DEVELOPMENT OF A THERMAL RISK MAP
CASE STUDY: KELANIYA CITY OF SRI LANKA

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ABSTRACT: The land surface temperature in city areas is increased compared to the adjacent rural areas as a result of industrialization and urbanization. This phenomenon is known as the formation of heat island. In the context of population density, Kelaniya is the second largest Divisional Secretariat (DS) division next to Colombo. Main access to Colombo from Kandy is laid across Kelaniya in which thousands of vehicles travel through. Therefore, Kelaniya is subjected to heat stress. Since this will cause to thermal discomfort, cooling devices are additionally driven by increasing the energy demand. The main Objective of this study is to develop thermal risk map for Kelaniya. Thermal band(s) of the Landsat images were used to derive LST. Derived temperature values were normalized, extracted the areas which are greater than 0.6 as heat islands and combined. According to the status of heat islands in the combined image, a map on the persistence of heat islands was derived. Areas which existed as heat islands in all three years, at least one year or none and other were considered as high, low and moderate thermal risk areas respectively. The areas with high thermal risk were extracted, intersected with GramaNiladhari (GN) divisions of Kelaniya and again classified into three risk classes as high, moderate and low. GN divisions with more than 50%, between 50% to 20% and below 20% of high thermal risk areas from its total area were referred as high, moderate and low thermal risk GN divisions respectively. More than 50% of the areas in Kelaniya still remains as low thermal risk areas. Therefore, actions should be taken to prevent the transformation of low thermal risk areas into other two categories while accelerating the conversion of moderate and high thermal risk areas into low thermal risk category.

1 INTRODUCTION

Statistics from United Nations show that the present world population in urban areas is around 54% (United Nations, 2010). It is predicted that this amount is to be increased up to 66% in 2050(Melorose et al., 2015). According to the facts and figures of department of senses and statistics, 19.2% people in Sri Lanka are settled in urban areas (Department of Census and Statistics, 2012). Colombo is the main central hub in Sri Lanka for both administrative and economy. Therefore, a higher amount of urban population is settled in Colombo due to its richness of facility and service availability. When people feel discomfort due to population saturation, they move from Colombo to nearby cities. With the time, such cities become more popularized and urbanized. To supply enough spaces to the newly added population, natural green cover in the earth surface is subjected to be removed and it replace with manmade materials such as concrete, asphalt etc. (Emmanuel and Fernando, 2007). This process imbalance the natural thermoregulation and air flow, and create warmer environment compared to rural areas by increasing its land surface temperature. This process is strengthened by the increasing of human activities as the population is increased. This is referred as the formation of heat island (Song and Wu, 2016). Thermal discomfort created from this process may help to develop number of social, economic and environmental problems (Senanayake et al., 2013). Use of additional energy (Ukwattage and Dayawansa, 2012)for artificial thermoregulation (electrical fans, air conditioners) and indirect heat emission occurred during thermoregulation are the other crucial problems arise as a result of this phenomenon.

Kelaniya DS division is having the highest population density in Gampaha district. Thousands of vehicles and people travel across Kelaniya in each day because the main access to Colombo from Gampaha is laid across Kelaniya. Consequently, the possibility to form heat islands is higher in Kelaniya compared to other DS divisions in Gampaha district. Therefore, the main Objective of this study was to develop thermal risk map for Kelaniya. This is based on two specific objectives which are; 1) to identify the urban heat island areas and their distribution with the time,2) to determine the persistency of heat islands in Kelaniya. After achieving all these specific objectives, it automatically achieves the main objective.

2 THE STUDY AREA

Highest urbanization and industrialization can be observed in the western province, and it can be referred as the main administrative and the economic hub in Sri Lanka. Among districts in the western province, highest urbanization and industrialization can be observed first in Colombo and second in Gampaha. Even the context of population density, Colombo is the highest and then Gampaha(1700/km^2)(Department of Census and Statistics, 2012). Kelaniya DS division (Fig. 1) is one of the important administrative divisions in Gampaha district, which is closest to Colombo city and having a tropical monsoon climate. It consists 37 GN divisions having total extent around 20km^2(ICTA, 2011).

