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RESEARCH ARTICLE

SPACE BORNE TECHNIQUE TO IDENTIFY THE RELATIONSHIP BETWEEN VEGETATION COVER AND URBANIZATION IN THE CITY OF COLOMBO.

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Manuscript Info	Abstract
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Urban vegetation coverage can be considered as one of the indicators that can be used to identify, the process of urbanization. Most of the time with rapid urbanization, vegetation coverage in a city tend to decrease. Hence, it is explicitly visible that the social background, building density and related factors to the urbanization process, have a high relationship with minimizing city vegetation coverage. There are many techniques that can be used to identify the relationship between the process of urbanization and vegetation coverage. Space borne (Remote Sensing (RS) technique) is one of the tools to identify such kind of phenomena. As the main commercial hub in the island, the city of Colombo has expanded as an agglomeration and also population density is increasing rapidly. Massive constructions have also covered major parts of the city, rapidly. In the past years, vegetation coverage minimizes with these processes. Considering all these facts, this study has attempted to identify the relationship between vegetation coverage and urbanization in the city of Colombo with the help of RS techniques. Hence, to identify the relationship between vegetation cover and urbanization, Landsat 8 OLI TIRS (2014) satellite images were used to construct Normalize Difference Vegetation Index (NDVI) and Urban Index (UI) to fulfill the study aim. The results indicated that, there is a significant negative relationship between urbanization process and vegetation coverage in the city.

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Background:-
The direct impact of urbanization is rapidly increasing buildup areas. Expansion of urban areas has profound effects on biodiversity and ecosystem functioning at local, regional, and global scales (Zipperer et al.2000). Land use pattern associated with urbanization process leads to modifications of surface microclimatic and hydrological conditions, including the formation of urban heat islands and changes in surface runoff pattern (Hass, 2013).

The vegetation coverage in a city plays a major role in providing an environment for recreation for the inhabitants. These vegetation areas are highly threatened by the transformed urban land use due to increasing pressure on land in most of the cities (Wijesekera & Manawadu, 2009). The citties' environment, sub urban areas, and towns, rely on vegetation to provide ecosystem functions such as air filtering, temperature amelioration, and water storage, filtration and drainage (Bolund & Hunhammar1999). When considering the vegetation coverage in city areas, it has a societal value in defining nature for millions of dwellers living in cities sustaining community health and well-

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being (Ulrich 1984; Kuo & Sullivan 2001; Fuller et al. 2007), as well as frequently contributing to the conservation estate by associate unique biodiversity (McDowell et al.1991; Lawson et al.2008).

According to Verma et al., (2009) the modern technology of RS allows us to collect numerous physical data rather easily, with speed and on repetitive basis and together with Geographic Information Systems (GIS) helps to analyze the data spatially, offering possibilities of generating various options (modeling), thereby optimizing the whole planning process. Also, RS data of various spatial, spectral, and temporal resolutions have been used to characterize land use and land cover change associated with urban growth and application of RS can greatly enhance our knowledge of urban ecological processes (Buyantuyev et al; 2007). Most of the researchers have investigated, the current progresses in RS and GIS having remarkable enhancement about the availability of high-resolution spatial and attribute data for examining the relationship between buildup areas and vegetation structure in a city.

The NDVI is effective in predicting photosynthetic activity, because this vegetation index includes both near infrared and red part of the EMR (Govaerts & Verhulst, 2010). Green leaves usually have low reflectance in the blue and red portions of the spectrum because of chlorophyll absorption, with a slightly higher reflectance in the green, so plants appear green to our eyes. Near infrared radiant energy is strongly reflected from the plant surface and the amount of this reflectance is determined by the properties of the leaf tissues: their cellular structure and the air-cell wall-protoplasm-chloroplast interfaces (Kumar and Silva, 1973). So this study used NDVI to extract the vegetation coverage through the Landsat satellite imagery.

Mapping city built-up areas using moderate resolution RS data such as Landsat TM/ETM+ data is complex, because urban areas contain manmade and natural features like vegetation, water body, bare land etc. (Sinha et al., 2016). Landsat 8 OLI TIRS, olso has the same magnificient capacity of capturing city build-up areas as moderate resolution RS data. These urban regions frequently show heterogeneous spectral characteristics and significant spectral confusion between land cover classes and as a result reduce mapping accuracy (do). UI is one of the methods to identify city buildup areas using satellite imageries. RS can be used to obtain a description of building density with a spectral transformation called UI (Kawamura et al., 1997). It is assumed that high pixel value indicates built-up area intensively.

