Analysis of Urban Heat Island in Colombo city, Sri Lanka - An Application of Remote Sensing Technique.

By

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DECLARATION OF THE CANDIDATE

I do hereby declare that work described in this thesis was carried out by me under the supervision of Prof.G.M. Bandaranayake and, Mr. S. Sivanantharajah and report on this thesis has not been submitted in whole or in part to any University or any other institution for another Degree/Diploma.

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ABSTRACT

Closed isotherm indicating of an area of the surface that is relatively warm is called heat island (HI), most commonly associated areas of human disturbances such as town and cities. Urbanization leads to rapid constructions, which use low albedo materials leading to high heat absorption in urban centers. In addition, removal of vegetation cover and emissions of waste heat from various sources contribute to the accumulation of heat energy, leading to formation of urban heat islands (UHIs). UHIs have many adverse socio-environmental impacts. Therefore, spatial identification of UHIs is a necessity to take appropriate remedial measures to minimize their adverse impacts. Satellite remote sensing provides a cost-effective and time-saving methodology for spatio-temporal analyses of land surface temperature (LST) distribution. This study mainly focused on identifying the spatial expansion of heat island areas of Colombo city and to relate it with the urbanization associated land use changes.

In this study, bands of Landsat-7 ETM+ and Landsat 8 OLI & TIRS imagery acquired in 3 distinct dates covering Colombo city of Sri Lanka will be analyzed for the spatio-temporal identification of UHIs. Vegetation cover of Colombo city was extracted by using NDVI method and subsequently examined with the distribution of LST.

According to this study it is possible to identify Colombo port area as a heat island. Furthermore possible heat island areas of Colombo city are developing last decade.

Keywords: Remote Sensing, Heat Island, Land Surface Temperature, NDVI , Sri Lanka, Colombo , Landsat,

Chapter One

1.1 Introduction

The urban heat island (UHI) effect has been observed as raise of temperature of cities by 1^0C to 3^0C compared to neighboring rural areas. Urbanization leads to rapid constructions, which use low albedo materials leading to high heat absorption in urban centers. In addition, removal of vegetation cover and emissions of waste heat from various sources contribute to the accumulation of heat energy, leading to formation of urban heat islands (UHIs). UHIs have many adverse socio-environmental impacts. Therefore, spatial identification of UHIs is a necessity to take appropriate remedial measures to minimize their adverse impacts. Satellite remote sensing provides a cost-effective and time-saving methodology for spatio-temporal analyses of land surface temperature (LST) distribution.

The rural-to-urban population shift has resulted in tremendous social upheaval and environmental pressure. When a city's population swells, demand for both utilities and transport also surges. The unavoidable result is greater congestion and higher levels of pollution. As urban populations increase, so does the competition for natural and non-renewable resources.

Urban Heat Island (UHI) usually referring to the relative warmth of air temperature near the ground. Urban Heat Island (UHI) forms in air due to cooling difference between urban and rural area. The annual mean temperature of a large city may be 1 -2 Celsius warmer than before development.

As of year 2010, 50.5% of the world's population resided in urban areas implies that majority of the world population lives in urban areas instead of rural areas. In the year

2050, urban population residing in urban sprawls of developing countries is expected to double in number (United Nations, 2011)

The roof tops and walls of high rise structures with darker surfaces, parking lots, roads and pavements constructed with asphalt and concrete tend to have low albedos. These dark low-albedo surfaces absorb higher amount of solar radiation and convert it to thermal energy. Consequently,

Excess amounts of heat energy accumulate in the immediate vicinity to above average levels. This phenomenon causes urban areas to have elevated temperatures compared to the surrounding rural areas. This temperature difference forms the land effect called urban heat islands (UHIs) (Comarazamy et al., 2010).

Temperature of every surface depend on it is energy balance which is governed by its properties

1. Orientation and Openness to sun, sky, and wind
2. Ability to reflect solar Infrared radiation
3. Availability of surface moisture to evaporate
4. Roughness of the surface

Properties of the materials utilized in construction of urban structures, such as solar reflectance, heat capacity and thermal emissivity plays a major role in formation of UHIs. In addition, the waste heat generated by factories, air conditioners and motor vehicles which are ubiquitous in urban areas contribute to the formation of UHIs (Guhathakurta and Gober, 2007; Khan and Simpson, 2001; Sailor and Lu, 2004; Weng, 2010).