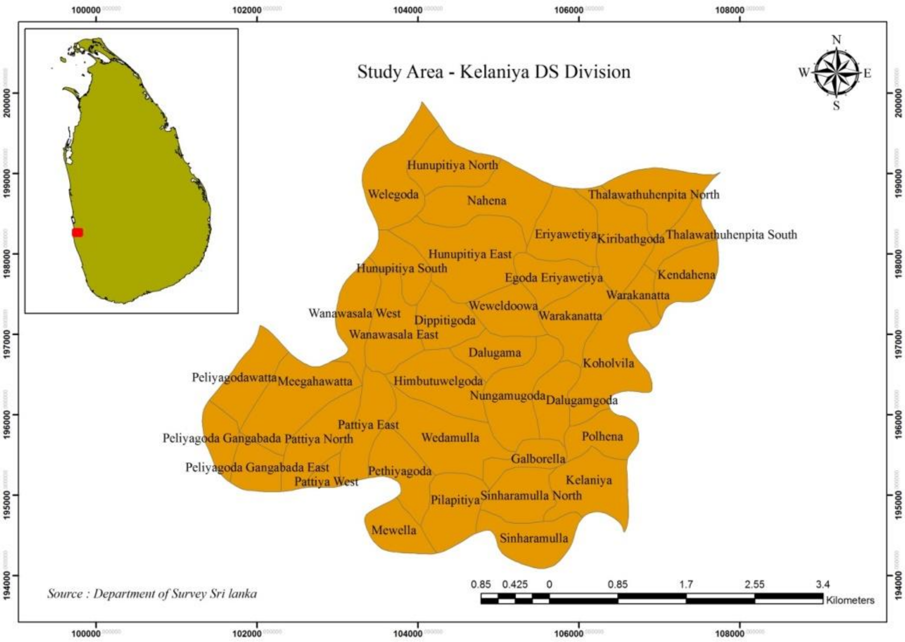

Figure 1. DS boundary map of Kelaniya with GN boundaries

3 METHODOLOGY

Satellite images from Landsat 5, 7 and 8 which covered the study area were taken into the analysis. Images from year 2006(TM), 2009(TM) and 2014(OLI/TIRS) were selected for the detailed study. Earth explorer (http://earthexplorer.usgs.gov)was the source web site, which used to obtain those images. Satellite images were analysed using the ArcGIS version 10.1. Topographic maps with 1:10,000 scale which published by the department of survey, Sri Lanka were used for area confirmation.

3.1 Derive land surface temperature

Thermal band(s) of the satellite images were separated and subjected to geometric and radiometric corrections. Then the digital numbers (DN) in the corrected bands were converted into radiance (Ukwattage and Dayawansa, 2012)values using Eq. (1).

Radiance = Gain x DN + Offset (1)

Converted radiance values were transformed into temperature values by considering the study area as a black body (Avdan and Jovanovska, 2016)explained in Eq. (2).

$$T_B = \frac{K_2}{\ln\left(\frac{K1}{L_\lambda}+1\right)} \quad (2)$$

TB = At Satellite Brightness Temperature, in Kelvin.

Lλ = Spectral radiance (Watts/ (m2 * srad * μm))

K1 &K2 are Thermal conversion constants for the bands

Earth surface is not a black body because it emits energy as radiation in different efficiencies. Therefore, emissivity correction is needed. Emissivity corrected brightness temperature (black body temperature) value gives the actual land surface temperature(Ukwattage and Dayawansa, 2012) in Celsius which described in Eq. (3).

$$LST = \frac{T_B}{1 + \left(\frac{\lambda T_B}{\alpha}\right)\ln\varepsilon} - 273.15 \qquad (3)$$

TB =Black body temperature in Celsius (^{o}C)
λ =Wavelength of emitted radiance (λ= 11.5 μm)
α= hc/K
h = Planck constant
c = velocity of light
K = Boltzmann constant
ε = surface emissivity

Emissivity values of different land features in the study areas were determined by calculating the normalize difference vegetation index (NDVI) and proportion of vegetation (Pv).

