Analysis of Hambanthota Coastal Zone Infringements Enforced by Coast Conservation and Coastal Resource Management Using Remote Sensing

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Abstract— *Sri Lanka is still a developing country. Therefore, various changes are taking place in the construction sector, both legally and illegally. Such illegal constructions are common in developing countries. With the development of the country, the number of illegal settlements is increased along the coastal zone of Sri Lanka. This process is harmful to the coastal conservation of the country. Therefore, Coast Conservation Act 1981, 1988, 2011(Amendment) was implemented by Coast Conservation and Coastal Resource Management department to protect coastal zone and reduce unauthorized constructions but there is a problem with whether the regulations of the Coast Conservation Act is properly followed or not at the coastal management zone. So, the main objective of this study was to identify infringements in the coastal zone. Locations were selected for this study by experies of this field and they were from Kudawella west to Mawella south and from Unakoratuwa west to Medaketiya in the Hambanthota district because that areas were the highly affected locations through the district. To fulfill that main objective of study, the proposed methodology was to create normalized difference build-up index maps using Landsat satellite images and final vegetation line coordinates. As final result, this study gained reclassified building index map for selected locations and this study depicts the role of remote sensing and geographic information systems to identify the sustainable development growth of an area.*

Keywords— **Coastal zone, Coast Conservation Act, Normalized Build-up Index**

I. INTRODUCTION

A. Background of the study

Sri Lanka has an open economy and is continuing in development. Therefore, various changes are taking place in the construction sector, both legally and illegally. In fact, such illegal constructions are common in developing countries as a result, the authorized departments are facing various problems due to these unauthorized constructions. Considering the quality of most of the constructed projects, it is less than other constructions. However, the quality of the projects does not affect the study as this study considers compliance with coastal protection laws and regulations in the coastal area (UDA, 2019).

This study never says that development in coastal zone is not a good thing but through this study, it has been investigated whether there has been a violation of the coastal zone on the Hambantota coast or not. The term "coastal zone" describes the region between a limit of 300m in direction of the land of the Mean High Water (MHW) line and a limit of two kilometers in the direction of the sea of the Mean Low Water (MLW) line in the Coast Conservation Act, No. 57 of 1981.Remotely sensed (RS) data and Geographic Information Systems (GIS) technologies are highly useful for such kinds of studies because RS analysis does not touch details physically. So, the user only wants knowledge about the analyzing process. They are modern technologies to deviate buildings from the satellite image. Also, can make a building index through satellite images with an understanding of building materials. Furthermore, this analysis hopes to give the required information about the infringement of coastal areas developed and undeveloped constructions. Accordingly, through this analysis, the authorized departments can get an understanding of the risk situations in those areas and the actions to be taken in the future. Also, can provide knowledge to people who continue day-to-day life in the coastal belt (CCCRMD, 1981).

B. Case Study

Sri Lanka is also making some progress in development while the world is advancing rapidly under new technologies. One of the biggest issues with the nation's overall growth is urbanization. With the development of the country, the number of illegal settlements is increased along the coastal area of Sri Lanka because there is a passion to work and live in the urban area. Districts close to the coast area to have major authorities and prominent locations in the city near the coast. Therefore, the establishment of human settlements near the coastal zone has accelerated. This process is detrimental to the country's coastal conservation. Therefore, Coast Conservation Act 1981, 1988, 2011(Amendment) were implemented. But there is a problem with whether the regulations of the Coast

Conservation Act are properly followed or not at the coastal management zone. It's a problem for the sustainability of coastal zone (CCCRMD, 1981). During the previous era, the Hambanthota district was also a rapidly developing town, and the coastal zone of the Hambanthota DS division area is also affected area through this manner. So, the investigation of infringement of the Hambanthota coastal zone according to the Coast Conservation and Coastal Resource Management (CCCRM) rules is most important today because there is a lack of analysis done with the help of RS data and GIS methods in Sri Lanka.

The main objective of the study was to analyze the infringement of the Hambanthota coastal zone enforced by CCCRM using RS and GIS by succeeding sub objectives as follows,

- To understand the role of RS and GIS in identifying sustainable development growth of settlement in an area.
- To generate building index maps using RS and GIS.
- To identify the infringement of the Hambanthota coastal zone enforced by the rules and regulations.

