3 : Shore area analysis

The land area has been extended towards the sea in several places where shoreline management structures are constructed and beach reclamation has taken place. To identify the growth and stability of the shore area in such places, an analysis was carried out using data extracted from Google Earth. Polylines were created by digitizing the shorelines of historical satellite imagery which belong to the same month or period of the particular year (Figure 4.2). These polylines were then imported into ArcGIS to create polygons using a common baseline.

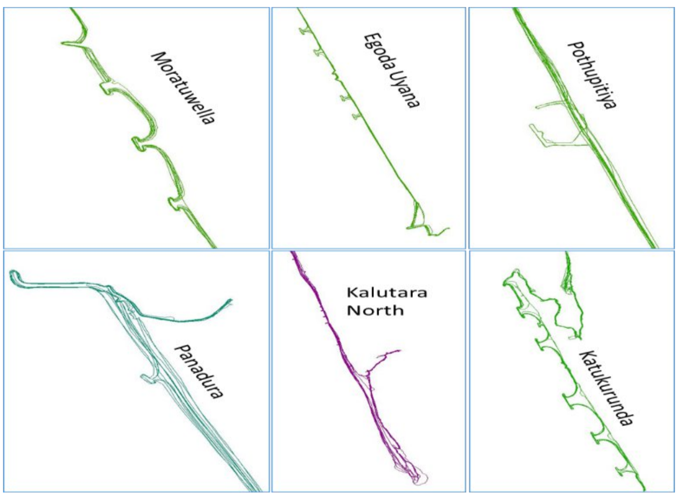

Figure 4.2 : Extracted shorelines of different years within the considered timeline

However, it is impossible to get the area of polygons in square meters as long as the coordinate system of the map layer remains in WGS84. Therefore, the map layer was projected into SLD99 which is the national coordinate system of Sri Lanka. Feature areas can then be viewed in square meters and the area figures were graphed over the respective captured dates of satellite images.

Image Classification

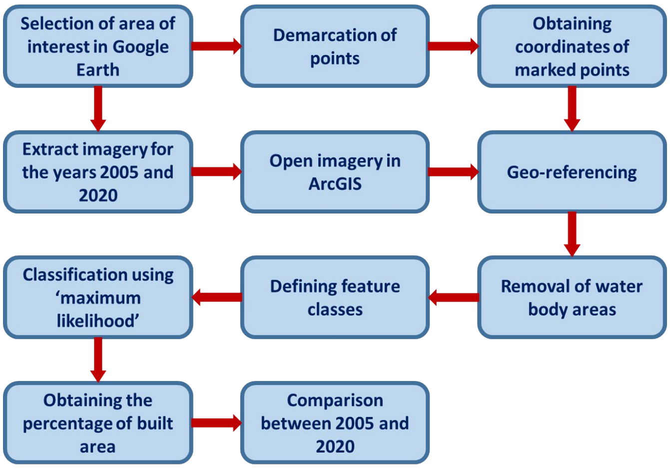

Figure 4.4: Image classification process

Figure 4.4 indicates the overall process of image classification and its sub-tasks. Seven locations of the study area were selected in Google Earth which was adjacent to the coastline and other major water bodies in the area; Kalu Ganga River and Bolgoda River (as indicated in Figure 4.5). The imagery was downloaded in their highest resolution (around 0.37m) available on Google Earth for the years 2005 and 2020 for each location. Images were set to include approximately 1km distance of land area from the coastline and the image tilt was set to zero always to avoid spatial distortions. The locations selected were Egoda Uyana, Panadura, Wadduwa, Vaskaduwa, Kalutara North, Kalutara South, and Katukurunda (see Figure 4.5). Then the imagery was transferred to ArcGIS and geometric corrections were made using the geo-referencing tool. At least three known coordinates are required for geo-referencing each image and therefore four coordinates were used to get better accuracy and verification.