There are many researches have done, using both physical and human aspect to reveal some important matters in urbanization process of the city of Colombo using space born techniques. But the comparison of UI and NDVI in RS is limited to the city of Colombo. Hence considering above facts, this study attempts to identify the relationship between the vegetation cover and the degree of urbanization in the Colombo city area. Using UI and NDVI this has been done accordingly with the help of Landsat 8 OLI TIRS Imagery 2014.

Aim of the study:-
Identify the relationship between vegetation coverage and urbanization in the city of Colombo, using space borne techniques (Special reference to Colombo city Municiple Wards).

Methodology:-

Study area
As the main commercial hub in Sri Lanka, the city of Colombo plays a vital role of rapid urbanization in the country. According to the WGS 1984 coordinate system, Colombo city's absolute situation is expanded in between $6^046'$ to $6^058'$ North Latitude and in between nearly $79^000'$ to $79^053'$ East Longitude (Figure 01).

The city, consists of 47 Municipal Wards (Figure 01and Table 01). Some of these Wards have a high population density while others show comparatively low population density. Also the building density and urbanization process also varies within the Wards. Nearing to the Colombo city harbor area, most of the sky scrapers can be seen. Water bodies like Beira Lake provides cooler environment to the surrounding community within the city. There are a few vegetated areas like Viharamahadevi Public Park, some newly constructed small public park lots, are contributing to make a cooler environment within the city. But this vegetation coverage does not provide sufficient safer and cooler background to avoid the stressful environment generated through traffic congestion, buildings, constructions etc. Considering all these facts, this study has selected the city of Colombo as the study area.
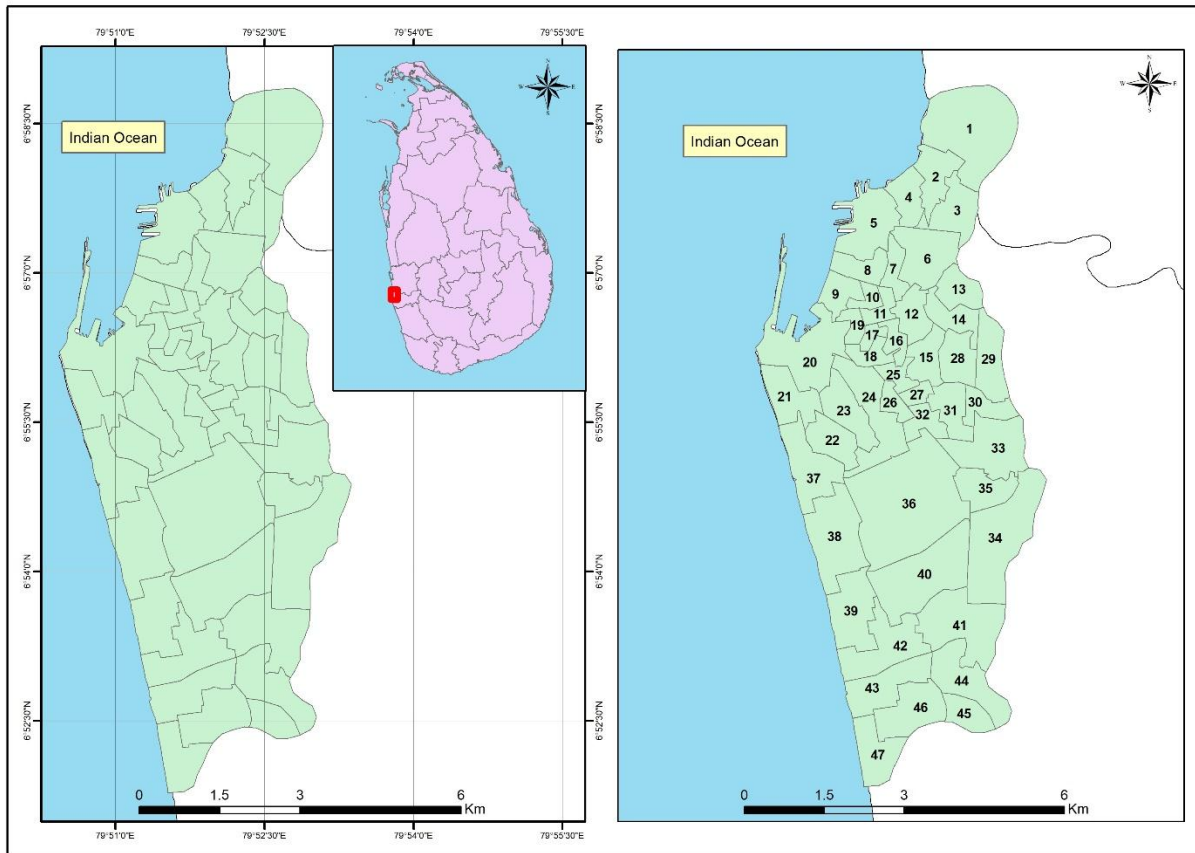
Figure 01: The city of Colombo and Municipal Wards

