A Study of Land Surface Temperature Variation in Selected Urban Cities in Sri Lanka

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Abstract - Land Surface Temperature (LST) is one of the prominent methods to conduct climate studies and commonly used to analyze the impact of land surface changes all over the world. Due to many anthropogenic activities, natural environment transformed into urbanized areas rapidly. As a result, certain climatic components including land surface temperature has been modified dramatically. Therefore, this study was conducted to estimate Land Surface Temperature (LST) in highest population growth cities in Sri Lanka. The main objective of this research was to examine the relationship of rapid urban population growth with Land Surface Temperature using Geographical Information System (GIS) and Remote Sensing (RS) techniques. The study was conducted in five cities in Sri Lanka and those cities were selected by the population growth rate. Population data were collected from two census and statistic survey conducted in 2001 and 2011. The study has estimated Land Surface Temperature using Landsat TM, Landsat 8 data and spatial and temporal variations were also taken in to the consideration. Finally the study has revealed that the maximum LST values of the selected cities varied from 29 ^{o}C to 37 ^{o}C. When considering about spatial pattern of LST in 2005 and 2016 the highest mean LST were shown in Hambantota in 2005 and 2016. In 2005 mean LST has varied from 25 ^{o}C to 27 ^{o}C and in 2016 it was from 25 ^{o}C to 29 ^{o}C. LST has been increased with the population growth rate and land surface changes. However, some external factors such as meteorological, physical and environmental factors have influenced on the changes in LST in certain urban cities.

Index terms – LST, Population Growth, Land use, GIS

I. INTRODUCTION

Land Surface Temperature (LST) is one of the key parameters in the physics of land surface processes from local through global scales (Liang Li Z. et al, 2013). According to the NASA Earth Observatory, USA, Land Surface Temperature is how hot the “surface” of the Earth would feel to the touch in a particular location and from the satellite point of view, the object it sees when it looks through the atmosphere to the ground.

Urban spatial areas have expanded rapidly during the last five decades and also rates of urban population growth are higher than the other areas (Xu H., 2007). The land-use and land cover changes occur rapidly and these have direct effect on the land surface temperature variation. Therefore, land surface temperature and population growth has a positive co-relationship with the earth surface. Many anthropogenic activities have directly affected the environmental transformation, and has created numerous major environmental problems. As a result of rapid growth of population, land surface modify dramatically and become impervious and reduce vegetation cover in any given urban area, Due to that the surface temperature of the earth gets modified accordingly.

To be more clear, land surface temperature is not the same as the air temperature that is included in the daily weather report, it is the warmth representation of earth’s landscape and strongly related to land surface emissivity (http://www.cssteap.org, 01.09.2016). Satellite base Land Surface Temperature is one of the best methods to identify the changes in environmental conditions for many research fields. Such widely used fields included, but not limited to evapotranspiration, climate change, vegetation changes, hydrological cycle and other environmental studies.

Furthermore, studying of land surface temperature variations with urbanization is very important for sustainable, environmental friendly future planning. It will also directly address the issue of how to reduce negative human impact on the environment. In Sri Lanka, many areas have been undergoing rapid urbanization, unhealthy land-use practices and land cover changes. Current urbanized areas can be identified as the densely populated areas in Sri Lanka. Therefore, more human impact and environment changes occurs frequently. Hence, identifying the spatial and temporal variation of land surface temperatures in cities which has the highest population growth is significantly important.