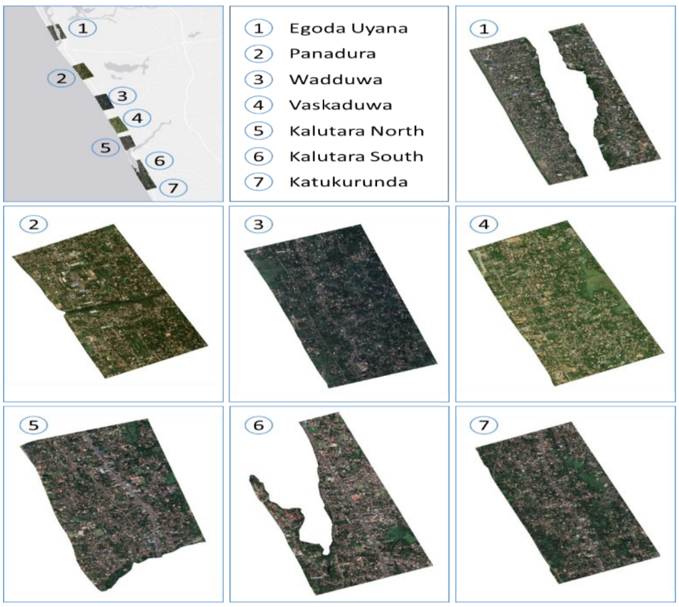

Figure 4.5: Key areas finally selected for classification

It was noted that areas with rough sea conditions in satellite images were making problems in classification. Also, the purpose of the classification was to estimate the extent of the built environment in the land area. As

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sea areas were not necessary for the classification process, they had to be removed before classification. The 'mask' tool in ArcGIS was helpful in this task to extract only the required area from the geo-referenced image. It was assured to keep the same cell size while masking to remain the image resolution as same.

The image classification process was carried out by considering three main land types (Figure 4.6);

1. Tree cover (includes home gardens, mangrove forests, coconut estates, and other dense vegetation)

2. Greenfield (includes grasslands, paddy fields, playgrounds, and swampy areas covered with aquatic plants)

3. Built area (includes buildings, roads, railway tracks, construction sites, and any other area paved by concrete/asphalt)

Training samples were selected from each image to specify classes and they were saved as 'signature files' which were later used for image classification. Training samples were chosen as 'polygons' from clearly identified homogeneous areas from the image to form each class (tree cover, green field, and built area) as shown in Figure 4.6. The method used in the study was 'supervised classification' which is a widely used image processing technique to distinguish land cover types in remote sensing studies. Under supervised classification, the 'maximum likelihood' technique was carried out to get the final classified image. Figure 4.7 is an example of a classified image within the study area.

Figure 4.6 : Selection of training samples (tree cover, green field and built area)

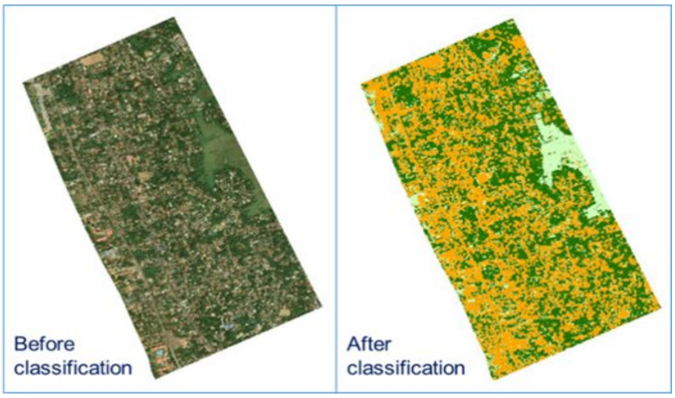

Figure 4.7 : After image classification carried out for a selected area

Impact Assessment

Field visits were carried out in August 2022 to make observations in several places along the study area to get a general insight into the impact of built area growth. Discussions were made with residents in the area regarding built area growth and environmental issues related to it. The details received from residents were helpful to understand environmental and socio-economic impacts of built area spread. The outcomes of previously held studies on similar scenarios, which are highlighted in Chapter 2 (Literature Review) were also considered for the impact assessment.

