Modeling of Relationship between Land use/Cover and land Surface Temperature Using ASTER datasets

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Introduction

Land Surface Temperature (LST) is an important factor in global change studies to estimate the radiation budgets in heat balance studies and as a controlling agent in the climate models. The information about LST has an important role in the issues and themes of earth sciences such as global environment changes, human-environment interactions and more specifically to urban climatology. The climate in cities, countryside, and other constructed areas is altered due to changes in land use/land cover (LULC) and anthropogenic activities of urbanization. The most imperative problem in urban areas is increasing surface temperature due to the conversion of vegetated surfaces to impervious surfaces. These changes affect the absorption of solar radiation, surface temperature, evaporation rates, storage of heat, wind turbulence and they can drastically alter the conditions of the near-surface atmosphere over the cities. The temperature difference between urban and rural settings is normally called urban heat island (UHI). The impact of urbanization leads to increase the surface temperature in urban areas mainly due to the alteration of natural surfaces.

Materials and methods

This research has been undertaken to analyze the potential of multispectral satellite data for retrieving the biophysical parameters, to estimate the land surface temperature. Also it explores the possibility of ascertaining the influence of urbanization parameters, land use/land cover (LULC) categories and vegetation density on surface temperatures/ temperature amplitudes. The study area is Tehran, Iran and the used data are temporal ASTER datasets. Thermal IR images acquired by ASTER sensor at 21 June 2001, 5 June 2005 and 9 September 2009, covering approximately 70% of the study area (Tehran city-Fig.1), were used to extract LST. In addition to these data, digital topographic maps at 1:25,000 scales were used to correct the images for geometric errors and to define the extents of the city. In order to reach an acceptable geometric accuracy, a multi-band image of 2001 was registered to topographic maps in the UTM coordination system. This image was used as a reference for correcting other images. The root-mean-square-error (RMSE) of this procedure was 0.45 pixels. These images were suitable for multi-temporal studies because there was little difference in sun elevation and azimuth at the time of image acquisition at different dates. Application of a proper radiometric correction procedure is necessary for extracting reliable LULC classes and estimating LSTs. In order to remove the effect of atmosphere in the classification and LST estimation, the Images were corrected by FLAASH and in-scene ISAC atmospheric correction algorithms.

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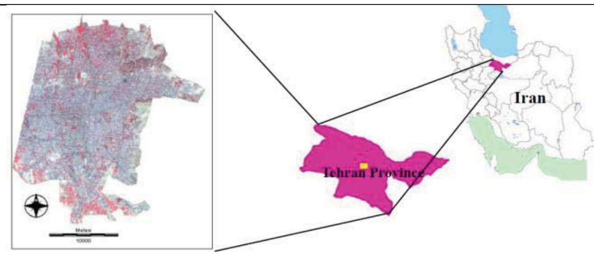

Fig. 1: Study area

Results and Discussions

In this study, multi-temporal ASTER thermal and reactive data were used to study the spatial and temporal dynamics of LST in relation to a biophysical parameter (vegetation index) in Tehran, a fast growing urban area in the semi-arid region of Iran,. Using satellite data, the following LULC classification scheme has been adopted: high-dense built-up, low-dense built-up, high-dense vegetation (forest), low-dense vegetation (including parks), sparse vegetation (including grasses), water bodies, and fallow land, waste land/bare soil and agricultural cropland (Fig 2). For image classification, unsupervised classification was initially performed on ASTER data for an idea of the spectral separability of the land use/land cover classes. Digital topographic maps at 1:25,000 scales were used to select the training areas. Based on the collected sample sets for respective LULC classes, training sets were selected in the False Color Composite (FCC) imagery for supervised classification using Maximum Likelihood Classification (MLC). Minimum Noise Fraction (MNF) was performed on the ASTER data to reduce the data redundancy and correlation between spectral bands. MNF was applied to band 1 to 3 of the ASTER images. The first three MNF components of ASTER data was used to classify the images using the MLC while the other components were discarded due to the higher proportion of noise content. The supervised classification (Maximum Likelihood classification (MLC)) was applied on the original bands as well as MNF components of ASTER image. The results show that the classification results improve using MNF components in comparison to using the MLC. After evaluating the error matrix, it has been found that there is a good improvement in the accuracies achieved with MNF (the overall accuracy has been improved to 6% higher).