II. METHODOLOGY

A. Study Area

Two locations on the Hambantota coast have been selected as the study area and those locations are shown in Figure 1. The Hambantota district is located southeast of Colombo, Hambantota is the country's third low-income district and the state's poorest coastal area having district. The next level of administration in the Hambantota district is organized into 12 DS. They are Tangalle, Hambantota, Ambalantota, and Tissamaharama, all of which are closer to the seaside. So Hambanthota district is one of the excellent locations for this case study because of its rapid development.

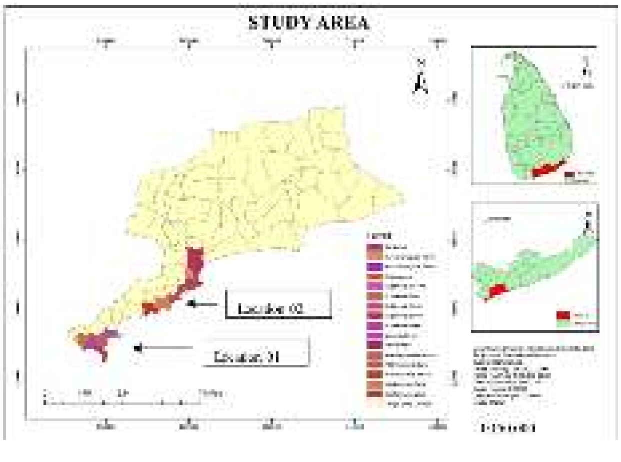

Figure 1: Study area of the experimental study

When considering 130 Km coastal zone there are many hotels, reception halls, ayurvedic spas, fishery harbors, international harbors, highways, national sanctuaries etc. According to specialists of Hambanthota CCCRM, Tangalle DS division is the area which has lot of infringements because of the tourism hotel industry. So, cas for thr case study, a 300m coastal line was selected within 130Km lengthy beach line. Due to representative disturbances, Tangalle DS division area was chosen for the case study and from that special GN divisions were selected. So, these were the locations in study area,

- Location 1- Kudawella west to Mawella south (Kudawella west, Kudawella south, Kudawella east, Mawella south)
- Location 2- Unakoratuwa west to Medaketiya (Unakoratuwa west, Unakoratuwa east, Pallikkudawa rural, Pallikkudawa urban, Kotuwegoda, Medaketiya)

B. Data

Basically the data were collected through the various platforms that available in open access and government authorities. This study used six Landsat images from four different satellites to deal with different stages of evolution (Landsat 9, Landsat 8, Landsat 7, and Landsat 4-5). The images for different years (2002, 2006, 2010, 2014, 2018, and 2022) were acquired with closer acquisition dates to avoid seasonal fluctuations in this area. Hambanthota Coastal zone development information were collected through Southern Province – Urban Development Authority, Building locations for accuracy assessment were gathered from Google earth and Final vegetation line coordinates, Coastal area construction permit count and other information were gathered from Coast Conservation & Coastal Resource Management Department in Hambanthota.The final vegetation line database was prepared through Arc GIS software platform while adding appropriate attribute information as well.

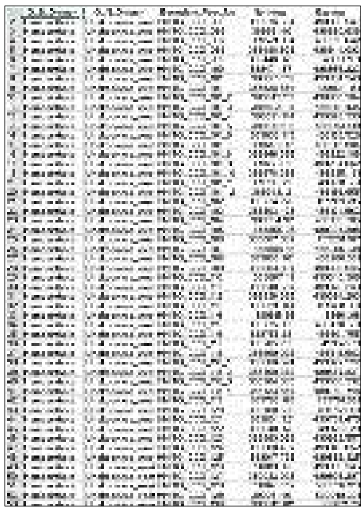

Figure 2: Spatial Database for Final Vegitation Line

SLD 99 Sri Lanka grid was use as the geographical reference coordinate system of the study. Here the program Arc GIS is used to determine the land use of the coastal area to generate NDBI. Finally, it may create maps to depict changes in the research region and classify them according to the value ranges collected.

