Atmospheric Research 167 (2016) 175–182

Contents lists available at ScienceDirect

Atmospheric Research

journal homepage: www.elsevier.com/locate/atmos

Urban heat evolution in a tropical area utilizing Landsat imagery

Jamil Amanollahi [a,*], Chris Tzanis [b,1], Mohammad Firuz Ramli [c,2], Ahmad Makmom Abdullah [c,3]

[a] Department of Environmental Sciences, Faculty of Natural Resources, University of Kurdistan, Iran
[b] Climate Research Group, Division of Environmental Physics and Meteorology, Faculty of Physics, University of Athens, University Campus Bldg. Phys. V, Athens 157 84, Greece
[c] Department of Environment Sciences, Faculty of Environmental Studies, Universiti Putra Malaysia, UPM 43400 Serdang, Selangor, Malaysia

ARTICLE INFO

Article history:
Received 4 May 2015
Received in revised form 20 June 2015
Accepted 28 July 2015
Available online 8 August 2015

Editor: S. Michaelides

Keywords:
Land Surface Temperature
Land use
Land cover
Digital number
GIS

ABSTRACT

Cloud cover is the main limitation of using remote sensing to study Land Use and Land Cover (LULC) change, and Land Surface Temperature (LST) in tropical area like Malaysia. In order to study LULC change and its effect on LST, the Landsat images were utilized within Geographical Information System (GIS) with the aim of removing the effect of cloud cover and image's gaps on the Digital Number (DN) of the pixels. 5356 points according to pixels coordinate which represent the 960 m to 960 m area were created in GIS environment and matched with thermal bands of the study area in remote sensing environment. The DNs of these points were processed to extract LST and imported in GIS environment to derive the temperature maps. Temperature was found to be generally higher in 2010 than in 2000. The comparison of the highest temperature area in the temperature maps with ground stations data showed that the topographical characteristics of the area, and the wind speed, and direction influence the occurrence of Urban Heat Island (UHI) effect. This study concludes that integration of remote sensing data and GIS is a useful tool in urban LST detection in tropical area.

1. Introduction

The environmental changes are due to, among others, changes in Land Use and Land Cover (LULC) (Brunsell, 2006). Environmental planning, management and monitoring require accurate information on land cover (Assefa, 2004). The variation of temperature in the center of urban locations, as opposed to that of nearby rural parts, which are several degrees higher, is referred to as Urban Heat Island (UHI) effect (Chou, 1985; Chen et al., 2014). One of the first researches about the UHI was conducted in Singapore by Nieuwolt (1966). UHI is a phenomenon that occurs due to changes in the biophysical attributes of the earth's surface in non-evaporating and impervious materials such as asphalt and tile (Charabi and Bakhit, 2011).

Land Surface Temperature (LST) has been used to assess the UHI and is a key parameter in controlling the water and energy balance between the atmosphere and land surface (Efstathiou et al., 2011). Traditionally, the assessment of UHI phenomenon was conducted using fixed thermometer networks or traversing a targeted area with a thermometer mounted on vehicles (Weng et al., 2004). Recently, LST acquired by remote sensing technologies has been utilized extensively in large scale to identify the characteristics of the UHI (Nichol et al., 2009). The first study to identify urban areas using Thermal Infrared (TIR) data of satellite sensor was undertaken in 1972 (Rao, 1972). Studies to drive LST were conducted primarily using National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) data for regional-scale urban temperature mapping (Streutker, 2002; Cai et al., 2011). Moderate Resolution Imaging Spectroradiometer (MODIS) on board Aqua and Terra satellites with high temporal (daily) and spatial resolution (1 km) is another sensor which has been used for studying LST (Imhoff et al., 2010; Vancutsem et al., 2010).

For local studies of UHI the TIR data of Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) with 120 m and 60 m spatial resolutions respectively, were also utilized (Weng et al., 2004; Chen et al., 2006; Li et al., 2009; Amiri et al., 2009). Weng et al. (2004) showed a slightly stronger negative correlation between LST and unmixed vegetation fraction rather than between LST and Normalized Differences Vegetation Index (NDVI) for land cover types. Chen et al. (2006) noted that higher temperature in the UHI was related to certain land-cover types. They found that the correlation between temperature and NDVI, Normalized Difference Water Index (NDWI), and Normalized Difference Bareness Index (NDBaI) is negative, while the correlation between Normalized Difference Build-up Index (NDBI) and temperature is positive. Li et al. (2009) showed that the patterns of UHI indicated by LSTs implied the existence of spatial correlation on

* Corresponding author at: Department of Environmental Sciences, Faculty of Natural Resources, University of Kurdistan, Pasdaran Street, Sanandaj, Iran, P.O. Box 416, 66177-15175. Tel.: +98 87 6627723 25x218; fax: +98 87 6620550.
E-mail addresses: J.amanollahi@uok.ac.ir (J. Amanollahi), chtzanis@phys.uoa.gr (C. Tzanis), firuz@env.upm.edu.my (M.F. Ramli), amakmom@env.upm.edu.my (A.M. Abdullah).
[1] Tel.: +30 210 7276838.
[2] Tel.: +60 162220607.
[3] Tel.: +60 196183743; fax: +60 3 89467463.

http://dx.doi.org/10.1016/j.atmosres.2015.07.019

the small and meso-scales. LST is affected by means of partitioning latent heat fluxes as well as surface radiant temperature response as a function of varying surface soil water content and vegetation cover (Xue et al., 2005). To find the LST variation in the specific places where LULC has been changed, the temperature data from ground monitoring stations in the study area are used. When significant difference in temperature is observed in all stations for the same time period, the LST variation may be due to other factors like climate change, but if these differences are not observed for all the stations then the LST variation may be due to LULC change.

In this study the Landsat 4 and 5 images on December 1990 and 2006 were analyzed to determine the LST variation due to LULC change, and also to estimate the rapid urban development in this period of time. To determine LST variation in all study area in the time when there are significant differences in temperature, Landsat ETM + on February 2000 and 2010 were utilized. To overcome the two main problems in the images, i.e. the cloud cover and gaps, Geographical Information System (GIS) and Landsat ETM + data were also integrated.

2. Data and methodology

2.1. Study area

The study area is characterized by uniform temperature (26 °C–27 °C), high relative humidity (70%–90%), and high level of rainfall (2500 mm), and the prevailing winds are generally weak (below 8 m/s) (MMD, 2010). The annual variation of temperature in the west coast, which is included in the study area of this research, is less than 2 °C. December and January are the months with the lowest average monthly temperature (26.5 °C), while April and May are the months with the highest average monthly temperature (27.5 °C) in Malaysia. Klang Valley is located at the southern part of the state of Selangor and covers an area of about 2826 km^2. Klang Valley is located between latitudes 2° 35′N and 3° 24′N and longitudes 101° 13′E and 101° 58′E (Fig. 1b). The main cites of Klang Valley are Kuala Lumpur, Kajang, Gombak, Putra Jaya, Klang, and Shah Alam. Kuala Lumpur, the capital of Malaysia, has two ground measurement stations in Cheras KL and Petaling Jaya (Fig. 1c).

2.2. Detection of LULC

The Environmental for Visualizing Images (ENVI) software was used for image processing and analysis. Landsat images of 27 December 1990 and 15 December 2006 were utilized to obtain the LST due to LULC change. The Landsat images were rectified to the Universal Transvers Mercator (UTM) projection system (datum WGS-84, zone 47N) and were geo-referenced based on topographical map (1:100 000) from the Department of Survey and Mapping, Malaysia using 50 ground control points. The nearest neighbor resampling algorithm was applied to preserve the brightness values of the pixels (Amanollahi et al., 2013). The root mean square errors (RMSEs) for image rectification were lower than 1 pixel (Amanollahi et al., 2012). The thermal bands—band 6—were then subjected to self-adaptive filter to remove the non-periodic noise that may affect the brightness temperature (Chen et al., 2006). In order to classify land cover and land use, three bands of images consisting of bands 5, 4, and 3 were combined (Li et al., 2009). The supervised classification with maximum likelihood algorithm was employed for the classification of land cover into four categories, namely: urban, vegetation, bare land, and water. Cloud covers were appeared to be lower than 5 percent in both images of 1990 and 2006. Cloud cover may decrease the accuracy of the classification. More than 90% of cloud covers concentrated above the vegetated area, thus the DNs of clouds