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RESULTS AND DISCUSSION

Shore Area Variation

Areas identified with significant shoreline changes are displayed here onwards with respect to the variation of the shore area. The variations are graphed over time and the nature of change is described with the amount of addition/reduction of the shore area. All the changes have occurred due to shoreline management structures except in Kalutara, where the shore area had collapsed due to improper flood management measures.

Moratuwa

According to the graph, it can be identified that shoreline management structures have upgraded the stability of the Egoda Uyana and Moratuwella coastlines to a certain level. However, the deposition of sediments (coastal accretion) remains unstable as the graph indicates sharp rises and falls of shore area, even after the completion of shoreline structures. All the shorelines extracted here are from January month of the respective year, which is within the northeast monsoon period when coastal accretion usually happens along the southwest coast of Sri Lanka. The shore area of the considered area has been increased by more than 20,000m^2 with the addition of shoreline management structures.

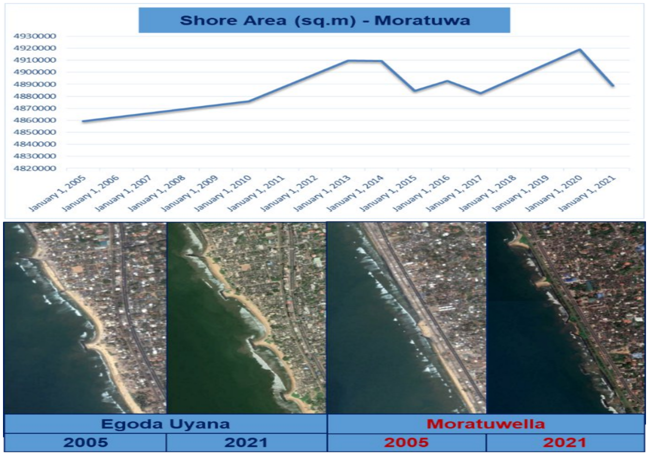

Figure 5.1: Shore variation – Egoda Uyana and Moratuwella

Panadura

In Panadura, the southern bank of the Bolgoda river mouth is well stabilized by the construction of the breakwater, which also demarcates the passage for fishery boats of the Modara fishery harbor. The shore area of Panadura beach has also increased significantly over time as seen on the graph. The increase of the shore area in Panadura beach is about 80,000m^2 due to the construction of a breakwater.