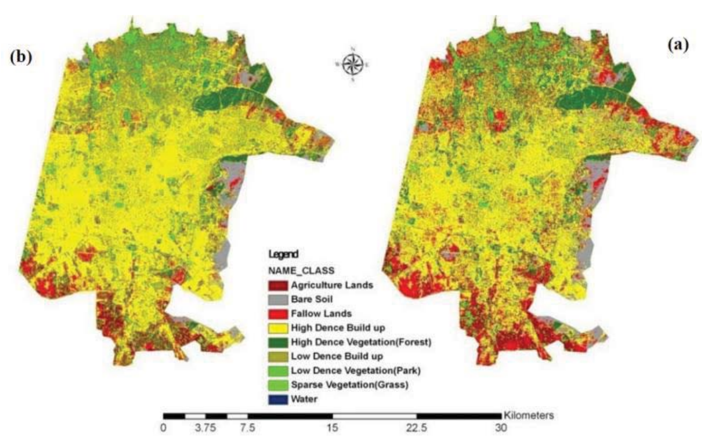

Fig.2: MLC Classification based on MNF components, (a) ASTER-2001 (b) ASTER-2005

Emissivity and LST values were estimated using Temperature and Emissivity Separation (TES) algorithms. The satellite derived LST values showed a good agreement with synoptic weather stations measured values in the study area. The land surface temperature ranged from 20.05 to 55.94°C with a mean of 34.00°C and standard deviation of 2.113 for ASTER 2001, 23.71°C to 67.88°C with a mean of

40.94°C and standard deviation of 3.047 for ASTER 2005 and 21.74°C to 73.65°C with a mean of 40.31°C and standard deviation of 4.560 for ASTER 2009 (Fig 3). In the images it is observed that east and south-east and north-east parts exhibit high temperature mainly due to waste land/bare soil and fallow land. Some high-temperature zones are also seen in the central part of the image mainly due to urban/build up land use. It is observed that high dense built up area, bare lands and fallow lands exhibit a higher surface temperature during different years. While low dense built up area, low dense vegetation (parks & grasses), agriculture lands and water bodies have lower surface temperatures.

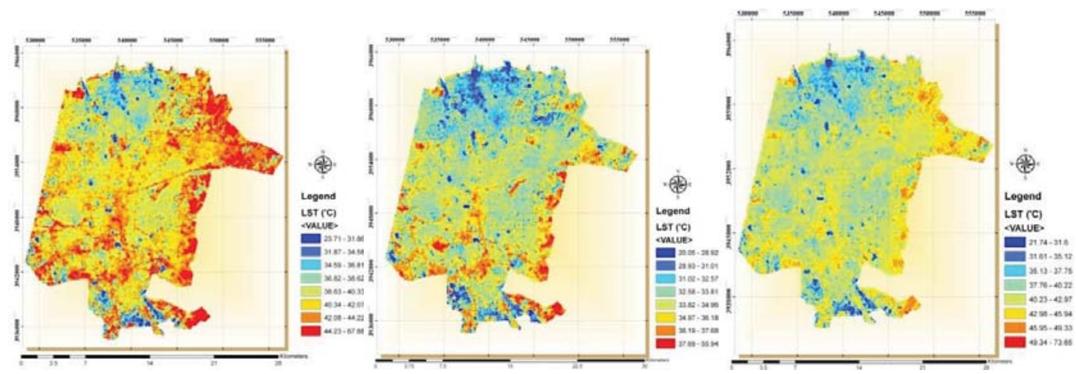

Fig.3: Spatial Distribution of Land surface temperature: 2001, 2005 and 2009 from left to right

Vegetation density was extracted using the NDVI and Vegetation Fraction Cover (FVC), and linear spectral unmixing model. The results showed that in city level, LULC has high impact on surface temperature regimes. NDVI and FVC with LST were found to be closely correlated in several LULC categories, especially in Vegetation areas. The high surface temperature, mainly, is due to low-dense vegetation. Relationship between LST changes and vegetation density (NDVI, FVC) analyzed for 2001 and 2005 images and result showed that NDVI and FVC values tend to be negatively correlated with the surface temperature of all land use/ land cover classes (with the exception of water). The strongest negative correlation between surface temperature and NDVI values is found over high-dense vegetation (-0.311, -0.226) followed by low-dense vegetation (-0.361, 0.277), agriculture lands (-0.369, -0.354) (values are for 2001 and 2005 images, respectively) and the same trend is also found in fraction vegetation cover, which assures potential for using linear regression to predict surface temperatures if NDVI and FVC values are known.

Regression coefficient between surface temperatures with FVC is higher than NDVI over low dense built up, followed by low dense vegetation and agriculture lands. The regression equations retrieved between LST with NDVI and FVC by 2001 and 2005 images are tested by the 2009 image. Regression based derived LST values and LST values retrieved by TES algorithm in ASTER 2009 image were compared by paired-sample T test.

Finally, there were no significant difference between LST values derived by TES algorithm and regression equations. Thus, these equations are suitable for retrieving LST, if NDVI and FVC values in this area are known. Not only the role of vegetation in LST is important, but also their distribution is important. Given the finding that surface temperature is negatively correlated to vegetation, it is advisable to afforest regions that are currently available for planting, especially in highly built up areas and barren land. This will in turn reduce the surface temperature of the region and thus to a certain extent influence the micro-climate of the region. Moreover, the manager of urban environment must consider above points and for expanding cities must pay attention to LST of the cities countryside.

Key words

LST, Land use/cover, TES, Spectral mixture analysis, FVC.