Detecting Urban Expansion Trends in Weligama Urban Council using Remote Sensing and GIS

KSLS Hasara#, JPC Singhawansha and NV Wickramathilaka

Faculty of Built Environment & Spatial Sciences, General Sir John Kotelawala Defence University, Sri Lanka

#35-sursc-0004@kdu.ac.lk

Abstract- The extensive history goes back to urban development, and human convinced build-up area and urban spreading through the specific region is one of the most important areas of human-induced urban expansion. Due to the unplanned urban expansion, Urban sprawl is a prominent issue in the cities nowadays. In today's world, these have become important topics in many scientific fields. This study probes the expansion of the 13 GN divisions in the Weligama urban council area. The main objective of this research is to find the urban land expansion index (SI). Remote sensing and GIS (Geographical Information Science) provide some methods for finding the expansion index using satellite imagery. Satellite images were used in 2005, 2010, 2015, and 2020 as primary sources taken by USGS earth explore. By using the NDBI (Normalized Difference Built-up Index) extract the built-up area and then the urban expansion index/sprawling index (SI) were calculated to identify the expansion of the study area. Finally, the maps of expansion of the built-up areas were prepared in Weligama urban council area to identify the urban expansion index. Considering such context for the town planning, it is better to use the expansion and sprawl analysis method to determine the extension patterns to create sustainable development. As per the results, the region has slightly expanded between 2005 and 2010, but between 2010 to 2015 and 2020 it takes a moderate speed for expanding the Weligama urban council area. Consequently, the final output shows that the urban expansion has happened along the beachside to the city center area.

Keywords: *remote sensing, GIS, NDBI (Normalized Difference Built-up Index), SI (Sprawling Index/ Urban Expansion Index), urban sprawl*

I. INTRODUCTION

The sustainable development of the country affects various areas of society. With during the development, the land cover undergoes various changes. Earth is the main nature resources that underlie many development activities. Spatial characteristics of the earth types of land use using and their transformations are tending for the urban planning in sustainable development. Urbanization is a major cause of land and land use changes transfers. Urban spatial expansion directly reflects the development of urbanization (WuDunn, Marc, Zakhor, Avideh, Touzani, et al). We can understand the nature as well advice on spatial decision making for sustainable urban development through urbanization and analysis urban expansion process. In today, a series of problems overwhelming the sustainable utilization of the urbanization considered with the land use, its structure, and the environmental protection. Urbanization monitoring provides essential information for long-term planning. Unfortunately, traditional surveying and mapping techniques are expensive and time-consuming estimate the urban center, especially in developing countries. As a result, interest in research is increasing directed for mapping and monitoring urban sprawl using GIS and remote sensing techniques (Krishnaveni, K. S. Anilkumar,2020)

Remote sensing is extensive technique that physically untouched and detecting objects, records the details by using the characteristics of electromagnetic waves of the objective from far distances and reveals characteristic and changing things through image analysis. This technique is cost effective and technologically

sound in the case of urban sprawl, it is increasingly used in analysis. GIS provides a flexible environment for displaying, storing and analyzing digital data required to detect changes. The combination of satellite remote sensing and GIS technology is becoming more advanced applicable to land use and land cover surveys especially in urban growth area. Weligama Urban Council area was selected as study area of this research because of it is increasing urban area year by year. It is essential to detecting the urban expansion for the urban planners and indicates the changing direction of the urban expansion in the Weligama, decision basis for sustainable urban development in this region.

The main objective of this study research is identifying the direction of increasing the urban expansion of Weligama urban council area. As for the relevant details, Finding the increasing of built-up area and finding urban expansion and sprawling of this case study.

In this study try to define urban expansion by using the changes of built-up area. Therefore, need to extract the built-up area through the NDBI according to the WuDunn, Marc Zakhor, Avideh Touzani,2019. Building area and bare land reflect MIR (Mid Infrared) more than NIR (Near Infra-Red). Water bodies do not reflect the infrared spectrum. For green surfaces, the reflectance of NIR is higher than that of MIR Spectrum. Image classification technology is a long and complex process. So that identifying the built-up area was focused on NDBI. This requires applying synthetic scope and many operations to the final result.