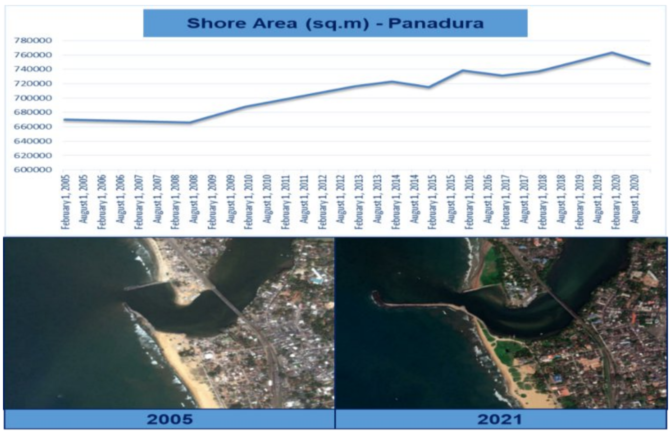

Figure 5.2: Shore variation - Panadura

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Pothupitiya

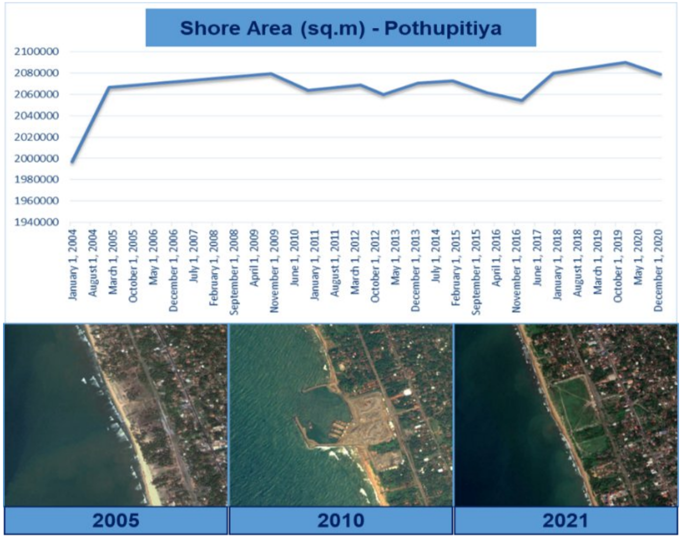

Figure 5.3: Shore variation - Pothupitiya

The Pothupitiya area consists of a natural dynamic coastline with a long sandy beach, unobstructed by shoreline constructions as found in satellite images. However, a small temporary harbor existed during the 2009-2010 period to transfer quarry material from the land to ships for the use of the Colombo Port expansion project. The harbor had been removed after the completion of the project in 2011. According to the graph and satellite images, any significant change in the coastline cannot be identified other than seasonal erosion and deposition patterns depending on monsoon periods.

Kalutara

The northern bank of Kalu Ganga river mouth had been stable for a long period until floods occurred in 2017 May. Some places on the sand bar which consisted famous Calido beach were excavated during the floods to make way for the water outflow to control the floods in Kalu Ganga. However, it caused the permanent collapse of the sand bar and decreased the beach area significantly as can be identified on the graph. The incident 'reduced' around 200,000m^2 of beach area (according to the graph) and made the Kalutara town area vulnerable to coastal erosion (Gunasinghe, et al., 2019). Later, the CCD started a beach reclamation project which was completed in 2020 adding an area of over 300,000m^2 of reclaimed land attached to the southern bank of Kalu Ganga river mouth, which is now identified as New Calido beach.

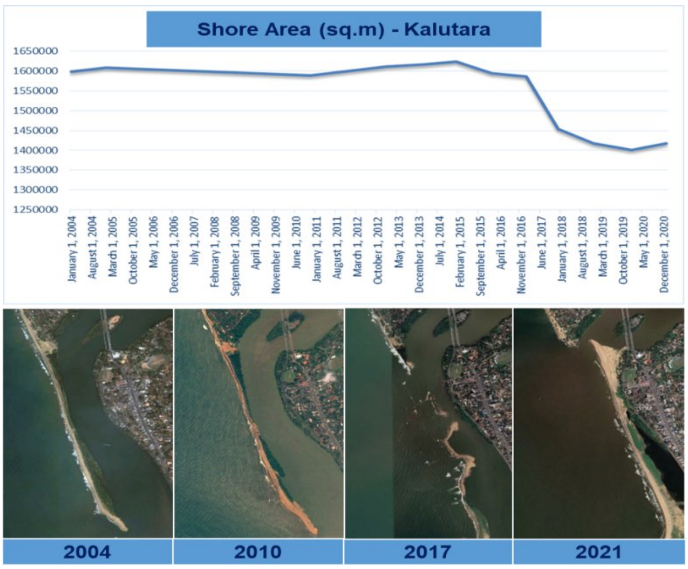

Figure 5.4: Shore variation – Kalutara

Katukurunda

The continuous construction of modified breakwaters (or artificial headlands) along the Katukurunda coast south of Kalutara town has contributed towards a gradual increase in shore area according to the results. And also, the coastline remains stable from 2012 onwards. The construction of shoreline structures had taken place during the 2004-2018 period with reference to historical satellite imagery. The addition of artificial headlands has contributed to an increase of shore area by around 150,000m^2 in this selected area.