Wards ID	Name of the Ward
01	Mattakkuliya
02	Modara
03	Mahawatta
04	Aluth Mawatha
05	Lunu Pokuna
06	Bloomandal
07	Kotahena East
08	Kotahena West
09	Kochchikade North
10	Ginthupitiya
11	Masangas Veediya
12	New Bazaar
13	Grandpass North
14	Grandpass South
15	Maligawatta West
16	Aluthkade East
17	Aluthkade West
18	Keselwatta
19	Kochchikade South
20	Fort
21	Slave Island
22	Wekanda
23	Hunupityia

24	Suduwella
25	Panchikawatta
26	Maradana
27	Maligawatta West
28	Maligawatta East
29	Dematagoda
30	Wanathamulla
31	Kuppiyawatta East
32	Kuppiyawatta West
33	Borella North
34	Narahenpita
35	Borella South
36	Cinnamon Garden
37	Kollupitiya
38	Bambalapitiya
39	Milagiriya
40	Thimbirigasyaya
41	Kirula
42	Havelock Town
43	Wellawatta
44	Kirulapone
45	Pamankada East
46	Pamankada West
47	Wellawatta South

Table 01: Name of Wards

Data Collection

This study depends on the space borne techniques. Therefore the necessary data, Landsat 8 OLI TIRS images on June 2014 were obtained from the website of United State Geological Survey (USGS). It inherits 30m X 30m resolution. The selected Landsat imagery does not cover with cloud and that was an advantage to select for the study.

Bands	Wave length	Resolution
Band 1 – Coastal aerosol	0.43 - 0.45	30
Band 2 – Blue	0.45 – 0.51	30
Band 3 – Green	0.53 – 0.59	30
Band 4 – Red	0.64 – 0.67	30
Band 5 – Near Infrared (NIR)	0.85 – 0.88	30
Band 6 – Short Wave Infrared (SWIR) 1	1.57 – 1.65	30
Band 7 - Short Wave Infrared (SWIR) 2	2.11 – 2.29	30
Band 8 – Panchromatic	0.50 – 0.68	15
Band 9 – Cirrus	1.36 – 1.38	30
Band 10 – TIRS 1	10.60 – 11.19	100*(30)
Band 11 – TIRS 2	11.5 – 12.51	100*(30)

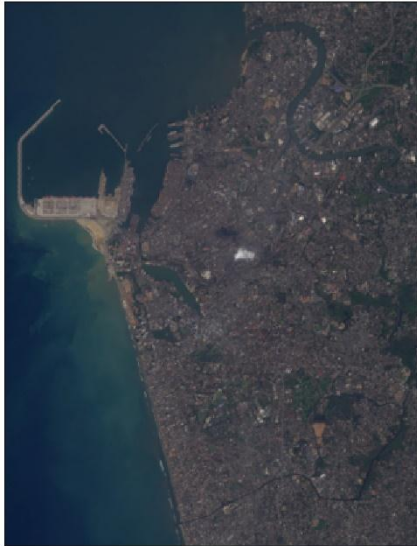**Table 02:** Specifications of Landsat 8 OLI TIRS Imagery