The urban land expansion index (SI), SI is divided into five stages. When SI<0.001%, it represents an area with no changer; when 0.001 %< SI<0.1%, it demonstrates that this area expanded slightly; while 0.1 %< SI<1% represent that area expanded at middle speed; when 1 %< SI<5%, it stands that the area had a fairly rapid expansion; and then SI>5% mean this area got through a sharp expansion (Yang, Jian Pu, Yingxia,2008).

The Weligama Urban Council area has been identified as the planning boundary. Weligama city it is located in the southern coastal strip near Weligama Bay in Matara Southern area. The Weligama Urban Council is the only urban council for the Matara district the urban areas

announced in the Official Gazette in accordance with the Urban Development Authority Law. Weligama Urban council area consists of 13 divisions of GN (Grama Niladhari) covering an area of 543.7 hectares (UDA,2019). Weligama is one of the major tourism attraction destination Matara and main commercial center of Matara district and administrative center of Galle district. Selected study area is extended up to 13 GN divisions around the Weligama urban council area. According to the Census and Statistic data in 2021, total population of the Weligama Urban Council area is 22,030. Basically, Weligama was developed based on the location which is strategically in Weligama Bay and the tourism industry and the fishing industry of the region (UDA,2019). There are several possible areas that can be used and advancing in the urbanization through the urban sprawl and expansion of the development with regarding the tourism and the fishing industry. Figure 1 shows the Study area of this research
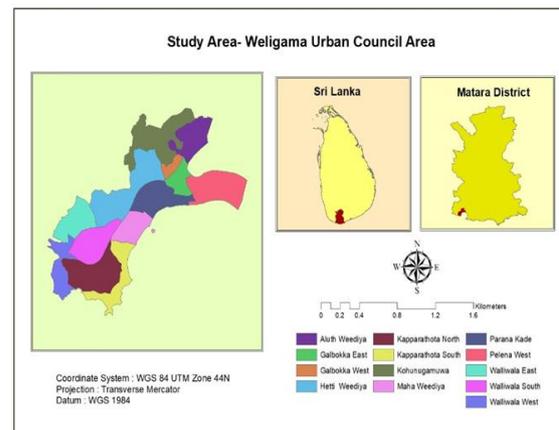

Figure 1. Weligama UC Area
Source: Urban Development Authority

II. METHODOLOGY

SATELLITE DATA

2005   2010   2015

Shape File of Relevant → Image Sub-

Normalized Difference Built

Field data (Google → Accuracy Assessme

Convert to Shape

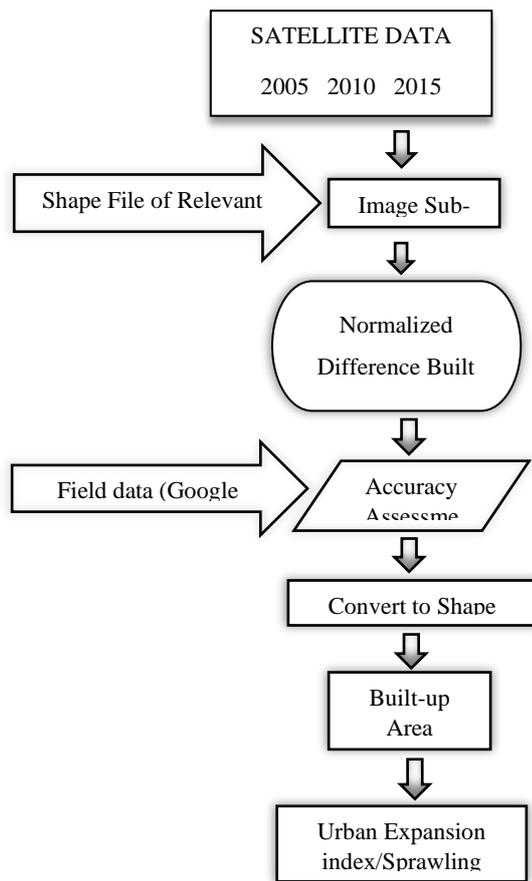Built-up Area

Urban Expansion index/Sprawling

Figure 2. Flow Chart

For this case study and the methodology directly based on the raster base building extraction, building indices NDBI. The analysis of this case study is literally based on the Built-Up area changes in 2005, 2010, 2015, and 2020.