Here also used Google Earth software and it recognize construction changes over time, but it can also identify ground locations and provide point locations for analysis in ArcMap software. Also used to determine the procedure's reliability of the final output.

C. Methodology

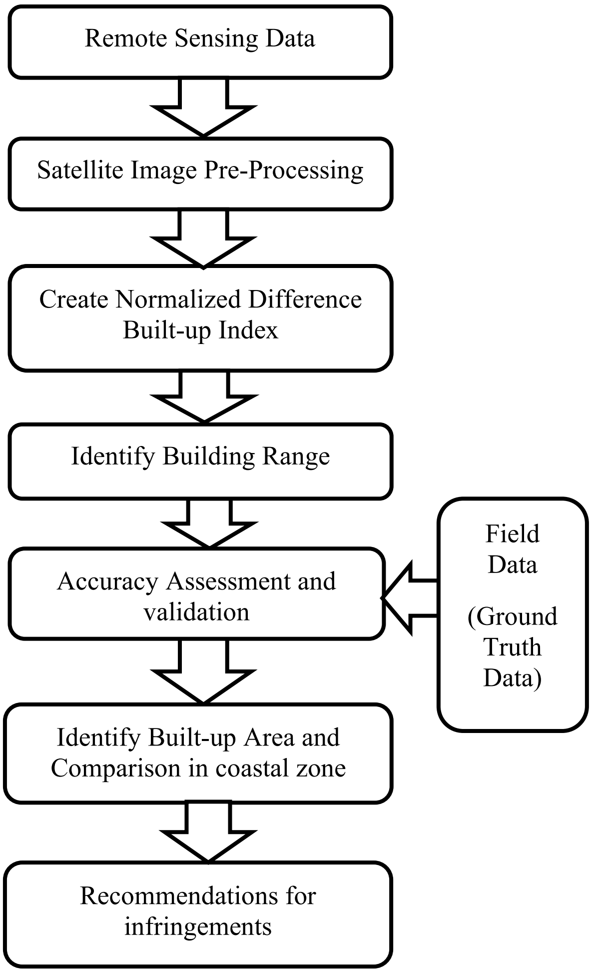

Figure 3: Methodology implemented over the study

First need for the study is the RS images during the time period of 2002 to 2022. Then visual interpretation must relate to the selected image with considering cloud coverage and the scan line corrector error of the satellite image. To make 300m buffer zone into the countryside, final vegetation line of the coastal line was very useful. According to data gathering issues, final vegetation line coordinates/CCD point coordinates were manually input into the excel sheet and then created buffer zone to clip study area from satellite images. The data related to the permits and legal actions issued by the CCCRM department was collected to conduct this analysis.

All of the satellite images used in this study had atmospheric and radiometric adjustments. After atmospheric correction, digital number (DNs to radiance value) data have to turned into "top of the atmosphere reflectance." The pre-processing techniques regarded by many expertise as the more effective, advised to urban studies.In RS, DN value is a changeable value given to pixels. Conversion from DN to Radiance is possible utilizing a metadata file. ArcGIS's raster calculator feature required that formulas be converted into statements that can be entered into calculators. The equation 1 is using to calculate the spectral radiance by using DN values, Multi bands and Add bands.

$$L\lambda = ML \times Q_{cal} + AL \qquad (1)$$

Here Lλ equals to Spectral radiance (W/ (m2 × sr × µm)), ML equals to radiance multiplicative scaling factor to the band (RADIANCE_MULT_BAND_n from the metadata), AL equals to Radiance additive scaling factor for the band (RADIANCE_ADD_BAND_n from the metadata) and Qcal equals to Level 1 pixel value at DN.

CCD points were the shoreline side boundary line. The covering area for coastal zone was 300m from the CCD points to the countryside and it defined as coastal zone. So, it was the case study area, and that strip go over to the processing.

