Analysis of Spatial - Temporal Structure of the Urban Heat Island in Tehran through Remote Sensing and Geographical Information System

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Introduction

Urbanisation changes the land cover types in urban areas and results in different climatic conditions, which has been termed as “Urban climate”. Urban climates are different from those of less built-up areas in terms of air temperature, humidity, wind speed and direction, and amount of precipitation. The previous researches show that urban areas are warmer than surrounding rural areas creating the “urban heat island” (UHI) (Rose and Devadas; 2009, 2). The buildings, concrete, asphalt and industrial activity of urban areas causes UHI. Replacing natural land cover with pavements, buildings and other infrastructures takes away the natural cooling effects. Also, tall buildings and narrow streets can heat the air trapped between them and reduce airflow. In addition, heat from vehicles, factories and air conditioners adds heat to the surroundings, further exacerbating the heat island effect. UHI can impact local weather and climate, altering local wind patterns, spurring the development of clouds and fog, increasing the number of lightning events, and influencing the rates of precipitation. Furthermore, the poor air quality that results from the increased energy usage for cooling purposes in heat-island city can cause discomfort for humans and affect health, aggravating asthma and promoting other respiratory illnesses (Liu and Zhang, 2011: 158).

Thermal remote sensing data play an important role in the study of UHI. First, UHI is studied using NOAA AVHRR thermal data (Balling and Brazell, 1988: 1289-1293; Gallo et al., 1993: 899-908; Gallo and Owen, 1988: 159-172; Streutker, 2002: 282-289). Later, thermal infrared data TM, ETM+ and ASTER are used to study UHI more precisely (Weng, 2001: 1999-2014; Weng et al., 2006: 1275-1286; Amiri et al., 2009: 2606; Flahatlar et al., 2011). Meanwhile, in some studies, The spatial and temporal variations of UHI are detected by using multi-temporal thermal images of landsat TM and ETM (Mo et al., 2011: 4616-4622).

Several researchers (Akbari, 1379; jangi, 1383; shakiba et al., 1388: 56-69; namdari, 1388; malekpour and taleai, 1389: 89-102, and 1390: 29-42) have studied the UHI in Tehran. But none of them have presented a comprehensive picture of its spatial and temporal variations. Thus, the main objective of this study is to study the spatial and temporal variations of UHI in Tehran urban area.

Study Area

The city of Tehran as capital of Islamic republic of Iran is located between latitudes of 35°33’10"N to 35°50’12"N and longitudes of 51°05’17"E to 51°37’36"E with an average elevation of 1600 m, is surrounded by high mountains in the north and east. Tehran experiences warm summers and cold winters. Tehran is a major center of culture, industry, commerce and transportation. The biggest city of the country, Tehran exhibits rapid population growth and urban expansion in the form of encroachment to the limited agricultural areas (malekpour et al., 2010). Due to its complicated expansion and urban structure and

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function the temperature variations are very important for its life and existence. Thus this study has tried to analyse the spatial and temporal variations of its temperature.

**Material and Methods**

In this paper, multi-temporal Landsat TM images (13 images) are used for the analysis of UHI in Tehran. LST is extracted using the mono-window algorithm presented in Qin et al (2001). Then, using appropriate statistical methods, spatial and temporal variations of LST were analysed. Based on thermal radiance transfer equation, the mono-window algorithm only requires three parameters of emissivity, transmittance and effective mean atmospheric temperature - to retrieve LST from Landsat TM 6. The spatial model to retrieve LST from Landsat TM using ERDAS spatial model tool is designed. In this model, only two measured parameters are required; near-surface air temperature and water vapour content of the atmosphere at the time of satellite pass, which can be easily obtained from synoptic weather stations of Tehran. These two parameters are then converted to air transmittance and effective mean atmospheric temperature. The third required parameter is the emissivity, which can be calculated from the normalised difference vegetation index (NDVI). The remaining useful data can all be obtained from the Meta file in the satellite image data.

It is impossible to compare thermal data from different years directly using absolute LST. Therefore, a normalisation technique (Xu et al., 2009) has been used to compare the computed LST of different years. The LST images were rescaled to the same level between 0 and 1 using the maximum and minimum values for those images. Then temporal variations were explored. The intensity of UHI from 1986 to 2010 was evaluated by the urban heat island ratio index (URI) (Mu et al., 2011). The URI was proposed to quantitatively compare the UHI differences in different years based on the ratio of UHI area to whole city area.

**Results and Discussion**

The temporal changes of LST during the study period showed that the distribution pattern of LST has changed. The area of moderate and very cool temperature of the city has been decreased but the area of very high temperatures (very hot areas) has been increased significantly. It is completely clear that spatial extent of UHI along with the spatial development of Tehran have been increased during this period of 25 years (1986 to 2010) and the extent of UHI has increased from 83 square kilometres (13 percent) to 99 square kilometres (16 percent). The temporal change of the intensity of UHI also showed that URI has increased. The URI has increased from 0.11 in 1986 to 0.15 in 2010. According to the spatial distribution of LST, UHI has maintained its principal center (Mehrabad airport) and The new hot clusters have emerged in the west (District 21 and west of district 22) and south-west (portion of District 18 and 19) of the Mehrabad airport. Our study showed that UHI of Tehran has extended toward the areas with an intensive decrease in vegetation and the extensive development of industries, working places and warehouses (the west and south-west of Tehran).

**Conclusion**

In this study, the mono-window algorithm is applied to retrieve LST in Tehran using the Landsat TM data. Then, using appropriate statistical methods, spatial and temporal variations of LST are analysed. Consideration of spatial-temporal variation of LST during the study period showed that the distribution of the UHI in Tehran has changed. Center of the UHI that had already been located on Mehrabad airport has extended toward the west and southwest of Tehran. The metropolitan of Tehran has witnessed a very fast urban sprawl during the study years from 1986 to 2010. The urban expansion was accompanied by increased UHI intensity of 0.11 in 1986 to 0.15 in 2010 over an almost 25-year period and resulted in the development of the severe UHI in the region and thus the degradation of the liveability of the city.

**Key Words:** air pollution, Urbanisation, heat Islands, Tehran metropolis