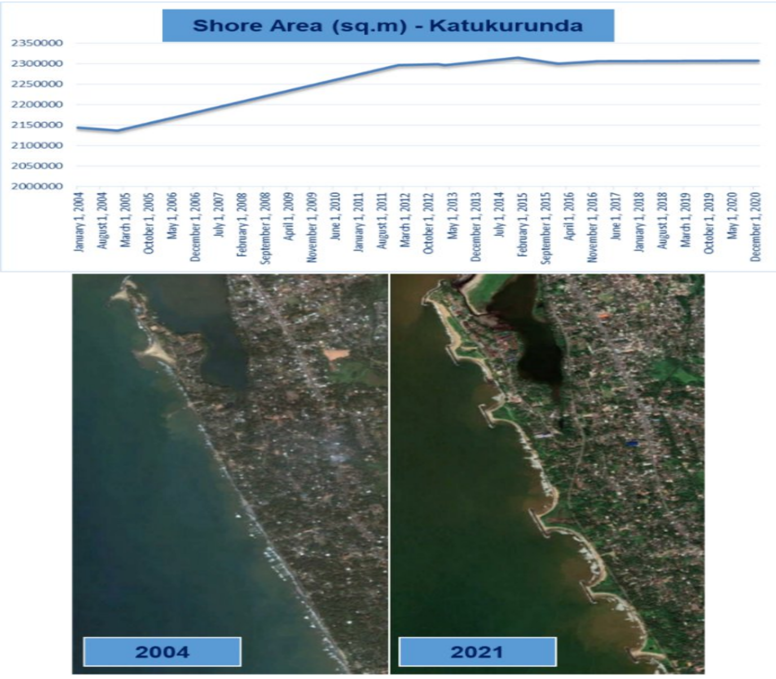

Figure 5.5 : Shore variation - Katukurunda

Outcomes of Image Classification

Out of the selected areas, Egoda Uyana has the highest built area density (60-65%) while Wadduwa is found to be the lowest (20-30%) for the entire 2004-2021 period.

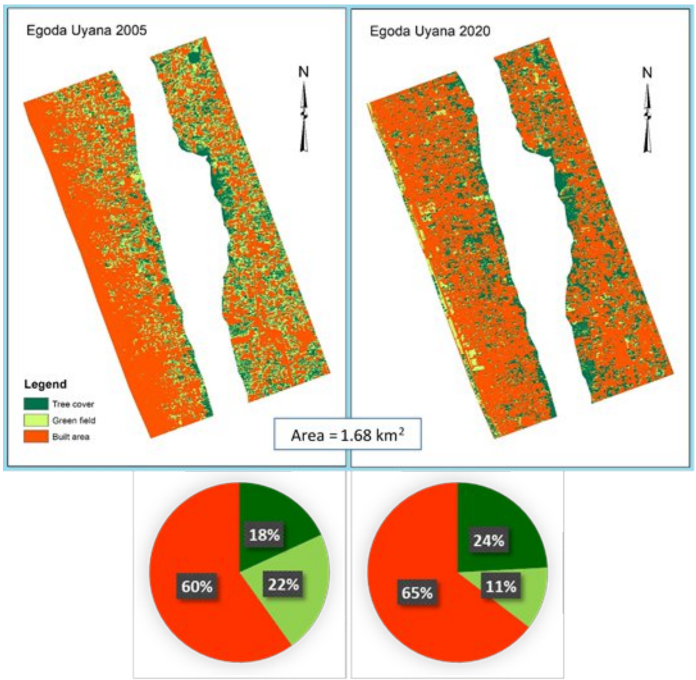

Figure 5.6 : Classification result - Egoda Uyana

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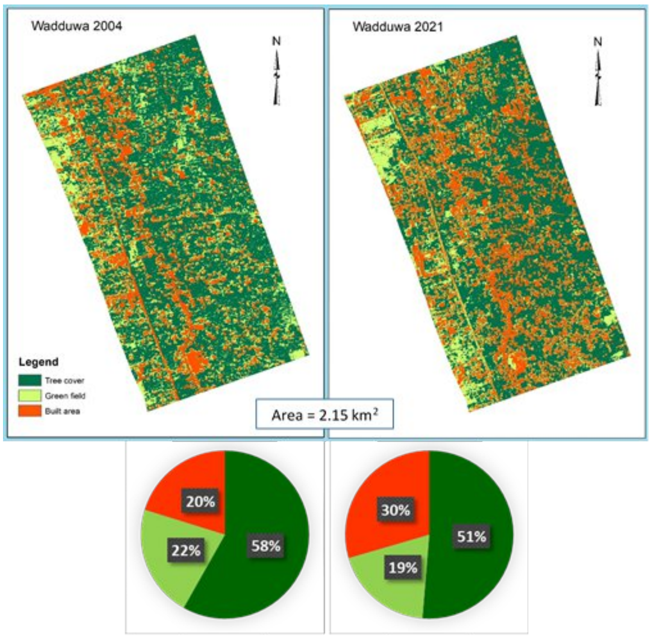