For this study using satellite images for the years of 2005, 2010, 2015, and 2020 as per the basic data source. Data including built up area investigation and recent built-up area from 2005 to 2020. Use data every year-end information. The resolution was 30m of the satellite images.

Table 1: Type of Data used

No.	Type of Data used	Resolution	Year
1.	Landsat 4,5 TM	30m	2005
2.	Landsat 4,5 TM	30m	2010
3.	Landsat 8	30m	2015
4.	Landsat 8	30m	2020

This table shows the type of satellite images and its resolutions by mentioning its respective years. The main source of the data were satellite images which were taken from USGS Earth explorer.

In this study, by using the NDBI formula (Shown in equation 1) we have to extract the built-up areas in the relevant area from the Landsat images from 2005, 2010, 2015, and 2020 respectively. After that need to detect the expansion of the build-up area of the study area and therefore by considering each five years in between 2005 to 2020. According to that process identify the urban expansion in three stages as 2005-2010, 2010-2015, and 2015-2020-years range.

By using the Google Earth, had to extract the build-up areas. Therefore, need to go through with the Google earth and detect the built-up areas as point vice. Generally, when collecting these point locations details at least have to collect approximately hundred points. For this study has to take nearly hundred-point details in respective years. After taking both of these relevant details and data, as for the next step need to investigate the comparison in between the NDBI extraction of the build-up area and the point data gather from the Google earth. NDBI can be calculated by the following formula. The figure 3, 4, 5 and 6 are shown the built-up area of respectively years.

$$NDBI = (MIR - NIR)/ (MIR + NIR) \longrightarrow 1$$

In Landsat 4-5 thematic mapper (TM), band 4 denotes the IR and band 5 denotes the MIR. In Landsat 8 respectively band 5 and 6 denotes to NIR and MIR.

Urban land expansion index (SI) was found by using below equation (shown in equation 2)

$$SI = ((UL_{(i+n)} - UL_i)/ nTUL) *100 \% \longrightarrow 2$$

Where SI says sprawling index/urban expansion index, UL(i+n) and ULi represent the land area at the moment of i + n and i respectively, and TUL is the total land area (Tian et al, 2005). Table 2 and

figure 8 represent statically data of urban expansion.
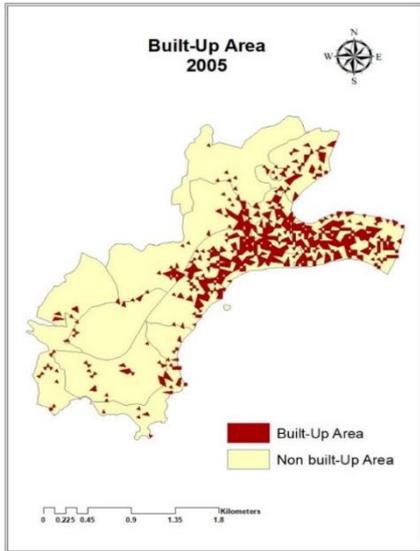
III. RESULTS and DISCUSSION
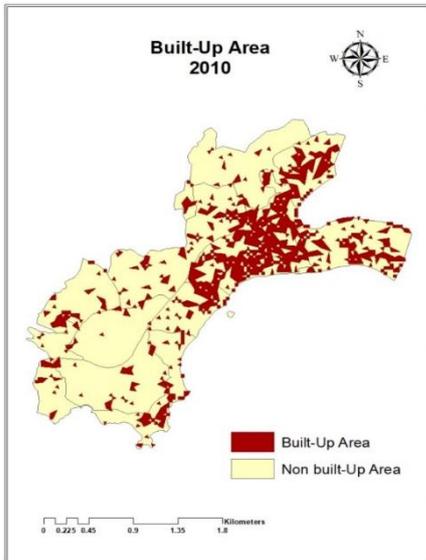