When compared to different land use/land cover areas, built-up land has a maximum reflectance in the MIR wavelength value range (1.55 to 1.75m) among in the NIR wavelength range (0.76 0.90m). In order to calculate NDBI, which is a useful technique for mapping urban built-up regions, use the formula below equation 2.

$$NDBI = \frac{(MIR-NIR)}{(MIR+NIR)} \qquad (2)$$

MIR, or band number 6 of Landsat-8, stands for intermediate infrared reflectance. So, in Landsat-8 band 5, NIR stands for near-infrared reflectance; NDBI values vary from -1 to 1. As the NDBI rises, the proportion of built-up area climbs as well.

More than 700 randomly generated validation points were employed to clearly distinguish between the built-up range and the non-built-up range, and multiple quantitative methods were used to evaluate accuracy. To determine the level of trust, gather more than 600 built-up and unbuilt-up sites once more. The total accuracy is calculated using this method as the percentage of all correctly predicted to all validation samples. The classification findings' similarity to random values is gauged by the Kappa coefficient.

Through the image classification and finally analyzed the variation of the infringement of coastal zone enforced.

III. RESULTS AND ANALYSIS

For this analysis process, ArcGIS program was the main processing platform. Location 1 starts from the Kudawella West to Mawella South and their coastline length was 6.6km. 6 GN divisions were analyzed for create NDBI maps for location 1. Nine GN divisions were analyzed for create NDBI maps for location 2. Coastline length of location 2 was 8.2 km and it starts from Unakoratuwa west division to Medaketiya division. Tangalle coastal zone was the most affected area from the illegal constructions, according to the knowledge of expertise working with coastal zone infringements.

The product of this case study is reclassified building index graphical representation for two locations of case study area. Landsat 4-5, 7, 8 and 9 images were used for image analysis and the resolution of the images was 30m. Before finalizing the output, NDBI maps was the main output of the study. After reclassification through the random points, an accuracy assessment has done proving the user accuracy, producer accuracy, overall accuracy, and the Kappa coefficient for 12 maps. The accuracy assessment of location 1 of the study area for the period 2002-2022 is shown on Table 1. Further, Table 2 represent the accuracy assessment of location 2 of the study area for the period of 2002 -2022.

Table 1: Accuracy Assessment for Location 01 Maps

Year	Produce Accuracy		User Accuracy		Overall Accuracy	Kappa Coefficient
	Built-Up Area	Non Built-Up Area	Built-Up Area	Non Built-Up Area		
2002	90.90%	100.00%	100.00%	90.00%	95.00%	0.84375
2006	95.20%	100.00%	100.00%	95.00%	97.50%	0.91266
2010	95.20%	100.00%	100.00%	95.00%	97.50%	0.91266
2014	95.20%	100.00%	100.00%	95.00%	97.50%	0.91266
2018	95.00%	95.00%	95.00%	95.00%	95.00%	0.81818
2022	100.00%	100.00%	100.00%	100.00%	100.00%	1

Table 2: Accuracy Assessment for Location 02 Maps

Year	Produce Accuracy		User Accuracy		Overall Accuracy	Kappa Coefficient
	Built-Up Area	Non Built-Up Area	Built-Up Area	Non Built-Up Area		
2002	88.20%	100.00%	100.00%	92.20%	95.10%	0.84060
2006	100.00%	100.00%	100.00%	100.00%	100.00%	1
2010	90.90%	100.00%	100.00%	93.00%	95.90%	0.86504
2014	85.70%	100.00%	100.00%	89.80%	93.70%	0.80915
2018	93.80%	95.00%	95.00%	96.20%	97.60%	0.90997
2022	88.20%	100.00%	100.00%	92.09%	95.30%	0.84528

Following maps illustrate that the building index in 2006 was less than in 2002 because of the tsunami disaster. The study area has sustaining massive damage to the building index in 2006.

