بسم الله الرحمن الرحيم

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ملاحظات: ....

CHANGE DETECTION OF URBAN HEAT ISLAND UNDER DIFFERENT ENVIRONMENTAL CONDITIONS USING REMOTE SENSING TECHNIQUES

Submitted By

Islam Hamdy Ibrahim El-Gamily

B. Sc. In computer Engineering, Faculty of Engineering, Arab Academy for Science, Technology & Marine Transport, 2005

Master In computer Engineering, Faculty of Engineering, Arab Academy for Science, Technology & Marine Transport, 2010

A Thesis Submitted in Partial Fulfillment

Of

The Requirement for the Doctor of Philosophy Degree

In

Environmental Sciences

Department of Environmental Engineering Sciences

Faculty of Graduate Studies and Environmental Research

Ain Shams University

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ABSTRACT

The Industrial revolution led to the Global Warming issue, while the continuous development of metropolitan urban areas leads to an environmental issue known as Urban Heat Island (UHI) or Urban Cool Island (UCI), especially if the urbanization took place over agricultural lands. UHI and UCI phenomenon are mainly due to the reflectance and emission of heat to the lower layer of the atmosphere. This issue has negative impacts on both the local and global environment. It also negatively affects human activities in terms of productivity, lifestyle and health issues. It also affects the healthy state of animals and vegetation.

This thesis is based on the hypothesis of considering the increase or decrease in the emissivity-corrected Land Surface Temperature (LST) in any urban area is not only due to UHI but also due to global drivers (global warming) and regional drivers (the effect of regional climatic and anthropogenic factors). The main objective of this research is to monitor and analyze the trend of changes in UHI/UCI using Thermal Infrared Remote Sensing. In this research, the UHI term refers to the change in the emissivity-corrected Land Surface Temperature after removing the Global driver (Global warming) and Regional Drivers effects.

The thesis is applied on two study areas: 1) EL-Sheikh Zayed city, the 6th of October City, Giza governorate; and 2) EL-Senbellaween city, Dakahliya governorate. The first study area represents the Land Use/Land Cover changes from soil/desert into an urban environment. In contrast, the second study area represents the land use/land cover changes from cultivated land into an urbanized environment.

The digital image processing capabilities of ERDAS Imagine software, ArcGIS Pro and PCI Geomatica software are utilized to restore the satellite

images and carry out the needed enhancement, analysis, and information extraction in terms of LST, Land use/land cover, Normalized Difference Vegetation Index (NDVI) and UHI/UCI. The research includes the design and development of two GIS-based models to calculate the emissivity-corrected Land Surface Temperature and calculating the UHI/UCI considering global warming and regional drivers effects.

The results were discussed and the recommendations were introduced. It was concluded that the first study area (EL-Sheikh Zayed city) suffers from the UCI effects, whereas the second study area (EL-Senbellaween city) suffer from UHI effects. Results indicated that some changes in Land Use/Land Cover, such as the changes from vegetation to urban, have a negative impact on the climate by more than 13 times of the global warming effects. It is recommended to disseminate social awareness regarding the UHI phenomenon. In addition, prohibition and criminalization of encroachment of agricultural lands are highly recommended.

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

The industrial revolution in the middle of the last century led to a new environmental issue known as Global Warming. This issue is mainly due to the injection of Green House Gases [GHG's] in the atmosphere, which is responsible for long-term negative impacts on the biotic and abiotic components on our planet (Howard, 1818).

The advancement of Remote Sensing (RS) techniques nowadays led to covering our planet with Thermal Infrared remotely sensed data (Dash et al., 2002). By analyzing those images, it was noticed that the Land Surface Temperature (LST) inside the dense urban areas is higher than those of the surrounding rural areas with a difference of up to approximately 5℃ (El-Hattab et al., 2018). Generally, urban areas reflect more heat to the lower layer of the atmosphere than rural or vegetated land areas. This phenomenon is mainly known as Urban Heat Island (UHI) (Kłysik and Fortuniak, 1999; Stathopoulou and Cartalis, 2007; Schwarz et al., 2011; Effat and Hassan, 2014; Effat et al., 2014).s

Many attempts to estimate UHI using remotely sensed data were undertaken (Gallo et al., 1993; Dousset and Gourmelon, 2003; Miao et al., 2009; Tomlinson et al., 2011; Nakata-Osaki et al., 2015; Li et al., 2018). Thermal Infrared Sensor (TIRS) data and relevant approaches were used to extract the emissivity-corrected LST (Sahana et al., 2016; Suresh et al., 2016; Rasul et al., 2017; El-Hattab et al., 2018; Kaplan et al., 2018). Satellite TIRS is used to measure the Top of Atmosphere Radiance (TOA Radiance), where brightness temperature values are calculated based on Plank's law (Dash et al., 2002; García-Santos et al., 2018).

The TOA radiance comprises three fractions of energy, emitted radiance from the Earth's surface, atmosphere upwelling radiance, and downwelling radiance (Prata et al., 1995). Therefore, these atmospheric effects need to be

corrected before estimating land surface brightness temperature (Miao et al., 2009; Schwarz et al., 2011; Effat et al., 2014). Additional radiometric corrections for the brightness temperature are applied to produce the emissivity-corrected LST. This correction includes the use of ground emissivity or Land Surface Emissivity (LSE) values. LSE is an essential factor to predict the emitted radiance, and it is the thermal energy transmitted across the atmosphere. LSE is the ratio of the emitted radiance of a certain object or material to that radiance emitted from an ideal blackbody at similar temperature (Planck's law) (Sobrino et al., 2004, 2008; Sekertekin and Bonafoni, 2020). This step is achieved by considering the roughness properties of land surfaces, the thermal properties, and the soil's moisture content (Sobrino et al., 2008; Emmanuel and Krüger, 2012; Schwarz et al., 2012).

In the present thesis, the Thermal Infrared (TIR) remotely sensed data is used to estimate the UHI/UCI effects.

1.2 STATEMENT OF THE PROBLEM

Metropolitan urban development leads to severe environmental impacts. These impacts are mainly due to the reflectance and emission of heat to the lower layer of the atmosphere. This phenomenon is known as Urban Heat Island (UHI). The UHI has severe effects on both the local and global environment. Locally, it negatively affects human activities in terms of productivity, lifestyle and health issues. The UHI might speed up the global warming issue and its related negative impacts, especially on built-up (urban) areas. This research study is concerned with studying and estimating the UHI issue and introduces a relevant policy to reduce its impact.

1.3 THE OBJECTIVES AND SCOPE

The main objectives of this research study are to: