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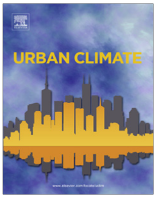

# Change detection of urban heat islands and some related parameters using multi-temporal Landsat images; a case study for Cairo city, Egypt

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ABSTRACT

Cairo has a unique geographic location and is one of the highest built-up densities worldwide. This study attempts to map and detect changes in land-cover and heat islands over Cairo through three decades using multi-temporal Landsat TM satellite data. Five sub-scenes (1984, 1990, 2001, 2006 and 2013) were selected for summer daytime. A supervised classification was used to map land use/landcover and changes. Landsat bands were used to derive the albedo and Normalized Difference Vegetation Index. The thermal band was used to retrieve the land surface temperature (LST) and urban heat island (UHI). Results show that during the observed period, the city experienced a massive urban growth. The UHI was fluctuating, the highest value recorded was in 2013 image. NDVI mean values decreased probably due to weak management policies for green areas. Based on the observed images, the LST values were higher over eastern zones. The highest albedo values were recorded in the eastern desert zones. It was also noticed that the UHI intensity and spatial distribution were higher and more dominant in such zones compared the UHI in the dense built-up areas of the city.

## 1. Introduction

An urban heat island (UHI) was defined by Oke (1982, 1995) and Voogt and Oke (1997, 2003) for different layers of the urban atmosphere, and for various surfaces and even the subsurface. UHI is the

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excess warmth of the urban atmosphere compared to the non-urbanized surroundings. Urban areas generally have higher solar radiation absorption and a greater thermal capacity and conductivity as they are comprised of buildings, roads and other impervious surfaces. Heat is stored during the day and released during night. Therefore, urban areas tend to experience a relatively higher temperature compared to the surrounding rural areas. This thermal difference, in conjunction with waste heat released from urban houses, transportation and industry, contribute to the development of an urban heat island (UHI). Urban climatologists have long been interested in the differences in observed ambient air temperature between cities and their surrounding rural regions (Landsberg, 1981; Weng and Yang, 2004). Heat islands can occur at a range of scales; it can manifest itself around a single building (Thurow, 1983) a small vegetative canopy (Taha et al., 1991), or a large portion of a city. Geographic location, prevailing weather conditions and anthropogenic activities impact the heat islands. Micro-urban heat islands (MUHIs) are isolated urban locations that produce "hot spots" within a city. UHI intensity is related to patterns of land use/land cover changes (LU/CC), e.g. the composition of vegetation, water and built-up and their changes (Chen et al., 2006).

UHIs have long been studied by ground-based observations taken from fixed thermometer networks or by traverses with thermometers mounted on vehicles. Taha (1997) reports, through meteorological simulations, that the anthropogenic heating in a large city core can create a heat island of up to 2–3 °C both during the day and at night. Evapo-transpiration from soil-vegetation systems is an effective moderator of near-surface climates, particularly in the warm and dry mid and low latitudes. Given the right conditions, evapo-transpiration can create 'oases' that are 2–8 °C cooler than their surroundings. Impervious surface is any surface that does not allow the natural infiltration of water (Johnson, 2004). Urban areas, with extensive impervious surfaces, have generally more run off than their rural counterparts. The runoff water drains quickly and, in the long run, less surface water remains available for evapo-transpiration, thus affecting the urban surface energy balance (Grimmond and Oke, 1991). The lower evapo-transpiration rate in urban areas is a major factor in increasing daytime temperatures. Many techniques for estimating impervious surfaces exist. Image classification using remotely sensed multi-spectral satellite imagery are widely used.

Spatially complete and time-synchronous coverage of an urban area can be obtained from thermal wavelength satellite sensors which measure surface temperature (Ts), thus unlike fixed stations and vehicle traverse the actual maximum and minimum temperatures over a city region can be obtained (Johnson, 1991) and intra-urban thermal patterns can be observed. Middle resolution satellite images have been utilized to study UHI. With the advent of thermal remote sensing technology, remote observation of UHIs became possible using satellite and aircraft platforms providing new avenues for the observation of UHIs. An extensive set of studies on the surface urban heat island (SUHI) phenomenon is conducted using middle spatial resolution such as Landsat TM/ETM+ and ASTER data. Landsat Thematic Mapper TM and ETM+ thermal infrared (TIR) data with 120 m and 60 m spatial resolutions, respectively, have been utilized for local-scale studies of UHI (Weng, 2001; Weng and Yang, 2004; Chen et al., 2002). A variety of algorithms have been developed to retrieve land surface temperature from TM/ETM+ imagery, such as mono-window algorithm (Qin et al., 2001), single-channel algorithm (Jimenez-Munoz and Sobrino, 2003; Jiménez-Muñoz et al., 2009) and the method proposed by Artis and Carnahan (1982). Landsat imageries have also been used intensively in mapping land-use/land-cover and in detection of changes (Shen et al., 2011; Peijun et al., 2010; Bauer et al., 2004). The ASTER sensor onboard the Terra satellite provides data at various resolutions from 15 m to 90 m. ASTER has several thermal infra-red bands that are well suited for analyzing LST, further studies can be found in Liu and Weng (2006a,b), Akhoondzadeh and Saradjian (2008).

### *1.1. Cairo city: location, problem description and literature review*

Cairo city is located at latitude 30° 06′ N and longitude 31 28′ E at an altitude of 74.5 m asl. The city is located in the east of the River Nile south of the Nile Delta. It is bordered from the west by the urban area of Giza Governorate on the western banks of the River Nile (Fig. 1). The city is characterized by the presence of El Moqattam hills to the south east and desert areas extending to the east direction (Robaa, 2003). The southern tip of the Governorate of Qalyubia-which currently represents the northernmost reach of Greater Cairo borders Cairo city from the north western side. The location of Cairo is