II. LITERATURE REVIEW

Satellite base Land Surface Temperature is one of the best factors to identify the environmental conditions and a key parameter for decision making. Remote Sensing is one of the main spatial data acquisition method and that process involves in collection of data, processing of data, analysis of the data or using the data for decision making process. Land Surface Temperature calculation mainly uses thermal remote sensing and thermal bands of the satellite images. Thermal remote sensing is clearly different from remote sensing and uses the optical and microwave region of the electromagnetic spectrum. Thermal Infrared lies between 8 – 14 µm wavelengths of the electromagnetic spectrum. Thermal remote sensing measures emitted radiation for temperature estimation and these measurements give the radiant temperature of a body, which depends on two factors kinetic temperature and emissivity (Prakash A., 2000). Thermal remote sensing is very useful to identify the surface temperature of the earth surface and there are so many applications based on the land surface temperature. Such as, climate change, water management, land-use and land cover changes, fire monitoring, volcanology etc. Different satellite systems provide thermal data for analysis and AATSR, AVHRR, MODIS, and Landsat are some of them.

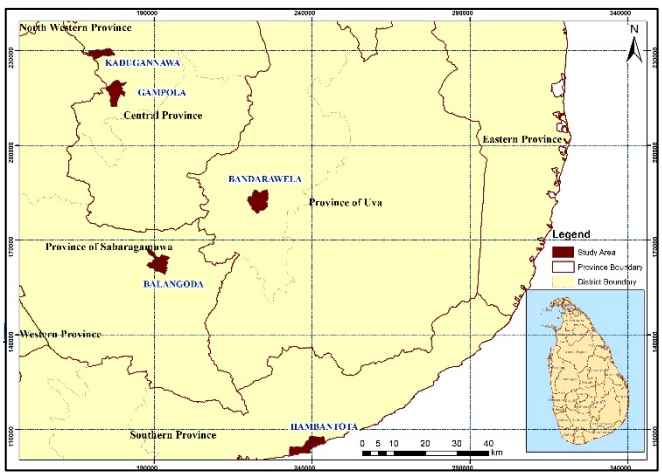
Land Surface Temperature estimation based research are common conducting in these days. Many research have documented the impact of urbanization and vegetation cover changes on climate and several of them focused mainly on Urban Heat Island (UHI) effects in the central core of urban areas. Some studies have mainly focused only on LST for green space planning in urban areas (Wardana I.K., 2015). However, very limited number of studies have been done to analyze the relationship between urban population growth and LST. Population shift to the urbanized and urbanizing areas resulted in residential expansion and created impervious, constructed surfaces, which predominantly influences the changes of land surface temperature. Land surface temperature estimation is essential for urban planning to mitigate the local climate changes and to create sustainable development within the region.

III. OBJECTIVES

The main purpose of this research was to examine the effect of rapid urban population growth on land surface temperature. GIS and RS techniques being used for that purpose.

Specific objectives

- Identify Land Surface Temperature for the highest population growth cities in Sri Lanka



- Compare spatial and temporal variation of Land Surface Temperature in selected urban cities

IV. STUDY AREA

The study area consists of five cities in Sri Lanka and those areas were selected by the rapid population growth rate according to the census 2011. According to this concept, selected cities are Kadugannawa, Gampola (Cities in the Central province), Bandarawela (Uva Province), Balangoda (Sabaragamuwa Provience), and Hambantota(Southern Provience). The absolute and relative locations are shown in figure 01.

Figure 01: Location Map of Five Selected Urban Cities in Sri Lanka
Source: Urban Development Authority, 2016

V. METHODOLOGY

Remote sensing data and census data were used in this study. Satellite data were obtained for two different years 2005 and 2016. March 17, March 26, 2005 and March 24, March 31, 2016 were selected due to satellite data availability. Landsat TM and Landsat 8 data were analyzed to estimate Land Surface Temperature and land use and land cover map. Red, NIR and Thermal band were used for this analysis. Cloud cover of the obtained images were less than 10% and all remote sensing data were obtained from http://earthexplorer.usgs.gov/ website of United States Geological Survey (USGS). Surface temperature were extracted using Arc GIS 10.1 software.

2001 and 2011 census data were obtained from Department of Census and Statistics, Sri Lanka. All population data were analyzed using MS Excel 2013.

- **Methods**

Research methodology can be discussed in to several parts using the objectives. The methodologies can be explained as bellow.

Identify the highest population growth cities

Population growth rate was calculated to identify the highest population growth cities in Sri Lanka. Population Growth Rate means increasing of number of individual population in a given period. In this calculation population census 2001 and 2011 data were used to calculate population growth rate and the formula identified as bellow;

(Eq 01:)

$$PR = \frac{(V_{Present} - V_{Past})}{V_{Past}} x100$$

Where:

PR = Percent Rate
$V_{Present}$ = Present or Future Value
V_{Past} = Past or Present Value

The annual percentage growth rate is simply the percent growth divided by N, the number of years (http://pages.uoregon.edu , 01.10.2016).

Calculate Land Surface Temperature

Several formulas were used to estimate Land Surface Temperature for urban areas and Landsat Thermal and Visible bands were used. Image preprocessing was done to minimize satellite errors, and Radiometric and atmospheric errors were corrected using Radiance Scaling Factors Provided in Landsat Metadata File. To estimate land surface temperature, used red, near infrared and thermal bands of Landsat images. Normalized Vegetation Index (NDVI) is also a necessary factor to estimate land surface temperature and red and near infrared bands of Landsat images were used to create NDVI for year 2005 and 2016. The following formulas were adopted to calculate land surface temperature.

Formula used for calculate land surface temperature:

(Eq 02:)

LST= (BT / 1+ W* (BT/P) * ln (e))

Where:

BT = At satellite temperature

W = Wave length of emitted radiance (11.5 um)

P = h* c/s (1.438*10^-2mk)

h = Planck's constant (6.626* 10^ - 34)5)

e = Velocity of light (2.998 * 10^ 8 m/s)

(Oluseyi I.O. *et al*, 2009)

To calculate this formula, several formulas have been conducted such as brightness temperature and calculate normalize vegetation index (NDVI). In Landsat thermal band data can be converted from spectral radiance to brightness temperature, and the thermal constants are indicated in metadata file. The formula can be shown as bellow;

(Eq 03:)

$$T = \frac{K_2}{ln\left(\frac{K_1}{L_\lambda} + 1\right)}$$

Where:

T = At satellite brightness temperature (K)
L_λ = TOA spectral radiance (Watts/(m2 * srad * μm))
K_1 = Band-specific thermal conversion constant from the metadata (K1_CONSTANT_BAND_x, where x is the thermal band number)
K_2 = Band-specific thermal conversion constant from the metadata (K2_CONSTANT_BAND_x, where x is the thermal band number)

Above equations directly taken from the http://landsat.usgs.gov/Landsat8_Using_Product.php .

Otherwise NDVI was calculate to deriving Land Surface Temperature and that formula can be mention as bellow;

(Eq 04):

$$NDVI = \frac{NIR-RED}{NIR+Red}$$

The NDVI is used for calculate the velocity of light. Those formulas can be indicated as bellow;

(Eq 05):

Proportion of Vegetation (PV) = (NDVI – $NDVI_{min}$ / $NDVI_{max}$ – $NDVI_{min}$) 2

(Eq 06):

e = 0.004 PV + 0.986"

Those formulas were identified to deriving Land Surface Emissivity (LSE) in this study.

Finally, those methods were compared to identify the relationship between the rapid population growth and the land surface temperature. Mean temperature of cities were extracted using zonal statistic method in ArcGIS 10.1. Those values compared with population density of selected cities in Sri Lanka using correlation statistics methods. Also identified mean temperature for each land-use and land cover types and compared their relationship to identify the variation of Land Surface Temperature.

VI. RESULTS AND DISCUSSION

Rapid urban expansion and rapid population growth in urban areas can be identified in Sri Lanka. Thus, Land Surface Temperature estimation is very important in those areas. Table 01 shows the descriptive statistics of Land Surface Temperature for selected ten cities and Figure 02 show a graphical representation of the Land Surface Temperature during period of March, 2005 and March, 2016.

Selected city areas for this study have shown highest population growth rate than the other cities in Sri Lanka and also these cities shown approximately more than 70% built-up/ homestead lands. Therefore, rapid population growth as well as surface changes in those areas can be concluded as the main reason for increasing maximum LST values in selected city areas. According to the table 01, maximum LST values of the selected cities varied from 29 ^oC to 37 ^oC.

When considering about spatial pattern of LST in 2005 and 2016 the highest mean LST were shown in Hambantota in 2005 and 2016. In 2005 mean LST has varied from 25 ^{o}C to 27 ^{o}C and in 2016 it was from 25 ^{o}C to 29 ^{o}C.

When considering the temporal pattern, the temperature has increased in 2016. According to the extracted mean temperature difference (Table 02) in 2005 and 2016, LST has been increased in five cities (Figure 03); Hambantota (2.491^{o}C), Bandarawela (0.746^{o}C), Gampola (0.291^{o}C), Kadugannawa (0.186 ^{o}C) and Balangoda (0.002 ^{o}C). In those cities Maximum LST has shown as Hambantota (37.169^{o}C), Bandarawela (33.173^{o}C), Gampola (34.652^{o}C), Kadugannawa (32.27 ^{o}C) and Balangoda (29.699 ^{o}C) (Figure 02). The Highest temperature values has been identified in built-up areas within the selected cities. The mean temperature values of different land use types also subjected the consideration (Table 03). In figure 04 shown correlation between the LST and NDVI of selected five cities. According to the figure 04, High crowded areas can be identified in these cities. The LST value gradually increased with density of built-up areas.

City	Mean Temperature (2005)	Mean Temperature (2016)	Difference
Hambantota	27.290	29.781	2.491
Bandarawela	25.313	26.059	0.746
Gampola	26.942	27.233	0.291
Kadugannawa	26.081	26.273	0.186
Balangoda	25.986	25.988	0.002

Table 01: Descriptive Statistics of LST for Selected Cities in 2005 and 2016

City	Population Growth Rate	March 2005			March 2016		
		Minimum Temperature	Maximum Temperature	Mean Temperature	Minimum Temperature	Maximum Temperature	Mean Temperature
Kaduwela	94.148	24.00	29.466	26.081	24.158	32.27	26.273
Bandarawela	25.678	23.719	32.669	25.313	23.374	33.172	26.059
Hambantota	10.869	24.00	33.054	27.29	24.057	37.169	29.781
Gampola	5.596	23.888	32.521	26.942	24.16	34.652	27.233
Balangoda	3.688	23.881	31.811	25.986	23.563	29.699	25.988

Source: Department of Census and Statistics, 2016 & Landsat image, 17/26 March 2005 and

Further, data analysis shows that during the year 2016 Land Surface Temperature has been increased than 2005 in all selected cities. Also, Maximum LST values have increased in above mentioned cities.

Comparing the trend of LST in two different study periods, cities which had higher LST in 2016 clearly indicate high population growth rate and more built-up/homestead areas than year 2005. As mentioned earlier, it is interesting to notice that some cities shown a small variation of its LST in 2016. Therefore, based on the data, a conclusion was made that weather patterns, environmental and geographical factors and additional issues may have influence on the expected results, other than the rapid population growth and land surface changes.