Figure 02: The city of Colombo,
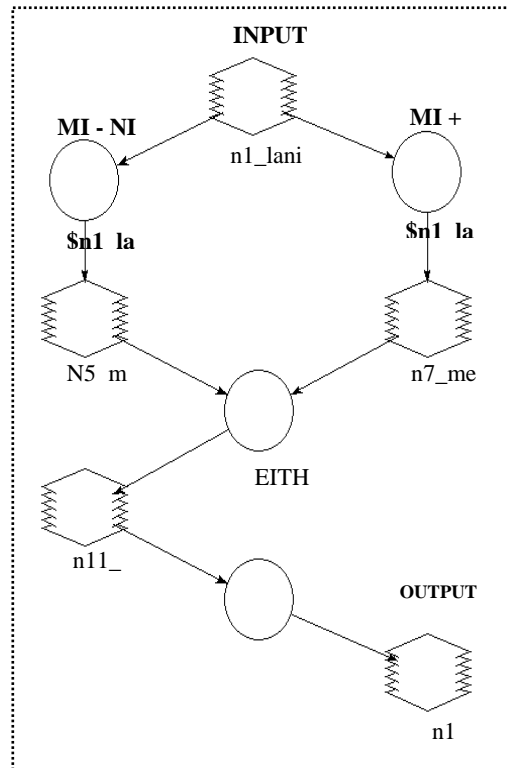Landsat imagery 2014
June

Figure 03: Model of UI
Source   : Erdas 10.1

Methods
It has identified both urbanization process and the vegetation coverage in the city. Erdas Imagine 10.1, RS software was used to generate grid base maps for urbanization and vegetation coverage in the city and ArcGIS 10.1 software were used to construct the pixel base Regression Analysis.

Constructing Urban Index (UI)
Landsat 8 OLI TIRS satellite data were used to construct the UI. This index depends on the Band 5 (Near Infrared - NI) and Band 7 (SWIR 2) that associated with Landsat 8 OLI TIRS data. ***UI values are varying 49 to 119. When the value reaching 119 it indicates high buildup density.***

Below mentioned formula was used to generate the UI.
   Formula for UI
$$UI = \left(\frac{MI-NI}{MI+NI} + 1\right) * 100 \text{ (Kawamura et al., 1997)}$$
The constructed UI, a model was created using Erdas Imagine 10.1 software (Figure 03).

Constructing Normalize Difference Vegetation Index (NDVI)
NDVI is a calculation of a simple formula consuming two satellite bands. This index is related to identify vegetation coverage and vegetation reflect. Healthy vegetation reflects very well in the near infrared part of the spectrum. Green leaves have a reflectance of 20 percent or less in the 0.5 to 0.7 micron range (green to red) and about 60 percent in the 0.7 to 1.3 micron range (Near Infrared). The visible channel gives some degree of atmospheric correction. The value is then normalized to the range -1<=NDVI<=1 to partially account for differences in illumination and surface slope *(Kidwell, 1994)*.
In RS, NDVI was used to identify the vegetation coverage in a certain area. This study produced NDVI with the help of Landsat 8 OLI TIRS data. To generate NDVI, used band 5 (Near Infrared - NI) and band 4 (Visible Red - R) that are available on Landsat 8 OLI TIRS data.

Formula for NDVI

$$NDVI = \left(\frac{NI-R}{NI+R}\right)$$

Regression analysis is one of the major statistical methods which can be used to show the relationship between two or more considerable variables. Hence to present the relationship between NDVI and UI, least square regression analysis was calculated. NDVI was taken as the independent variables and UI has been chosen as the dependent variable. This regression calculation carried out according to the Municipal Wards of city of Colombo (Figure 01). Apart from pixel distribution calculation, using the function of "Zonal Statistics as a Table" available in ArcGIS 10.1 software link to calculate the regression analysis. This function provides mean values of NDVI and UI according to Municipal Wards in city of Colombo.

Results:-

As mentioned in methodology when considering the generated grid themes for UI, it shows a remarkable relationship with NDVI (Figure 04). In reality, the highly populated areas like Ginthupitiya, Maradana, Kochchikade, Maligawatta East and West, Grandpass North, Aluthkade East Wards are being showed high UI values. These areas are having less NDVI values (Table 03). Areas like Cinnamon Gardens, Thimbirigasyaya and Narahenpita Wards are enriched with good vegetation coverage. Hence NDVI values for these Wards show high values. All the NDVI pixel values for Colombo city was varied from 0.05 to 0.2. It is visible, the City has considerable vegetation cover. But when considering UI values, these values were varied from 49 to 119. It says good urbanization.
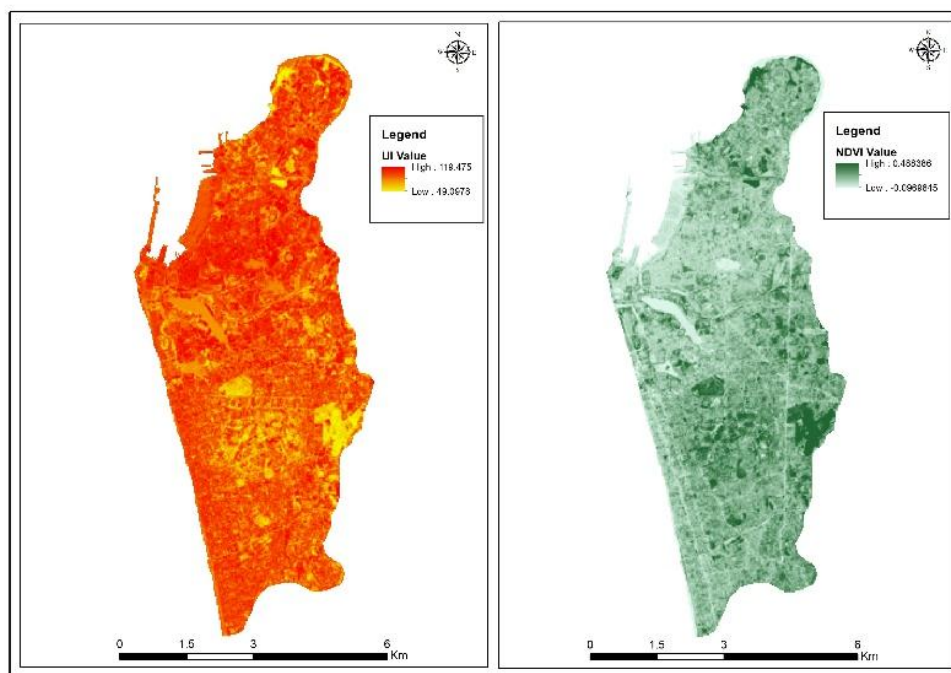

Figure 04: UI and NDVI results of Municipal Council of Colombo

Eg: When considering Ward no 16, that Ward has UI value 97.01 and NDVI value 0.056. Within this situation, we can say that this Ward has less vegetation cover and lots of construction.

Ward ID	NDVI	UI	Ward ID	NDVI	UI
1	0.143544	89.9656	24	0.118029	92.17987
2	0.141445	93.06733	25	0.101473	95.27806
3	0.142716	91.19878	26	0.117101	93.7925
4	0.165855	89.65855	27	0.116615	93.97371
5	0.096216	91.57361	28	0.140932	89.87939
6	0.136841	92.11288	29	0.134856	93.4575
7	0.117919	94.58343	30	0.179814	88.23779
8	0.091342	93.66342	31	0.164895	90.68418
9	0.052655	94.33286	32	0.13656	94.01706
10	0.088869	98.72836	33	0.183427	88.91294
11	0.094746	97.5545	34	0.23216	81.91618
12	0.09043	98.46222	35	0.14472	91.53904
13	0.100709	95.23898	36	0.185779	86.28326
14	0.115124	95.36924	37	0.107462	89.16766
15	0.109783	92.19255	38	0.12629	91.88191
16	0.055527	97.01878	39	0.122822	92.60069
17	0.076166	101.5706	40	0.196806	84.73024
18	0.118291	94.34682	41	0.165743	89.79179
19	0.075991	99.99392	42	0.150194	90.74107
20	0.0631	94.98293	43	0.137932	91.15311
21	0.107204	89.1986	44	0.168713	90.14808
22	0.114495	94.35163	45	0.169322	89.95531
23	0.097393	87.46957	46	0.134247	93.07307
			47	0.113858	92.83152

Table 03: Mean Pixel values of UI, NDVI
Source: Generated through ArcGIS 10.1 Zonal Statistics tool

