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A comparison between London and Baghdad surface urban heat islands and possible engineering mitigation solutions

Jasim M. Ali[a,b,*], Stuart H. Marsh[a], Martin J. Smith[a]

[a] *Faculty of Engineering, The University of Nottingham, Nottingham, UK*
[b] *Faculty of Engineering, University of Anbar, Anbar, Iraq*

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ABSTRACT

This study adopts remote sensing techniques to compare the Surface urban Heat Island (SUHI) in Baghdad and London as they represent different climatic conditions, natural environments and levels of urban development. It tests the reported correlation of land surface temperature (LST) with land cover in the literature under different conditions and, based on the findings, suggests engineering mitigation strategies for each city. The land surface was characterized using supervised classification and spectral indices, using the Landsat 8 optical bands (2–7), and the LST was retrieved from Landsat's thermal band 10 after emissivity calibration. Two Landsat 8 satellite images were used, acquired in July 2013 when maximum surface temperature would be expected in both these capital cities. Image processing included radiometric calibration and atmospheric correction and various land surface indices were then calculated. The independent validation of land cover types was performed using higher spatial resolution optical data, and LST patterns were validated using ASTER thermal images. Land cover types or indices and land surface temperature display high correlations, with most having a positive relationship with LST, but vegetation has a negative relationship. The hottest surface type also differs for the two cities. Consequently, covering the soil in Baghdad with new construction, for example, reduces the surface temperature and hence urban heat island effect, while the same action in London increases it. Thus, engineering solutions to urban heat island issues need to take local factors into account.

1. Introduction

Urban expansion is becoming a common concern worldwide as people leave rural areas and accumulate in major cities. Urban growth has economic benefits but also environmental consequences affecting climate change and global warming, leading to a direct impact on humans' lives (Xu, Ding, & Wen, 2009). The conversion of vegetation cover or bare soil to buildings and other impervious surfaces has altered the urban ecosystem, biodiversity and microclimate by triggering negative environmental phenomena such as urban heat islands (UHI) (Xu et al., 2009). Remote sensing (RS) techniques can be used to determine the spatial change of the most important urban biophysical and environmental characteristics. The traditional way of evaluating the UHI is by measuring air temperature; nevertheless, recent studies employ remote sensing to determine radiated surface temperature (Weng, 2012). Mirzaei and Haghighat (2010) clarified that the resultant surface temperature contains the effects of surface radiative and thermodynamic properties, including surface moisture, surface emissivity, surface albedo, the irradiative input at the surface, and the effects of the near surface atmosphere, in addition to the turbulent transfer from the surface. The wide application of RS techniques in urban areas has included urban feature mapping based on their spectral signatures, as a time and cost effective approach compared to traditional methods such as field surveys (Weng, 2012). They also provide quantitative observations about the environment in regions of the electromagnetic spectrum which are outside the visible region (Chuvieco and Huete, 2010), such as temperature. Other techniques to study the UHI and simulate the urban climate are present in the literature such as Research and Forecasting (WRF) and ENVI-met. Morini, Touchaei, Castellani, Rossi, and Cotana (2016) employed the WRF coupled to multi-layer urban canopy model (UCM) and building energy model (BEM) to study the impact of albedo increase to mitigate the UHI. Shen, Chow, and Darkwa (2013) used the ENVI-met to simulate urban climate parameters to evaluate the influence of microclimatic design on mitigating the UHI effects.

* Corresponding author at: Faculty of Engineering, The University of Nottingham, Nottingham, UK.
E-mail address: Jasima094@gmail.com (J.M. Ali).

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Oke, Spronken-Smith, Jáuregui, and Grimmond (1999) explained that the surface temperature is not only important to study urban climatology, but it is central to the energy balance of the surfaces. Balling's study (Balling and Brazel, 1988) is one of the earliest studies to apply thermal remote sensing to examine urban climates; this study concluded that the surface temperature is correlated with the land use and day to day variability of its spatial patterns. Beyond this, a study by Wang, Bou-Zeid, and Smith (2011) emphasised that surface temperatures and conductive heat fluxes through solid media (roofs, walls, roads and vegetated surfaces) are of major significance not only for microclimatic conditions outdoors but also for the comfort of residents indoors. Sobrino et al. (2013) have evaluated the SUHI influence in the city of Madrid by thermal remote sensing. They employed airborne hyperspectral data and in situ measurements, and the results demonstrated the presence of a night-time SUHI influence with a highest value of 5 K. A study by Rasul, Balzter, and Smith (2015) employed six Landsat images to examine the spatial formation of the daytime Surface Urban Cool Island (SUCI) of the central districts of Erbil city in the north of Iraq. Their results indicated that the urbanised areas have lower LST acting as cool islands, compared to the rural area. Deng and Wu (2013) have examined the impacts of urban biophysical compositions on SUHI using normalized difference vegetation index (NDVI), percent green vegetation (%GV), and percent impervious surface area (%ISA). They used a spectral unmixing and thermal mixing approach; the result showed that NDVI and%GV-based regression models perform well in rural areas, while%ISA-based models perform well in urban areas. Furthermore, the influence of temporal aggregation of LST data for SUHI has been studied by Hu and Brunsell (2013). Their study found that the SUHI values in the daytime are larger than during the night-time, and the impacts of aggregation in spring and summer are higher than in autumn and winter. Hadjimitsis et al. (2013) have used satellite Earth observation data and ground meteorological data to study the effect of SUHI in Cyprus using Artificial Neural networks (ANN). Their findings have revealed that the approach can perform successfully as good correlations between ground and satellite measurements were identified. However, further modification is needed in order to improve this methodology due to the course 1 km resolution of MODIS LST data.