Figure 3. Built-up Area 2005
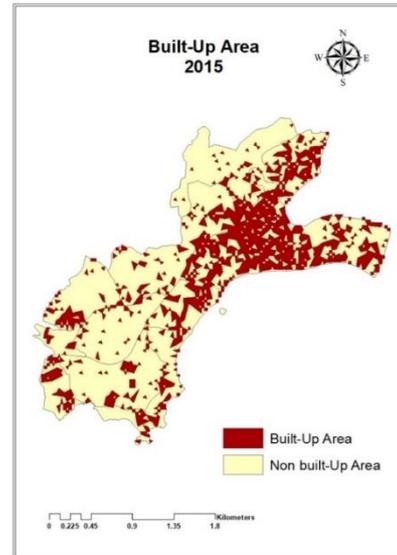

Figure 4. Built-up Area 2010
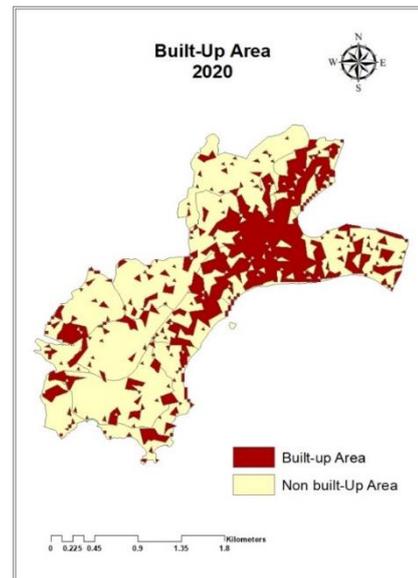

Figure 5. Built-up Area 2015
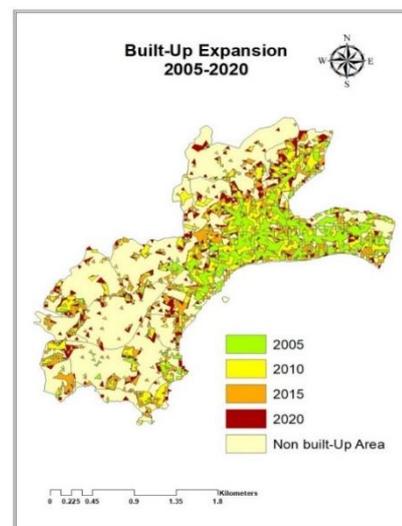

Figure 6. Built-up Area 2020
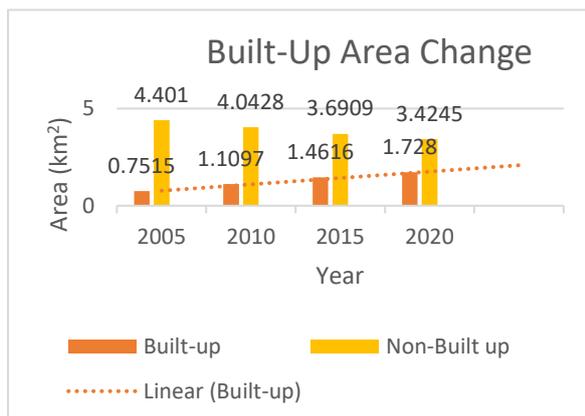

Figure 7. Built-up Area final map

Figure 8: Built-up are change bar chart

Above figure 7 shows how the urban region was expended through the past years. Also, it shows the ratio difference in between built-up and non-built-up areas in the study area. By looking through that gradually the urban expansion is spread among the Weligama Urban Council area. However, the growth of built-up area and its expansion directly affected to the bare lands in the region according to the chart details.

Table 2: Urban Expansion Index / Sprawl Index

GN Division	SI(2015-2020)	SI (2010-2015)	SI (2005-2010)
Aluth Weediya	1.475	0.625	1.875
Galbokka East	1.504854369	0.873786408	1.844660194
Kohunugmuwa	0.510204082	0.233236152	0.626822157
Maha Weediya	0.868167203	0.996784566	0.675241158
Parana Kade	1.023454158	0.66098081	12.36673774
Pelena West	0	1.073825503	-1.040268456
Walliwala East	0.618556701	0.283505155	1.082474227
Walliwala South	0.218818381	0.525164114	0.10940919
Walliwala West	-0.503355705	1.845637584	0.570469799
Kapparathota North	0.141287284	0.737833595	0.266875981
Kapparathota South	0.108108108	0.567567568	1.162162162
Galbokka West	1.978021978	1.538461538	2.417582418
Hettiweediya	0.56372549	0.416666667	0.968137255