These pixel values of UI and NDVI in Wards showed a remarkable relationship. The areas having high UI values, was carried minimum NDVI values. Figure 05 shows the pixel distribution of each variables in each Wards.
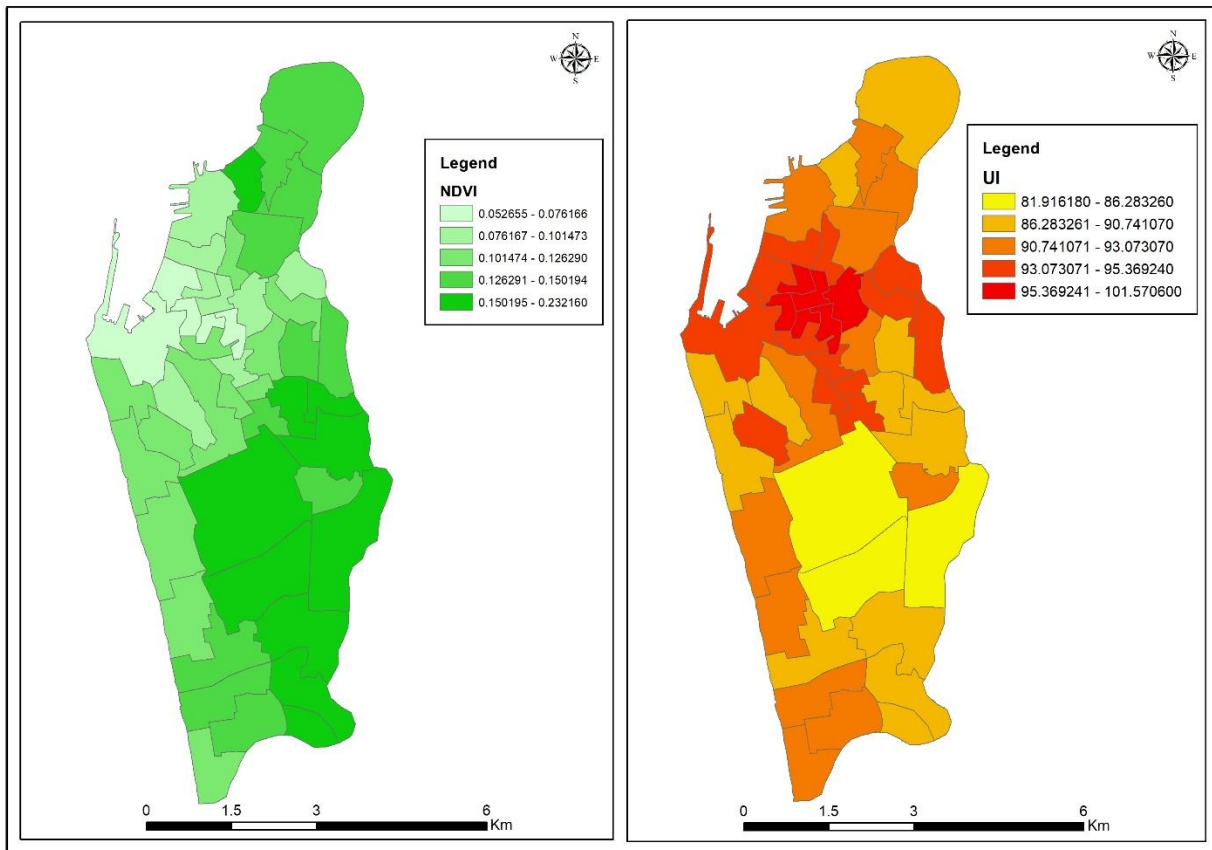
Figure 05: Pixel values for Municipal Wards

When paying attention to the pixel values of the City Wards, it is highly visible that the City Wards where, NDVI value is high, the UI is lower minimum. When it comes to the UI high areas NDVI is minimum. For an example, the City Wards of 36 and 40 (Cinnamon Gardens and Thimbirigasyaya) shows high NDVI values compared to the other City Wards. Especially, Thimbirigasyaya Ward shows the lowest UI values among the other Wards of the city. The specialty of this area is that this area is not covered with high construction of buildings. Also bears a low population density than other regions and tend to maintain vegetation coverage. Also Cinnamon Gardens inherits the Viharamahadevi Public Park with good vegetation coverage.

When, the middle part of the city is compared, these areas carry a high population density. Also high density of buildings can be seen, because of the population concentration. These areas are situated near the Colombo harbor and most of the industrial buildings can be seen there. Hence, the UI values are high in this area and NDVI is low. Figures 06 and 07 show the difference of vegetation coverage in Viharamahadevi Public Park area which is situated in the middle part of the city and Grandpass area nearing to the Colombo Harbor.

Figure 06: Viharamahadevi Public Park
and Diyath Uyana area

Figure 07: Grandpass area and
Mihindusenpura flats in
Dematagoda

When considering the relationship of pixel distribution in Wards, attention was paid to get a well distributed pixels magnificently. All the NDVI values of City Wards, show their DN values towards 0.05and above. It means, the city vegetation coverage is moderate. Also, UI values in all City Wards, DN values are above 81 (Table 03). To identify the relationship in-between pixel values of NDVI and UI simple regression analysis method was used. In this situation, the study investigated how the urbanization process effects the vegetation coverage.