3.2 Heat island extraction and estimate their persistency

Derived land surface temperature values were normalised (LST_N). Then the areas having normalized land surface temperature value greater than 0.6 (LST_N> 0.6) (Ukwattage and Dayawansa, 2012)were extracted as heat islands for each year. Changes of heat island status were estimated by combining the heat islands in each couple of years at once. A map which was prepared based on the status changes of heat islands were classified into four classes as non-heat islands, newly added heat islands, prominent heat islands and heat island left off. According to the persistency trend, heat islands can be categorized in to three classes as high, moderate and low risk.

4 RESULT AND DISCUSIION

After gone through the all calculation procedures, heat island areas per each year was extracted and mapped. Distribution of heat islands in each year was described in Fig.2. Area wise comparison in heat island distribution was displayed in Table 1. According to both the map and the table, areas under heat island condition were expanded rapidly with the time. Highest expansion was observed in year 2009 to 2014.

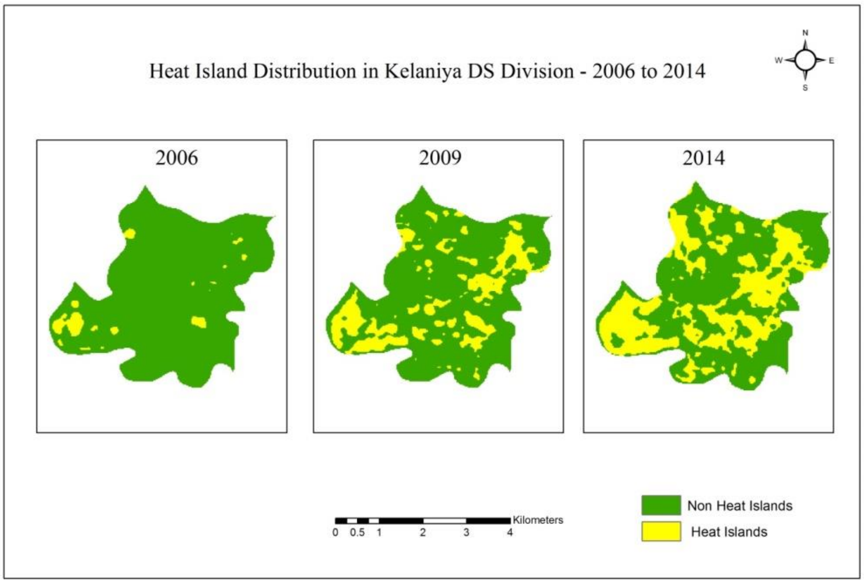

Figure 2. Heat island distribution map for Kelaniya

Table 1. Heat island expansion in Kelaniya

Category	2006	2009	2014
Heat Island Area in km^2	0.76	4.61	13.69
Heat Island Area in %	3.7	22.17	65.82

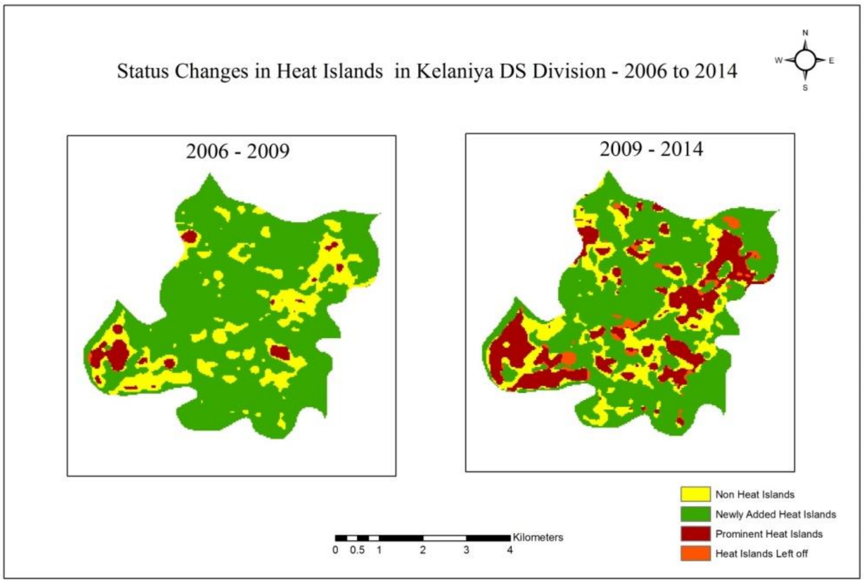

Figure 3. Persistency of heat islands in Kelaniya

Change of status of heat islands in Kelaniya DS Division was displayed in Fig. 3. Based on the changes of status in each heat island area, heat island persistency can be determined. Therefore, area basis summarization of the persistency of heat islands is described in Table 2.