The urban expansion index between 2005 and 2010, According to the details shown in table the urban sprawling indexes of the Weligama Urban Council area land use have the following features between 2005 and 2010. In whole five years the area was taken middle speed expansions according to the relevant details. Only Pelena GN division area was the place that does not expand many more. Not only was that Parana Kade GN division expanded sharply in that era. Typically, in 2005 to 2010 Weligama urban council area

does not try to make any unacceptable expansions during this period of time. The urban expansion index between 2010 and 2015, from the table it can be seen in Pelena west, Walliwala west and Galbokka west GN divisions were trying to reach the fairly rapid urban expansion. Rest of other GN divisions were slightly expanded during this 2010 to 2015 time period. The urban expansion index between 2015 and 2020.When considering the 2015 to 2020 five years of period Aluth Weediya, Dalbokka east, Parana Kade, and Galbokka west GN divisions were increased their expansion in fairly and rapidly. Pelena west and Walliwala west are the only GN divisions that were not any changes since in 2015. However other GN divisions were take their changes in middle speed expansion.

Table 3: Accuracy Assessment

Accuracy Assessment NDBI					
		2005	2010	2015	2020
Producer Accuraccy(%)	Built-Up	85.5522	90.4762	95.7143	90.35088
	Non Built-Up	92	93.0556	88	85.33333
User Accuraccy(%)	Built-Up	95.2381	96.8153	93.7063	90.3509
	Non Built-Up	83.1325	80.7229	91.6667	85.3333
Overall Accuracy(%)		90.4306	91.25	93.02326	88.3598
Kappa Coefficient		0.79681	0.80038	0.844989	0.75684

It measures how well a particular area is. This includes the acronyms for percentage of features observed on the ground that are not labeled on the map. The higher number of leakage errors shows the lower accuracy of the product. Calculated by dividing the number of pixels correctly categorized in either category by the total number of pixels in the corresponding column. User accuracy given by dividing the number of correctly classified pixels in each category, by the total number of pixels

Classify into that category. In overall accuracy takes the probability of an individual being correctly classified by the test. In here it was taken by both producer and user accuracy values.

According to this case study, it is able to reach over 85% in overall accuracy in all the years. Cohen's kappa coefficient, which is commonly used to estimate interrater reliability, can be used in the test-retest context. In the test-retest, the kappa coefficient indicates the agreement between the frequencies of two sets of data collected on two different occasions (Chong

Ho Yu,2005). Considering that by takeover 0.6 range of kappa coefficient while having good level of strength of agreement.

IV. CONCULSION

Built-up areas are considered as indicators of urban expansion phenomenon. In this study based on the built-up area therefore the use of NDBI effective to extract the urban expansion of the area. Commonly used urban expansion Metrix is called Urban Expansion Index/ Sprawling Index (SI) and it is used for measurement, quantification of urban sprawl and urban expansion phenomena in urban developed area.

Since the improvement and opening up, Weligama urban territory has expanded rapidly. Using satellite and remote sensing technology, we can quickly monitor, track and analyze urban expansion. However, this paper has studied the urban land expansion and sprawl in three respective stages of 2005-2010, 2010-2015 and 2015-2020 in Weligama urban council area and the land expansion state of each GN divisions in Weligama Urban Council can be easily seen according to the urban expansion index. Apart from the few decreased due to the changes in administrative divisions, and the territory of the Weligama Urban Council have expanded gradually in every five years. This indicates that the accelerated urbanization process promotes continuous urbanization land use in Weligama urban council area. The accuracy assessment showed that the overall accuracy is 90.76% with kappa coefficient of 0.79975 averagely. Finally, as per the result gaining from this shows that the direction of the urban expansion of the Weligama Urban Council area along the beach side to city center.

Urban planning authorities can take advantage of this techniques for extracting built-up areas and analyzing urban sprawl for effective city planning and sprawl control. there is a need for create innovative approaches and further refine existing methods and techniques in order to take full advantage of diversity from remote sensing data within urban areas.

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K.S.L.S. Hasara. Fourth year student and Undergraduate of General Sir John Kotelawala Defence University, Southern Campus, Department of Spatial Sciences.