According to the generated scatter plot diagram shows negative relationship between NDVI and UI (Figure 08). To prove that, linear squared regression line were generated and plot on the scatter plot. The NDVI and UI regression line parameters show **$\hat{Y}$ = 102.33 − 78.448 X (NDVI).** When UI is 0, NDVI is -78.448. When increasing NDVI by one unit, UI will decrease by 102.33 units as an average. Adjusted R^2 is 0.6181. It means 61% of the variation of UI can be explained by the NDVI. Liner correlation coefficient is –0.78. It means there is a high negative linear relationship between NDVI and UI.
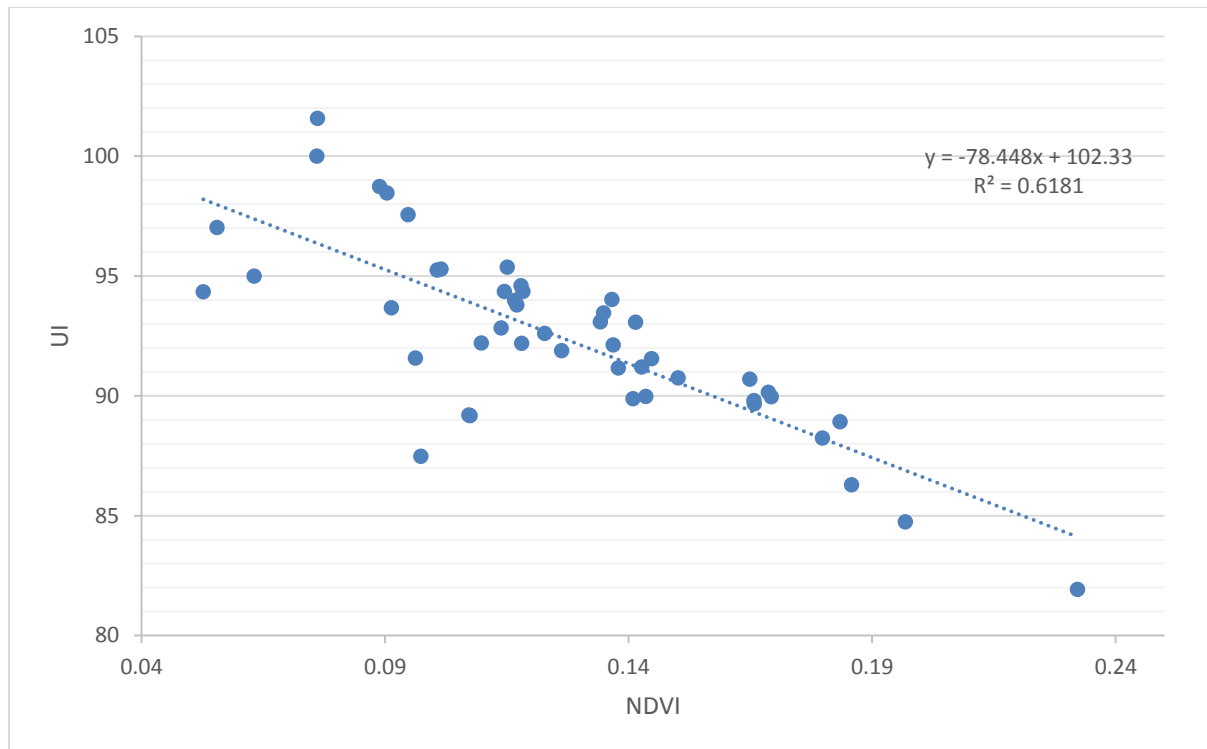
Figure 08: Relationship between NDVI & UI

Conclusion:-
It has proven that the city of Colombo has a limited vegetation cover. This vegetation coverage vanished with the city development. When focusing UI, most of the DN values concentrated towards North Western part of the City, where the commercial hub situated. Harbor, container yards, services centers, main transportation centers like main bus stand and railway station tend to minimize vegetation in the area. Highest vegetation of the city visible in eastern part of the City, because of the small marshy lands. Also parks like Viharamahadevi Park provides cooler environment to the city. Further, with the city development, the government implemented some environmental programs to increase vegetation coverage.

This study reveals that, space borne techniques are advanced techniques to identify the relationships in environmental studies.

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