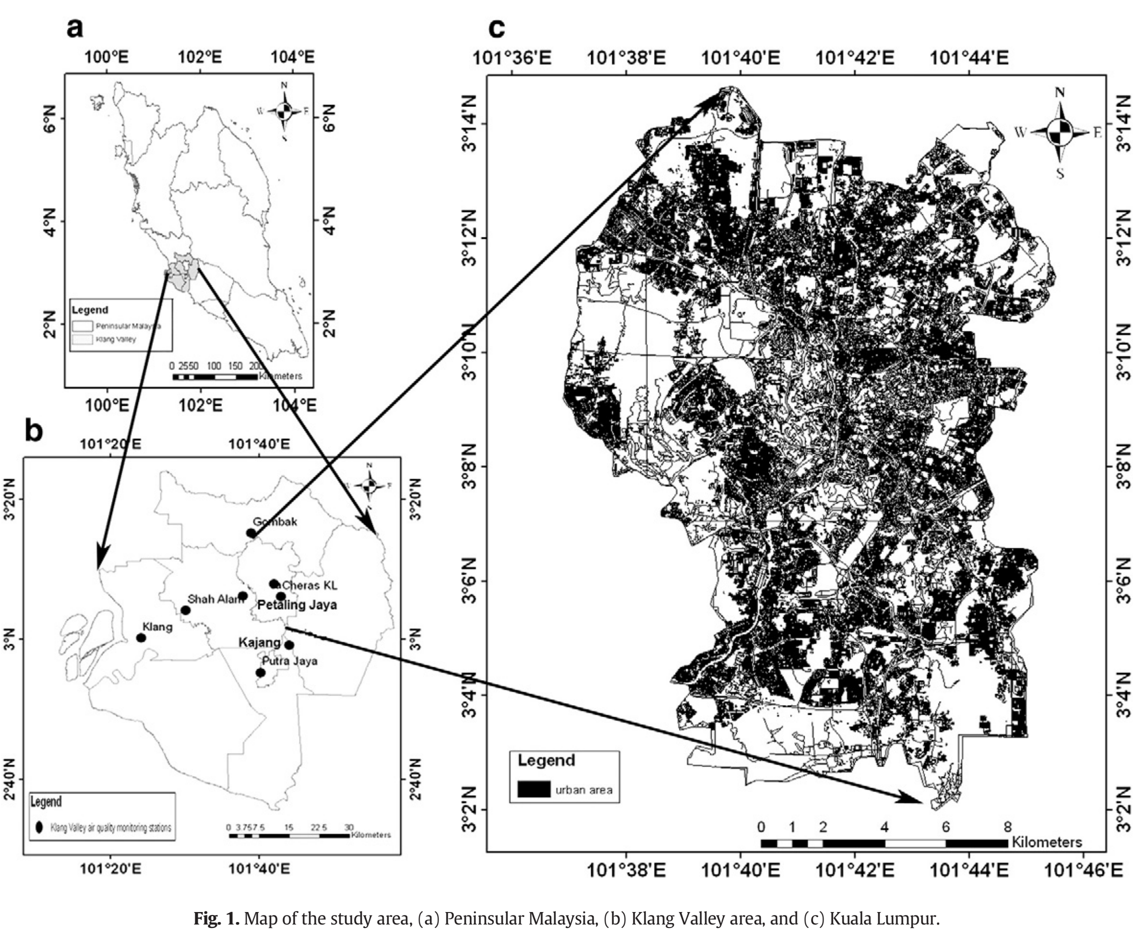

Fig. 1. Map of the study area, (a) Peninsular Malaysia, (b) Klang Valley area, and (c) Kuala Lumpur.