Figure 5.7 : Classification result – Wadduwa

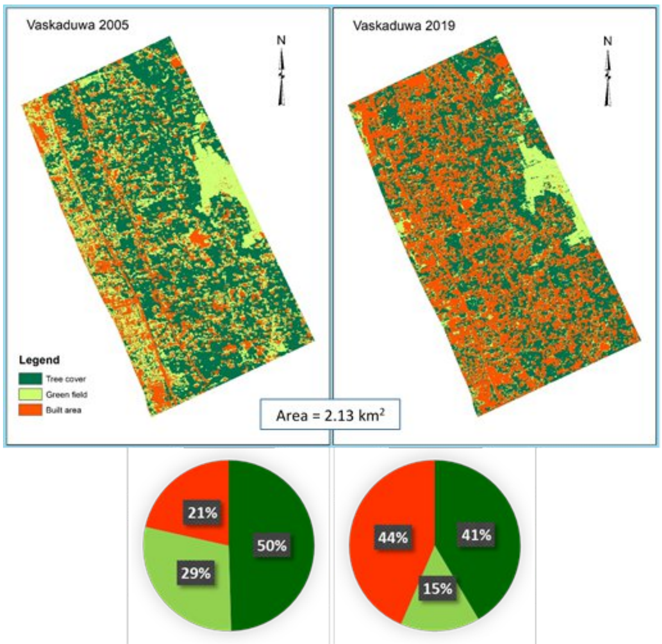

Figure 5.8 : Classification result – Vaskaduwa

Significantly, Vaskaduwa area has shown the highest percentage in terms of built area growth; more than doubled from 21% to 44% of built-up area coverage for the considered timeline, as seen in Figure 5.8.

Table 5.1 : Summary of Image Classification Results

Classified Area	Built Area		Tree Cover		Green Field	
	2005	2020	2005	2020	2005	2020
Egoda Uyana	60%	65%↑	18%	24%↑	22%	11% ↓
Panadura	28%	39%↑	51%	48%↓	19%	11% ↓

Wadduwa	20%	30%↑	58%	51%↓	22%	19%↓
Vaskaduwa	21%	44%↑	50%	41%↓	29%	15%↓
Kalutara N.	34%	48%↑	34%	38%↑	32%	14% ↓
Kalutara S.	40%	54%↑	39%	35%↓	21%	11% ↓
Katukurunda	20%	35%↑	49%	42%↓	31%	23%↓

Limitations and Problems with Classification

For the image classification, images were extracted which were in cloud free condition. However, in certain instances there were some images with little cloud coverage and unclear conditions due to the fog. These conditions may have caused wrong impressions in classification process and it was found that clouds are misinterpreted as built area. However, only a few of the images had been unavoidable with the problem of cloud or fog since most of the times, there were clear satellite images within or closer to the required time period when the desired image was covered by clouds or fog.

It was understood that the shade of the buildings and trees make wrong impressions in classification. This factor was also unavoidable since the shaded areas were too dark and classified as 'tree cover' in many instances although they were built areas in reality. Also, it was noted that the spectral quality of the images greatly affect the process of classification. The images extracted from 2020/2021 were in good quality and the images from 2004/2005 were not appeared to be in that clarity. The reason behind this may be the differences of spectral resolution of images due to the advancement of the image capturing techniques over the time.

The effect of 2004 tsunami was clearly visible in the Egoda Uyana 2005 image (Figure 5.6) and the devastated area had been classified as 'built area' by the classification process. The southwestern stretch of the classified image appears in constant red which indicates built area.

In general, there is an 'accuracy assessment' process available in many image processing applications (such as ERDAS) that can be carried out during the post classification. It enables the user to determine the accuracy of the classified zones of the processed image over the ground truth. However, this option was unavailable in ArcGIS 10.7.1 and therefore the accuracy of the classified images cannot be determined.

