Study on Land Surface Temperature and Land Use / Land Cover Distribution in Weligama DS Division, Matara, Sri Lanka

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Abstract - Land use/ Land cover (LULC) changes are mainly related to the reduction in vegetation cover and increased built-up areas in terms of urbanization. One of the significant implications of urbanization is the increase of land surface temperature (LST). The main objective of the study was to assess the spatial and temporal changes in LST with LULC dynamics in Weligama DSD, Matara for the period 2005-2020 using Thermal infrared bands (TIR) of Landsat images. The study further aimed at mapping the spatial and temporal distribution of NDVI and NDBI of the study area and developing relationships between LST and NDVI and NDBI to assess the environmental changes in Weligama DS Division, Matara. The LULC analysis revealed that vegetation (46%) is the abundant land use in the study area, followed by built-ups (32%). Water bodies contribute a smaller percentage (06%). LST map showed a gradual increase in land surface temperature from 2005 to 2020. LST analysis revealed that higher surface temperature in built-up and bare surfaces and low in healthy vegetative areas. The minimum LST ranged from 23-24°C, maximum LST ranged from 32-32.4°C and average LST ranged from 25-27°C from 2005 to 2020. The NDBI and NDVI maps showed a gradual increase in built-up areas and a decrease in vegetation, respectively. Further it indicated that the impact of urbanization was high around the coastal line of Weligama city whereas, the inlands of the study area are occupied with vegetative lands. The developed LST regression model showed a strong positive relationship with NDBI (r^2 = 0.73, 0.61, 0.76 and 0.64) and moderate inverse relationship with NDVI (r^2 = 0.45, 0.60, 0.59 and 0.59) in 2005, 2010, 2015 and 2020, respectively.

Keywords: Land surface temperature, land use/land cover, NDBI, NDVI

I. INTRODUCTION

Population growth, widespread industrialization and migration of rural population to urban areas cause urban expansion. Urban growth and sprawl are global phenomena that significantly influence the biophysical environment, leading to severe ecological and environmental problems [1]. Rapid and unplanned urbanization can change the area's land use/ land cover (LULC), particularly reduction in vegetation cover that increase the built-up areas. One of the significant implications of urbanization is increase of land surface temperature (LST), primarily by heat discharge due to increased energy consumption, increased built-up surfaces having high heat capacities and conductivities and reduction of vegetation cover [1]. Remote sensing and GIS (Geo information system) can be used to map the LST and LULC changes by using visible, IR (Infra-red) and TIR bands and numerous spatial techniques. The analysis of temporal remote sensing data helps in understanding the land cover changes and their impact on the environment. The TIR of space-borne sensors' remote sensing data helps retrieve land surface temperature.

II. MATERIALS AND METHODS

A total of 04 satellite images were selected for the period from 2005 to 2020. Clouds free Landsat 4-5 – MSS/ TM and Landsat 8 OLI/ TIRS data (path/row 141/56) were freely downloaded from USGS website (https://earthexplorer.usgs.gov/). used to assess LST, NDVI and NDBI Acquired satellite data were of Weligama DSD (Divisional Secretariats Division). Satellite images were downloaded as separate bands and relevant bands were layer stacked and radiometric and atmospheric corrections were done using ENVI 5.3 software. Pre-processed images were clipped and masked using study area map using DSD maps from Survey Department of Sri Lanka. TIR bands were used to develop LST maps and Visible and IR bands were used to develop NDVI (Normalized difference vegetation index) and NDBI (Normalized difference built-up index) maps of Weligama DSD, Matara. Apart from time series multispectral and thermal satellite images, high resolution Google earth images are used to verify the study area's land use/ land cover information. The unsupervised classification was conducted to extract the essential information from the imageries to prepare the LULC map of the study area Landsat 8 OLI/TIRS using the 'Iso-cluster unsupervised classification' tool from ArcGIS 10.7. LSTs were derived from Landsat 8 thermal infrared (TIR) bands (band 10 & 11). The variability of retrieved LST was correlated regarding NDVI and NDBI to identify the impact of different LULC types determined on LST changes over 15-year period.

III. RESULTS AND DISCUSSION

LULC analysis reveals that the major part of the LULC of the Weligama DSD is covered by vegetation, followed by built-up areas consisting of 46 % and 32 % of the total, respectively. Study [2] showed that the land conversion for urban development (78.68-85.15%) accelerates the decrease of vegetation in the study area (21.31-14.5%) during 2012-2017, respectively. Demand for lands and constructions of building complexes and households along the Southern expressway (29.7 ha) [2] drastically affected the vegetation cover and coconut cultivation.

The average LST varies between 25.1-26.9°C for the period of 2005-2020. The highest temperatures were recorded within the built-up areas, while the lowest was in vegetation and water bodies. LST was increased gradually from 2005-2020 in the study area (Figure 1). The high range of LST was observed around the bay and coastal line and lower in the inner land of the Weligama DSD. The development in the coastal areas of Weligama DSD using materials such as concrete, stone, metal and asphalt increased the surface radiance temperature. The minimum LST of the study area showed a gradual inclining from 23 to 24°C between 2005 and 2020 and the maximum LST approximately remained the same over 15-year period. Overall, the LST maps revealed that barren lands and built-up areas showed the highest LST due to high human activity intensity whereas, the LST is lower in the area surrounded by water bodies and vegetation. This implies that land-use types should be rationally planned and a cooling effect should be induced through green vegetation and water [2].