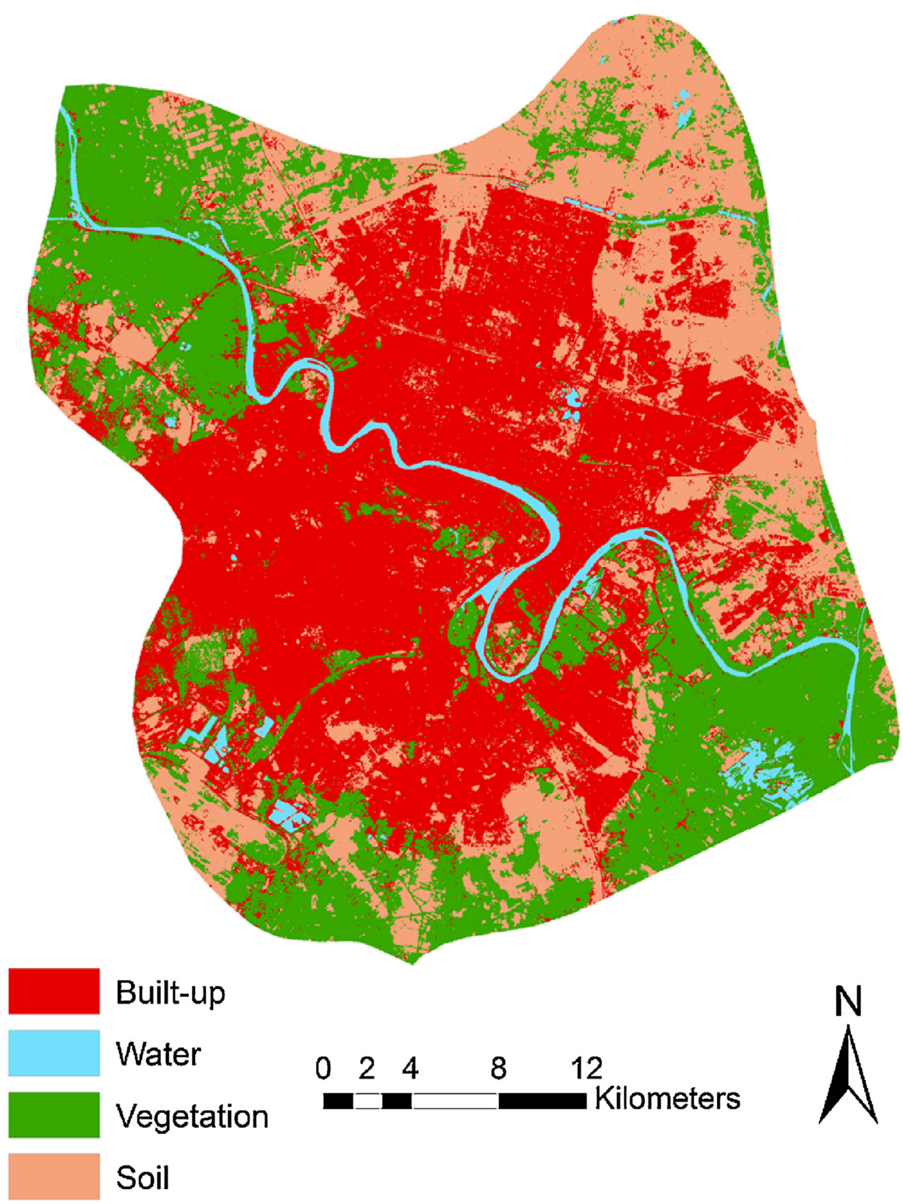

Fig. 1. Classification of Baghdad's land cover based on Landsat 8 data.