Overview of the Impact – Shoreline Engineering

An important concern about shoreline management structures is that they diminish the natural character of beaches, making them a distraction to tourists. It has also been observed by a coastal community that much of the coastal vegetation had disappeared after the construction of shoreline structures in the area. Beach nourishment which is usually supported by submerged breakwaters, is relatively a good option to create a friendly environment for tourism and recreation while providing coastal protection as well.

Also, the construction of coastal protection measures involves a huge cost. For example, the beach reclamation project in Kalutara cost an amount of Rs. 890 million (Daily Mirror, 2020). Another environmental concern is the large amounts of quarry rock extracted for the construction of shoreline structures. In general, huge numbers of cubic meters of quarry rock are required for the construction of groynes, breakwaters, and revetments.

The map shown in Figure 5.9 illustrates the overall nature of the coastline of the study area to the installment of shoreline structures. The coastline can be categorized into four main sections according to the characteristics identified during the shoreline analysis.

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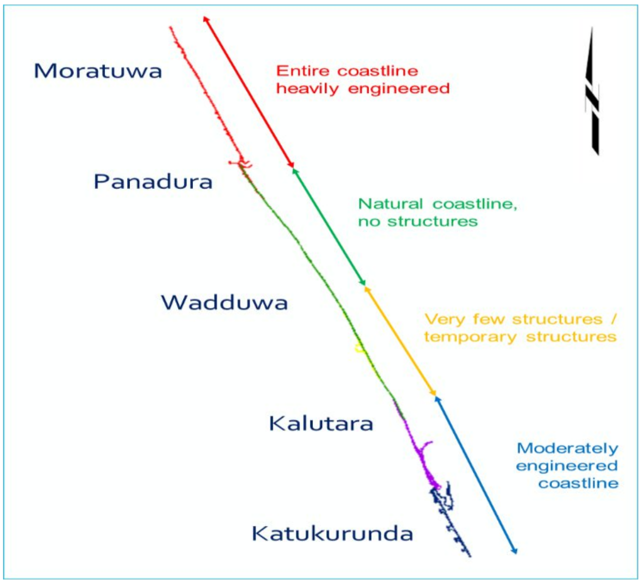

Figure 5.9: Identified nature of coastline sections

It is notable that the Moratuwa area (including Egoda Uyana), which has the highest built area density for both 2005 and 2020 years (60% and 65% respectively) according to the post-classification images shown in Figure 5.6, has an entirely engineered coastline. In contrast, the Wadduwa coast which indicates the lowest built area coverage for both years (2004 and 2021, 20% and 30% respectively as highlighted in Figure 5.7), exists in a very natural condition since no shoreline structures were identified during satellite imagery analysis along Wadduwa coast.

CONCLUSION

The study was focused on identifying the impact of urbanization mainly by analyzing satellite imagery. The study area was selected from Moratuwa to Kalutara on the west coast of Sri Lanka. The population density figures of nearly 2000, 4000 and 8000 persons per sq. km in the three DS divisions were ideal to contrast the impact of built environment with respect to the population density of each division. The analyses were carried out considering two main indicators; shore area variation due to shoreline constructions and growth of built area coverage. Overall, the shoreline constructions were identified as performing well in maintaining the coastline stability as highlighted inshore area variations found in several locations. However, the natural character of the coastline was diminished by these shoreline structures causing a possible threat to tourism.

When considering the summary according to the details in Table 5.1, it is significant that all the areas selected for classification indicate a growth in built environment, most probably due to the urbanization southwards of Colombo. In addition, a growth in shoreline constructions is also noted in many parts within the study area converting much of the natural coastlines into engineered coastlines.

Moreover, it was noted that shoreline constructions have been installed mostly in coastal zones with high-density built area coverage. Even the existing natural character of other coastlines is also likely to disappear soon as the built environment continues to grow rapidly. Therefore, strict guidelines should be included and followed in coastal zone management in order to control the spread of the built environment, since many environmental issues were observed prevailing in densely urbanized coastal areas.

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