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Assessment of Urban Heat Island based on the relationship between land surface temperature and Land Use/ Land Cover in Tehran

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ABSTRACT

In this study, the relationship between land surface temperature (LST) and Land Use/Land Cover (LULC) in Tehran Metropolitan City was studied using Landsat TM satellite image. For this, LST was calculated in accordance with the algorithm (Jiménez-Muñoz & Sobrino, 2003) and the LULC map was prepared based on supervised classification method. According to the LST map obtained by processing the thermal band of the satellite image, areas affected by Urban Heat Island (UHI) were detected to examine their status in relation to the existing LULC classes and the population density. The results showed that UHI created in Tehran are different in terms of the causative agent. This difference is primarily due to the status of LULC in the region and reflects the close relationship between land cover and land surface temperature. Also, the distribution of vegetation and green spaces in different areas of Tehran City was studied by normalized vegetation index (NDVI) using remotely-sensed data. Correlation study between the land cover and land surface temperature showed a negative correlation between these two parameters. Study of the average surface temperature in six LULC classes indicated full compliance of heat islands with LULC classes.

1. Introduction

The century 21, during which about half of the global population have been urban dwellers, is called "urban century". According to forecasts, this amount will reach even more than 70% by the year 2050. Cities are places with sever consumption of various sources and increasing the release of contaminants. They are also a serious threat to ecological resources and can restrict urban facilities and the rapid growth of urbanization (Hosseini, Pourahmad, & Pajoohan, 2015; Mirkatouli, Hosseini, & Neshat, 2015). The rapid growth of urbanization and the development of areas covered with man-made land cover versus the lower the level of natural cover is one of the main causes of global climate change (Streutker, 2002; Touchaei & Wang, 2015). Population growth in urban areas, especially in developing countries, puts a lot of pressure on natural resources and causes gradual loss of these resources (Amiri, Weng, Alimohammadi, & Alavipanah, 2009; Feizizadeh & Blaschke, 2013; Peron, De Maria, Spinazzè, & Mazzali, 2015). In recent decades, UHI, which are known as areas with negative temperature gradient compared to the surroundings, is one of the most important factors affecting the quality of human life (Wong & Nichol, 2013; Mirzaei, 2015). UHI phenomenon is a risk arising from uncontrolled growth of urban areas (Mirzaei et al., 2012). Even if the global climate is not getting warmer, cities are now faced with the problem of rising temperature (Hoverter, 2012; Zinzi, & Agnoli, 2012; Dimoudi et al., 2014; Giannopoulou et al., 2011; Taha, 2015).

Cities with different physical surfaces than the surrounding environments (rural areas) influence on their microclimate (Cai, Du, & Xue, 2011; Meng & Liu, 2013). The behavior of urban surfaces is far different from the behavioral pattern of natural surfaces in terms of the absorption of shortwave and long wave radiation, evaporation, release of man-made heat, and the block of prevailing wind (Mirzaei & Haghighat, 2010). The difference in physical material of urban surfaces is very high. Man-made cover and surfaces such as asphalt, flooring, and concrete, instead of natural pervious surfaces such as soil and vegetation, reduce evapotranspiration and increase sensible heat in cities. As a result, cities experience a warmer weather than surrounding areas. Furthermore, accelerated deformation and design of buildings and the emergence and spread of skyscrapers as well as increased industrial activities have led to

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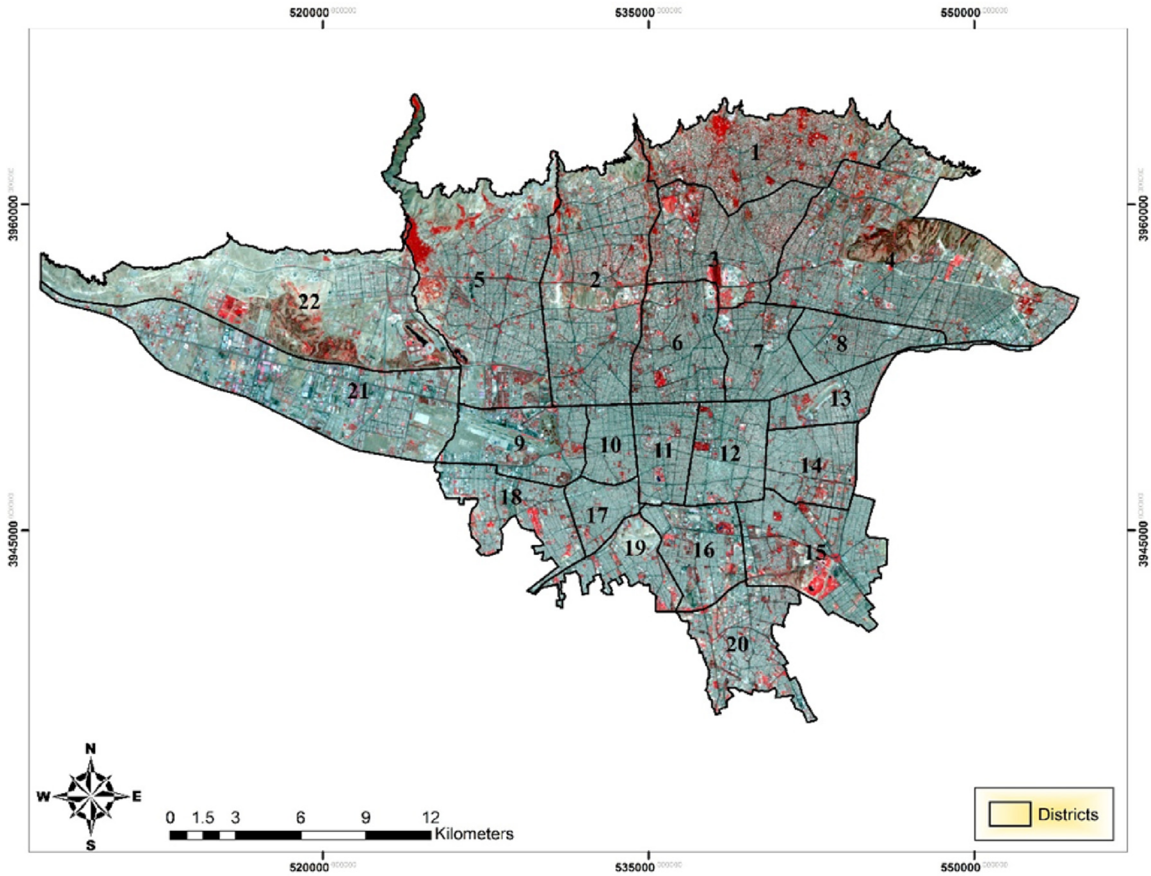

Fig. 1. Situation of the study area, Tehran.

the development of UHIs (Liu & Zhang, 2011; Busato, Lazzarin, & Noro, 2014; Radhi, Sharples, & Assem, 2015).

Nowadays, raw materials are designed and built in such a way that have a high potential in absorbing solar radiations, high impermeability, and the desired thermal specifications for energy storage and release of heat. Knowing these thermal characteristics can lead to develop appropriate strategies for mitigation of the impacts of UHIs (Gagliano, Detommaso, Nocera, & Evola, 2015).

Megacities with compact constructions and a variety of activities, especially in the CBD, fully affect on their climate and the climate of surroundings (Boehme, Berger, & Massier, 20105; Morris et al., 2015). Natural cooling process in urban environments undergoes problems due to the extensive changes in the pattern of urban design and structure. A complex network of high-rise buildings and narrow streets, that makes trapping the heat absorbed during the day, impairs air circulation and consequently the process of reducing the temperature in urban areas. Calculating the amount of LST is considered a starting point for the analysis of UHI (Mather, 1986; Malekpour, Taleai, & ASSIST, 2011).

One of the strategies adopted to reduce the heating and cooling load of buildings in urban areas is the increased use of thermal insulation (such as roof coatings). Despite the positive role of thermal insulation in buildings to prevent the loss of heat energy in the winter, they increase indoor temperature of buildings in summer, which results in increased energy use for cooling purposes (Gagliano et al., 2015). In studies of urban climate change, the LST has been recognized as one of the most important parameters affecting the UHI phenomenon (Liu & Zhang, 2011). Further, in many of the studies on the analysis of UHI, a very close relationship between LST and LULC as well as considerable impressibility of UHI by this relationship have been emphasized (Weng, Lu, & Schubring, 2004). Expansion of synthetic surfaces is a marker for centralized human activities that lead to an increase in Earth's surface temperature (Su, Gu, & Yang, 2010).

The exact calculation of the LST and the study of relationship between current LULC and LST can be an important factor in order to solve many problems in the field of climate change in urban areas and interaction between humans and the environment (Ramachandra & Uttam, 2009). Developing remote sensing technology, launching various satellites, and obtaining images with high spatial resolution power at large spectral range as well as providing imaging capabilities at reasonable intervals with repetitive coverage of the Earth's land surface has made possible monitoring and investigating of the land surface (Mallick, Kant, & Bharath, 2008). So far, a large number of satellites and sensors equipped with thermal infrared bands have been used for the study and monitoring of UHI. In the absence of regular and dense network of ground weather stations, temporal and spatial distribution of LST based on thermal imaging can be used to supply the required input data for the study of UHI (Feizizadeh, Blaschke, Nazmfar, Akbari, & Kohbanani, 2013). Images captured by Landsat TM sensor are one of the most widely used satellite images in the field of environmental researches that uses the data of the band 6 within the range between 10.4 and 12.5 μm to study and analyze the ground surface phenomena such as UHI (Ramachandra, Aithal, & Sanna, 2012).

According to the foregoing, the present study was carried out to follow three objectives: (1) the study of LST in Tehran using Landsat TM satellite images, (2) analysis of the spatial distribution of LST and its relationship with LULC and Normalized Difference Vegetation Index (NDVI), and (3) analysis of relationship between LST and the population density as well as its impact on energy consumption and the health of residents in the study area. To calculate