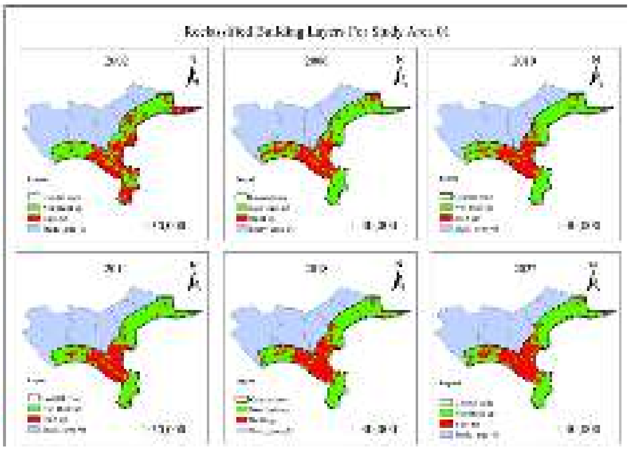

Figure 4: Reclassified Building Index Maps for Location 01

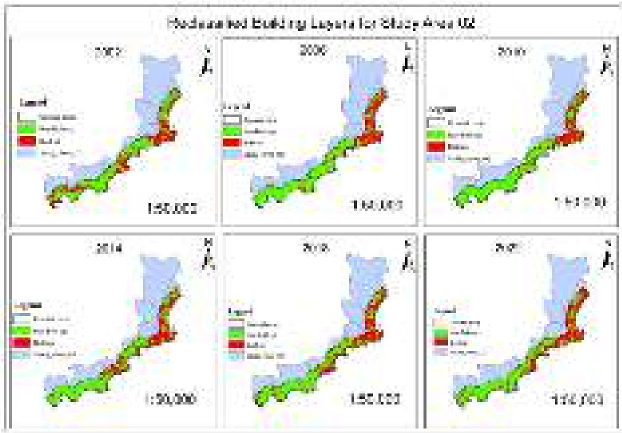

Figure 5: Reclassified Building Index Maps for Location 02

The main reason for that situation is illegal construction. Hence after the tsunami disaster, the CCCRM department implements the rules and regulations for constructing the settlements in the coastal zone. But the problem is, the rules were implemented over a considerable period. Nowadays, according to the building index map of 2022, the building index is highly increased because the rules were not implemented. Further, the identified issue is building permits not issued by the coastal conservation department with increasing the building index of the area. Table 3 represents the classified area calculation for the built-up area and non-built-up area in location 01 from 2002 to 2022.

Above mentioned information is clearly described in Figure 6. By examining the above figures and graphs can be identified the area affected by the tsunami and the drop of building idex from 2002 to 2006. After that how the construction field in the coastal area is increasing from 2006 to 2014.

Table 3: Classified Area Calculation for Location 01

Year	Non-Built-up Area(m×m)	Built-up Area (m×m)	Non-Built-up Area (perch)	Built-up Area (perch)
2002	1296900	837900	51275.05	33127.74
2006	1483200	651600	58640.73	25762.06
2010	1520100	614700	60099.63	24303.16
2014	1387800	747000	54868.93	29533.86
2018	1223900	910900	48388.88	36013.91
2022	1145500	989300	45289.21	39113.58

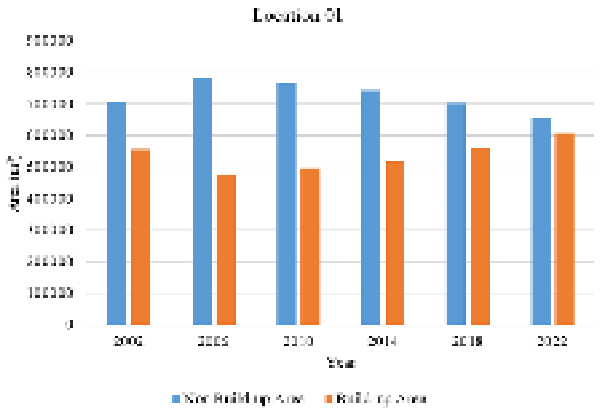

Figure 6: Classified Area Calculation for Location 01

In CCCRM department, there was only permit areas from 2014 to 2022. Between 2014 to 2018 there is 42100m^2 area newly constructed at location 01. It shows the Table 3. But in the CCCRM records there is only 37525.35m^2 area for permits. Also 2018 to 2022 there is 48100m^2 area difference and it shows in Table 3. Here also in CCCRM records there is only 46482.87m^2.

Table 4: Classified Area Calculation for Location 02

Year	Non-Built-up Area(m×m)	Built-up Area (m×m)	Non-Built-up Area (perch)	Built-up Area (perch)
2002	703800	556200	27825.88	21990.27
2006	782100	477900	30921.59	18894.55
2010	763500	496500	30186.21	19629.93
2014	743300	516700	29387.57	20428.577
2018	701200	558800	27723.08	22093.069
2022	653100	606900	25821.37	23994.78

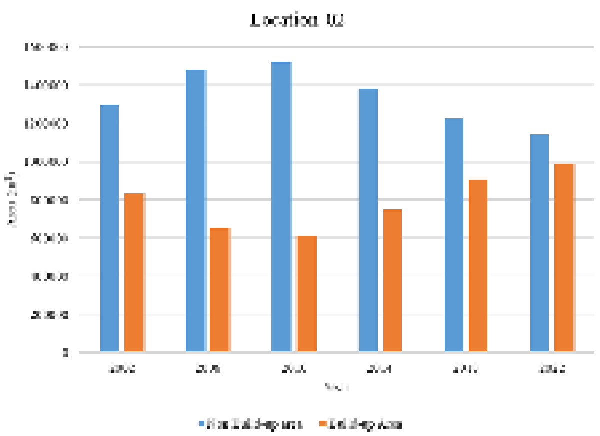

Figure 7: Classified Area Calculation for Location 02

Through that difference can obtained the total infringement area. Between the years 2014 to 2018 there is 163900m^2 area newly constructed at location 02. It also showed in Table 4. Here also 158735.67m^2 in CCCRM permits. The area difference between 2018 to 2022 in classified maps is 78400m^2. There only include 75289.51m^2 permit area (CCCRMD, 1981).

Through that details, location 01 and 02 areas can define as infringement areas. The main reason for that is the building index is highly increased from year 2014 to 2022. It can be clearly identified by illustrating the above figures and the NDBI analysis. Further, this information was clearly reported in CCCRM department.

IV. DISCUSSION

As mentioned earlier, Sri Lanka is still a developing country. People settled in the coastal region for personal reasons. They decided to live in the coastal areas because there is no place to settle on the upper side and because most of the coastal areas are very close to urban areas and it is very convenient for them to conduct their daily life. However, construction is essential for the development of a country, the constructions that are being done and are destroying the environment are being filed and here it studied as a summary with using NDBI techniques.

The coastal region, which has been gradually developed for the past 20 years, was completely destroyed by the 2004 tsunami disaster, as well as business constructions and the homes of the common people. It's clearly depicted by 2002 and 2006 maps (Anputhas et al., 2005). Through the column chart can identify the building area variations. According to column chart can mainly identify how the building index increasing. 2010-2018 time period was golden era for the construction field. So, in that era graph directly shows huge increase of buildup area. Due to this huge increasing rate the coastal zone will covered with buildings entirely. So CCCRM department had to get actions to secure the coastal zone. The accuracy of the output of the study can improved if QuickBird satellite images are used instead of Landsat satellite images to conduct the analysis.The study should be conducted covering entire coastal area of Sri Lanka because Sri Lanka is an island and current coastal areas are filled with unauthorized constructions. So, through this kind of study those unauthorized areas can be detected, and necessary actions can be taken to minimize such issues.

If there any need to construct sustainable development at coastal zone, CCCRM Department have a responsibility to issue permits for that project in secluded areas in coastal zone. RS and GIS act huge role to finding such kind of area. Also analyses through RS and GIS are very useful because representing purpose is very important to identify infringements.

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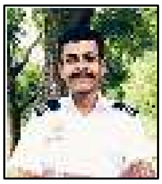
ACKNOWLEDGMENT

I would like to express my sincere gratefulness towards to the Faculty of Built Environment & Spatial Sciences of General Sir John Kotelawala Defence University who assisted to success this research and special thanks to Coast Conservation and Coastal Resource Management Department and Urban Development Authority for helping me to succeed in this research. I would like to acknowledge every person who helped us in different ways during the research work.

AUTHOR BIOGRAPHIES



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