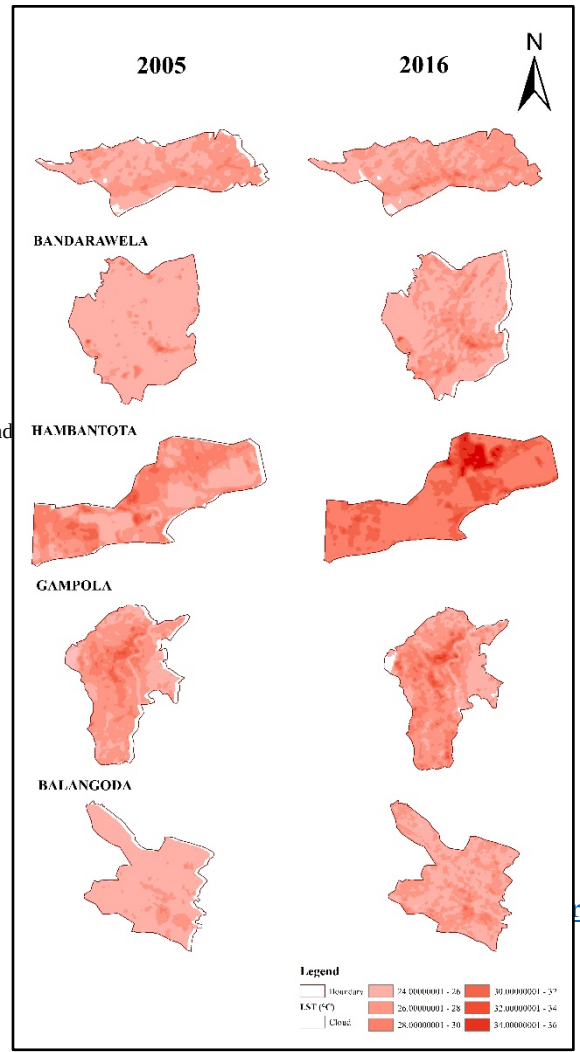
In analyzing of different factors that may be a reason for decreasing the LST in some cities, major focus was on the factors that can effect the surface temperature variation were taken to consideration. Even though, the study considered land use changes in the area as the major factor, as an example satellite images in Hambanthota area shows higher LST values in 2016 than 2005, while both areas have more build up areas in 2016 than 2005.According to figure 04, can conclude that land use pattern changes of those areas were affected by the increase of LST value in 2016.

Weather pattern such as rainfall data for particular study period were taken into the consideration as a major reason for reducing Land Surface Temperature. As the rain droplets can absorb temperature/heat in the atmosphere, collectively LST can be reduced. The study period of March was selected due to it being considered as one of the least rainfall occurrence month in Sri Lanka, but certain variations in rainfall pattern can be expected.

Table 02: Mean Temperature Difference in 2005 and 2016 for Selected Cities

Source: Landsat image, 17/26 March 2005 and 24/31 March 2016 from http://earthexplorer.usgs.gov/

Daily rainfall data for year 2005 and Year 2016 are shown in Table 04. Rainfall data were received from the Meteorological Department, Sri Lanka and if the selected city



City	Rainfall (mm) – 17/26 March 2005	Rainfall (mm) – 24/31 March 2016
Kadugannawa	4.2	27
Gampola	0	14

hasn't a rainfall collecting station, data from the nearest station were taken. As expected March 2005 indicate as a dry season for the most of the country, and none of the selected cities had not received any precipitation. However, only two cities Kadugannawa and Gampola had received some precipitation during March 2016. Hence, rapid population growth and land surfaces changers occurred due to the rapid urbanization in Kadugannawa and Gampola, precipitation initiated the changes of expected Land Surface Temperature.

Figure 02: Graphycal Representation of Land Surface Temperature Distribution in Five Cities
Source: Landsat image, 17/26 March 2005 and 24/31 March 2016 from http://earthexplorer.usgs.go

Hambantota area had not received any precipitation during March 2005 and March 2016. Therefore, the LST has been increased than the other cities.