In order to implement mitigation measures against UHI formation, it is important to identify the LST distribution in urban areas and determine areas with anomalous high temperatures. Satellite remote sensing provides an excellent cost-effective and time-saving methodology to analyze spatially and temporally distributed LST, since the coverage of satellite imagery extends over a large area.

Colombo, the commercial capital or administrative hub of Sri Lanka is located between Northern latitudes 6-55 06-59 and Eastern longitudes 79-50 –79 53 0 extending over 37 km^2 of area. It is lies low country wet zone of Sri Lanka. Contemporary urban development and planning projects have converted Colombo into a highly urbanized city in South Asian region, with a resident population of 637,865 and a floating population of nearly 100,000 (2001 census data) encompassing the highest population density in the island. Also mean annual ambient temperature of Colombo city is 27^0 C and average rainfall is 2450mm per year.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Min Temp	22	22	23	24	25	25	25	25	25	24	23	23
Max Temp	30	31	31	31	31	30	29	29	30	29	30	30
Avg Temp	26	26.5	27	28	28	28	27	27	28	27	27	26.5
Avg Rainfall	88	96	118	260	353	212	140	124	153	354	324	175
Relative Humidity	75	76	78	81	82	82	81	80	80	83	82	78

Tab_1: Colombo Average Temperature

This study focuses on identifying the LST distribution pattern and temperature anomalies in the Colombo city by analyzing Landsat-7 and Landsat 8 satellite imagery obtained during 2000–2015.

Imagery from Landsat satellite has been acquired since 1972 and freely available in internet. Landsat is the main source of satellite images of this research. Landsat images have medium level spatial resolution and spectral resolution. Spatial Resolution of Landsat is enough to extract coastline changes and methods used to extract details from satellite images can be used to another type of satellite images too.

Landsat 8 equip with two sensors. One is Operational Land Imager (OLI) and next one is Thermal Infrared Sensor (TIRS).Bandwidth of TIRS is narrower than previous Landsat satellite thermal sensors

1.2 Research Problem

Since the Colombo area is rapidly developing identifying Heat island and areas which requires immediate remedy is vital. This research address how to identifying Urban Heat Island effectively using remote sensing methods, Identifying deviation of heat island with past data and predict the areas which are in high risk. Usual method of identifying heat island is air temperature measurements taken from standard meteorological stations or mobile stations but these methods are costly and law spatial resolution.

1.3 Significant of the study

Urban Heat Islands imposes adverse impacts on ecological balance of environment.it increase energy consumption of area, compromised human health and comport. Identification of Urban Heat Islands (UHI) helps relevant personals to come up with remedies.

Remote sensing technology with the advantage of large area and simultaneous observation can overcome various restrictions on ground surveys macroscopically, fast, comprehensively, dynamically and low cost than conventional method of surveying and analysis .(Zang,Jiang,Xu ,2013,). Because of above mentioned reasons technology of remote sensing is more suitable for developing countries like Sri Lanka. This research is very important since few remote sensing researches done in Sri Lanka

1.4 Objective of the study

Main objectives

Main objectives of this study were to spatially identify the UHI formations in Colombo city,

Specific Objective

Also identify the relationship between vegetation cover and LST distribution and to develop an Environmental Criticality Index based on the LST and availability of vegetation. The results of this study can be effectively utilized in future urban planning projects in order to take appropriate remedial measures to minimize the adverse effects of UHIs in Colombo city.

Chapter Two

2. Literature Review

Research has done by Arthur C Clark institute for modern Technologies, Sri Lanka. In this study, thermal bands (10.40–12.50 μm) of Landsat-7 ETM+ imagery acquired in 3 distinct dates covering Colombo city of Sri Lanka were analyzed for the spatio-temporal identification of urban Heat Islands (UHIs). Vegetation cover of Colombo city was extracted by using NDVI method and subsequently examined with the distribution of Land surface temperature (LST).