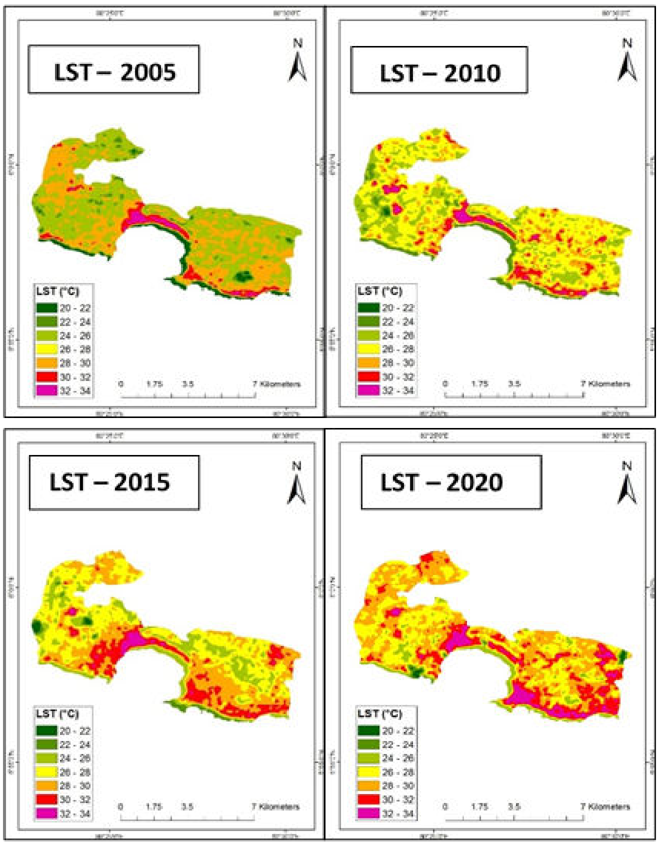

Fig. 1 Land Surface Temperature (LST) Maps, Weligama DS Division

The highest NDBI values were recorded within the urban and barren areas, while the lowest was vegetative and water bodies. The impact of urbanization was high around the bay of Weligama city. The minimum and maximum NDBI of the study area showed a gradual declining from -0.55 to -0.65 and inclining from 0.69 to 0.82, respectively, between 2005 and 2020. The trend of NDBI explains that the urban development of the study area has a steady growth over 15-year period. The maximum NDVI of the study area showed a gradual declining from 0.79 to 0.66, respectively, between 2005 and 2020. Lower NDVI values were evident in water bodies and built-up areas, while higher NDVI values were evident in vegetative areas.

The assessed NDBI and NDVI values showed significant ($p<0.05$) positive (0.85, 0.77, 0.87 and 0.80) and negative correlations (-0.67, -0.77, -0.76 and -0.78) with LST for the period of 2005, 2010, 2015 and 2020, respectively. Linear regression models were developed using relationships between NDBI and LST (without considering the water bodies). The obtained regression models revealed a strong positive correlation between NDBI and LST (r^2 = 0.73, 0.61, 0.76 and 0.64) from 2005-2020, respectively. LST maps of the study area show that the maximum surface temperatures were related to built-up areas. Therefore, it can be noted that built-up or urban land-use class induces much more surface temperature variations than other LULC classes.

Land surface temperature (LST) is sensitive to vegetation cover. The regression models revealed that NDVI and LST had moderate negative correlation (r^2 = 0.44, 0.60, 0.59 and 0.59) from 2005 to 2020, respectively. The high NDVI and low LST indicate a good cooling effect in urban cities. In urban lands, appropriately increasing the number of green areas such as parks with large trees is conducive to improving the city's thermal environment [3, 4]. The relationship between LST and NDVI could be impacted by the spatial combination of different land-use types. Overall, moderate NDVI (vegetation cover) and a high level of NDBI (built-up cover) contribute to the high spatial distribution of LST in the Weligama DS division over 15-year period.

IV. Conclusions

LST, NDBI and NDVI can be considered three primary indices to study the ecological and environmental changes. The study analyzed the applicability of freely available moderate spatial resolution satellite imagery in evaluating environmental impacts LULC pattern on the urban, suburban and rural environment and coastal ecosystem in Weligama DS Division, Matara. LST analysis revealed that higher surface temperature in built-up and bare surfaces and low in healthy vegetative areas. The assessment of NDVI and NDBI changes indicated that the impact of urbanization was high around the coastal line of Weligama city whereas, the inlands of the study area are occupied with vegetative lands such as grass and cultivable lands. The temporal differences of LST had significant correlations ($p<0.05$) with NDVI and NDBI of the study area over 15-year period. The LST showed a strong positive relationship with NDBI (r^2= 0.73, 0.61, 0.76 and 0.64) and moderate inverse relationship (r^2= 0.44, 0.60, 0.59 and 0.59) in 2005, 2010, 2015 and 2020, respectively. Based on the results drawn from the study it is identified the TIR bands of Landsat 4-5 TM and Landsat 8 OLI/TIRS images have the potential to detect the LST level and NDBI and NDVI changes in the Weligama DS division to take proper environmental management practices over urban heat issues.

References

[1] V.V.Chaithanya, B.V.Binoy, and T.R.Vinod. Estimation of the relationshipbetweeen urban vegetation and land surface temperature of Calicut city and Suburds, Kerala,

India using GIS and remote sensing data. International Juornal of advanced Remote Sensing and GIS, Vol. 6,Pp2088-2096,2017.

[2] Weligama Development Plan (2019-2030) – Volume I, Urban Development Authority - Sri Lanka (2019). https://www.uda.gov.lk/attachments/devplan_detailed/Development%20Plans%202019-2030/Weligama/English.pdf

[3] M.T.Kavak and S. Karadogan,. Investigation of normalized difference vegetation index and land surface temperature using remote sensing techniques. In proceeding of the International Conference on Dicle University,2017.

[4] K.Shigeto. Relation between vegetation, surface temperature, and surface composition in the Tokyo region during winter. Remote Sensing of Environment Vol.50, Pp52–60,1994.