Table 2. Persistency of heat islands in Kelaniya

Category	2006 – 2009 in km^2	2009 - 2014 in km^2
Non Heat Islands	16.15	12.37
Newly Added Heat Islands	3.86	3.81
Prominent Heat Islands	0.75	3.98
Heat Island Left Off	0.03	0.62

With the time the extent of the areas considered as non-heat islands were decreased. There is a slight decrease in the extent of newly added heat islands in year 2009 to 2014 compared to 2006 to 2009. Extent in the areas which were left off their heat island status were decreased with the time. However, a considerable increase can be observed in the areas which were categorized as prominent heat islands in 2009 to 2014 compared to 2006 to 2009.

Based on the trend of heat island persistency, a thermal risk map was prepared as displayed in Fig. 4 and it was classified to three risk classes as high, moderate and low. Area basis description about each risk class in Kelaniya DS division is explained in Table 3. From the total area, around 37% of land is under high and moderate thermal risk while 62% of land is still under low thermal risk condition.

Table 3.Thermal risk classes and their extent

Risk Class	Area in km^2	Area in Percentage Basis
High Risk	3.98	19.15
Moderate Risk	3.8133	18.35
Low Risk	12.99	62.50

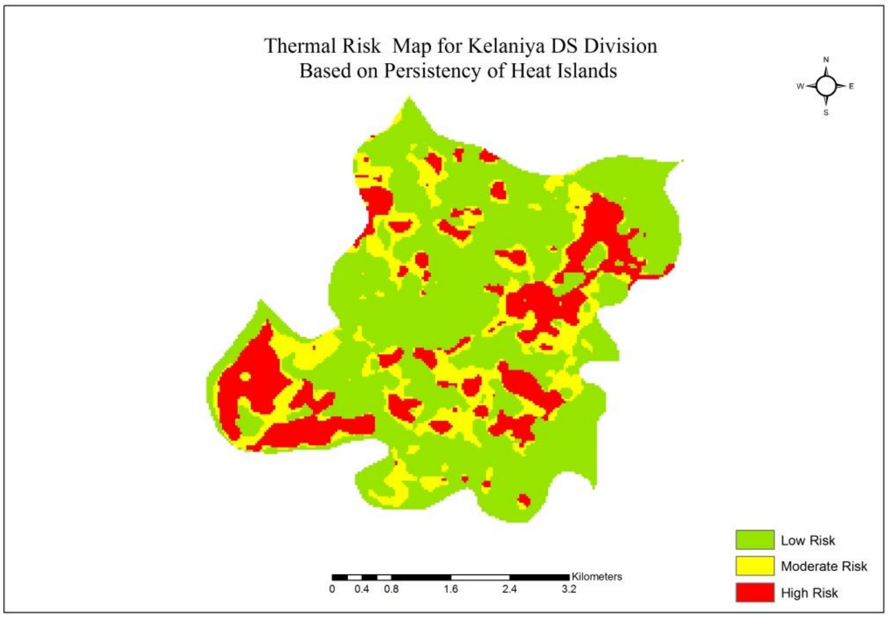

Figure 4. Thermal risk map for Kelaniya

5 CONCLUSION

Heat island areas are rapidly increased with the time. Highest increase (from 43.65km^2) was observed in the period during 2009-2014. Therefore, a highest amount of heat generation was to be occurred during that period. More than 50% of the area in Kelaniya still remains as low thermal risk areas. Most of the high thermal risk areas are located near Colombo. Therefore, actions should be taken to prevent the transformation of low thermal risk areas into other two categories while accelerating the conversion of moderate and high thermal risk areas into low thermal risk category.

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