A deductive index was defined to identify the environmentally critical areas in Colombo city based on the distribution of LST and availability of vegetation cover. Accordingly, Colombo harbor and surrounding areas were identified as the most critical areas. Remedial measures can be taken in future urban planning endeavors based on the results of this study.

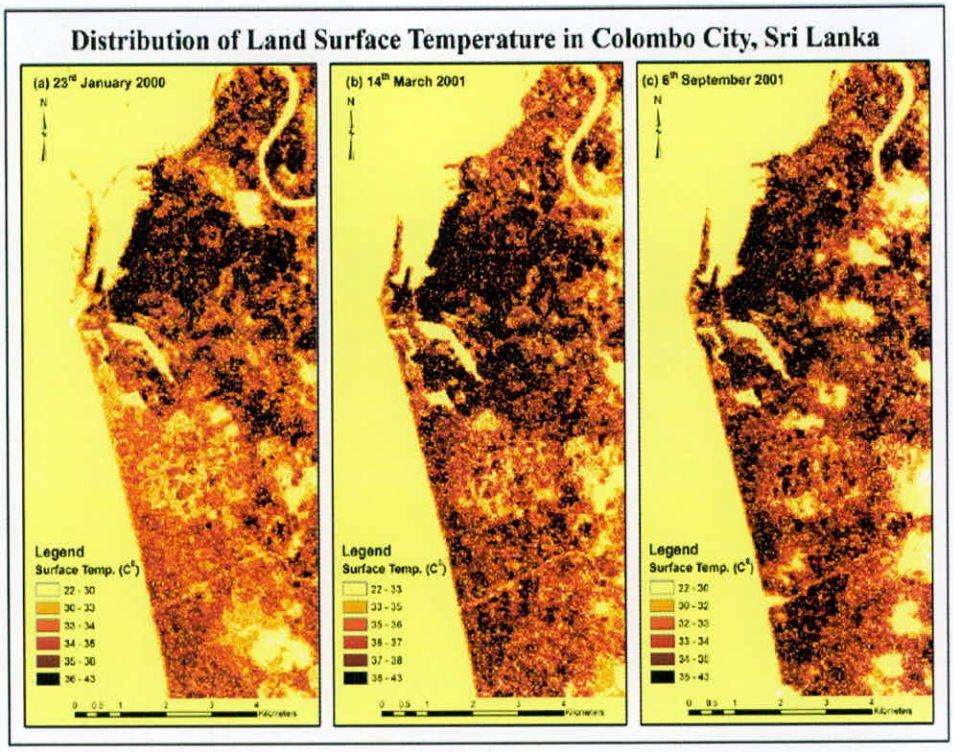

Fig_1 – Distribution of land surface temperature in Colombo city. Sri lanka on (a) 23rd January 2000 (b) 14th March 2001 (c) 6th September 2001

UHIs are persistent zones with above average LSTs. For the purpose of identification and classification of these persistent features, a temporal analysis requires to be employed to exclude short-term temperature anomalies such as temporary heat producing entities. In order to satisfy this condition, Landsat-7 ETM+ images captured in 3 distinct dates were utilized to identify UHIs in the study area. Consequently, high LST zones common to all 3 satellite images were designated as UHIs in Colombo city.

To calculate Land surface temperature equation of Landsat 7 science data user hand book were used in this research and apart from that new index were introduced by researchers. To identify the level of combined environmental criticality in Colombo city on the basis of LST and availability of vegetation cover. The LST layers and NDVI

layers used in Eq.(8) were stretched using histogram equalization method from 1 to 255 pixel values to enhance the clarity and contrast of the resultant layer and to avoid erroneous infinite Environmental Criticality Index values caused by the presence of 0 stretched-NDVI values in the calculation:

$$ECL_{Lst-veg} = \frac{LST_{streached\ 1-255}}{NDVI_{streached\ 1-255}}$$

$ECL_{Lst-veg}$ -Environmental Criticality Index based on LST and availability of vegetation cover

, $LST_{streached\ 1-255}$ and $NDVI_{streached\ 1-255}$ - LST and NDVI values histogram stretched from 1 to 255

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