Table 03: Mean Temperature for Different Land use Types in 2016

Land-use	Mean temperature (^oC)
Homestead/Built-up	29.69
Coconut	26.82
Rubber	26.23
Tea	26.79
Water Bodies	26.46

Source: Landsat image, 24/31 March 2016 from http://earthexplorer.usgs.gov/

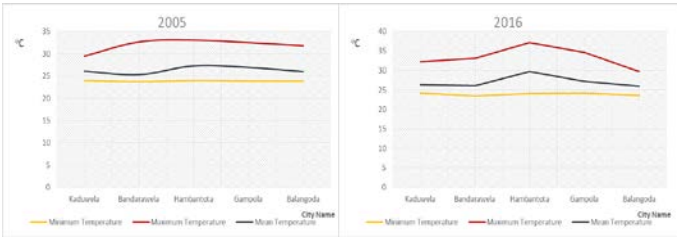


Figure 03: Mean LST for Selected Cities in 2005 and 2016
Source: Landsat image, 17/26 March 2005 and 24/31 March 2016 from http://earthexplorer.usgs.gov/

In contrast the city of Kadugannawa has shown relatively different situation than other cities. In March 2005, Kadugannawa shown 26.081 ^oC mean temperature value and in 2016 it shown as 26.273 ^oC, but it can be identified as the highest urban population growth city in Sri Lanka. Therefore, precipitation has made any significant changes on LST in the area and the elevation can be considered. In geographical /location consideration of Kadugannawa, we see that it is situated on a higher elevation area than the other cities. Therefore, changes in local wind patterns and air temperature influence on the lower differences of LST in 2016 than March 2005. Bandarawela shown as the second highest population growth rate city in Sri Lanka but it has also gotten the same impact due to the physical changes of the environment.

Table 04: Daily Rainfall data for LST estimated dates in two different study period

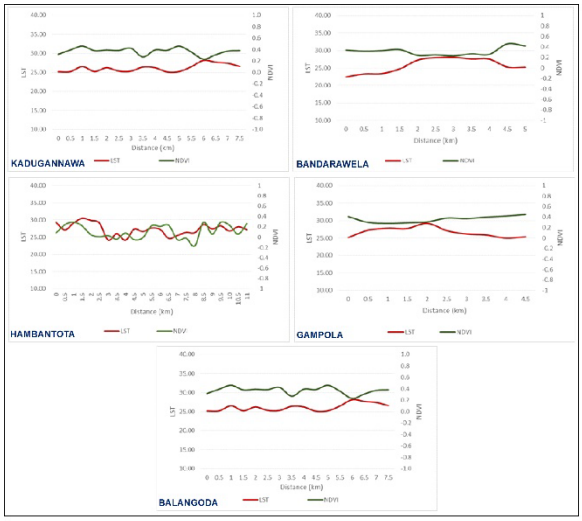
Source: Department of Meteorological, March 2005 & March 2016.

According to the above results, can conclude that LST has been increased with the population growth rate and land surface changes. However, some external factors such as meteorological, physical and environmental factors have influenced on the changes in LST in certain urban cities.

VII. CONCLUSIONS

This study has attempted to identify the relationship of LST variations in rapid population growth cities in Sri Lanka. Therefore, five cities which has highest population growth according to the census 2001 to 2011 were taken into the consideration. Spatial and temporal variation in those cities were also considered. Using satellite based methods, LST data for each city were estimated for March 2005 and March 2016. Results of the study in conclusion show that, LST has increased in all five cities and the highest value can be identified in Hambantota area. The highest LST mean differences have shown in Hambantota. Clearly some external factors had influence on the LST. Land use/land cover changes, rainfall, humidity, elevation and surrounding water bodies were identified as major external factors that influenced the changes in temperature variation in an area.

Figure 04: LST & NDVI for Selected Cities (using east to west Profile)



Source: Landsat image, 17/26 March 2005 and 24/31 March 2016 from http://earthexplorer.usgs.gov/

Finally, the study has revealed that the rapid population growth and urban expansion directly affected the increase LST. However, some physical, meteorological or

environmental factors play critical role on fluctuation of LST in certain areas.

VIII. FUTURE SCOPES

With rapid population growth all around the world. Population shift to urbanized areas will be continued. As a result natural land surface areas (natural vegetation, streams and etc.) will be convert in to more built-up areas. Therefore, best management practices should utilize for suitable urban planning to mitigate temperature increase in the cities.

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