THERMAL REMOTE SENSING FOR EXAMINING THE RELATIONSHIP BETWEEN URBAN LAND SURFACE TEMPERATURE AND LAND USE/COVER IN TABRIZ CITY, IRAN

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ABSTRACT

This study investigates the relationship between Land surface Temperature (LST) and land use/cover (LUC) in Tabriz city, Iran. LST were assessed based on ASTER thermal images. Results showed that LST was highly influenced by LUC and that LST is sensitive to vegetation and moisture. A minimum value of 8.57°C was observed for reflective water bodies, while a maximum of 30.34°C was observed for industrial areas. The relationship between the LUC and LST maps was analysed. LST was found to be positively correlated with impervious surface but negatively correlated with vegetated land.

Index Term- Thermal remote sensing, ASTER**,** Land surface temperature, land use, Tabriz city

1. INTRODCTION

An increasing number of studies analyses urban climate and in particular differences in observed ambient air temperature between cities and their surrounding rural regions, which collectively describe the urban heat island (UHI) effect [1-2]. Land surface temperature (LST) is one important parameter. LST research shows that the balance of land surface energy can be influenced by the conversion of surface soil, water content and vegetation [3]. Thus, mapping urban biophysical and thermal conditions and their relations with land use/cover (LUC) has attracted increasing interest. The LST is the energy balance of land surface energy and has been extensively studied along with the technology development of effective sensors for thermal remote sensing [3]. The measurement of LST using satellite thermal infrared sensors from which brightness temperatures of land surfaces can be derived using Plank's law [3]. Thermal remote sensing image processing allows to examining the relationship between LST and biophysical descriptors. Based on this idea, the main objective of this research is to investigate LST and LUC relationship in Tabriz city, Iran. Tabriz has about two million inhabitants and is the industrial and agricultural centre of the East Azerbaijan Province.

2. METHODS

ASTER images acquired on June 25, 2011, were used in this research. ASTER data have 14 bands with different spatial resolutions, i.e., two visible ban ds and one NIR band with 15-m spatial resolution, six SWIR bands with 30-m spatial resolution, and five TIR bands with 90-m spatial resolution [4-5-6-7]. The original ASTER digital numbers (DNs) were converted to radiance values using Erdas IMAGINE software. Separate bands were layerstacked and transformed to pixel sizes of 15 by 15 m to preserve the spatial features provided in the VNIR bands.

In order to achieve LST from ASTER satellite images, Normalized Difference Vegetation Index (NDVI), which provides an estimate of the abundance of actively photosynthesizing vegetation, was computed as [8]:

$$NDVI= (NIR-RED)/ (NIR+RED) \quad (1)$$

In a next step, we selected ASTER band 13 (10.25 – 10.95 μm) to compute LSTs, because the spectral width of this band is close to the peak radiation of the black-body spectrum released by the urban surface of the study area. Two steps were taken to compute LSTs: (1) converting spectral radiance to at-sensor brightness temperature (i.e., black- body temperature); and (2) correcting for spectral emissivity [7]. We adopted the most straightforward approximation to replace the sensor response function with a delta function at the sensor's central wave length to invert LSTs with the assumption of uniform emissivity [7-9-10-11]. The conversion formula is [7]:

$$T_c = \frac{C_2}{\lambda_c 1n\left(\frac{C_1}{\lambda_c^5 \pi L_\lambda} + 1\right)} \quad (2)$$

where T_c is the brightness temperature in Kelvin (K) from central wavelength, L_λ is spectral radiance in $Wm^{-3} sr^{-3} \mu m^{-1}$, λ_c is the sensor's central wavelength, C_1 is first radiation constant ($3.74151*10^{-16}$ $W \cdot m^{-3} \cdot sr^{-3} \cdot \mu m^{-1}$) and C_2 is the second radiation constant (0.0143879 $m \cdot k$). The temperature values obtained above are referenced to a black body. Therefore, a correction for spectral emissivity (ε) became necessary in regard to the nature of land cover [7]. Each of the land cover categories was assigned an emissivity value according to the emissivity classification scheme by Snyder et al. [12]. The emissivity-corrected LSTs were computed as follows [7-13]:

$$LST = \frac{T_c}{1 + (\lambda * T_c/p)1n\varepsilon} \quad (3)$$

Where λ= wavelength of emitted radiance (for which the peak response and the average of the limiting wavelengths) [λ=10.6 μm]. p=h*c/ σ ($1.438*10^{-2}$ $m \cdot K$), σ= Boltzmann constant ($1.38*10^{-23}$ JK^{-1}), h=Planck's constant ($6.626*10^{-34}$ $J \cdot s$) and c= velocity of light ($2.998*10^{8} ms^{-1}$) [7].

3. RESULTS

The main outcome of our research include: a map of absolute land surface temperatures and insight how LST is related to LUC for the area of investigation. The derived LST values reveal surface temperatures ranging between 8 and 30°C. The relationship between the LUC and LST maps was investigated to comprehend their interactions. A cross- comparison between the LST map and the LUC map (see table 1) revealed a minimum value of 8.57°C for reflective water bodies, while a maximum of 30.34°C was observed for industrial areas, closely followed by constructed areas (21.14 - 29.52 °C). However, moderate temperatures (18 - 28°C) were observed within non-vegetated areas (e.g. airport, market areas and bear lands). Further water bodies and vegetated areas were assigned to the lower temperature category (8-21°C).

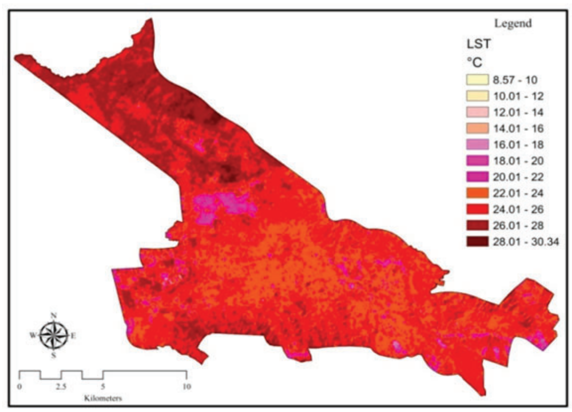

Figure 1. LST map of Tabriz city

Figure 1 shows LST results for Tabriz city derived from ASTER images. The LST map was compared to a very detailed land use/cover map of Tabriz which was produced by photogrammetric methods from aerial photography in a 1:2000 scale (figure 2).

Table 1. Comparative results of LST and LUC

LUC class	LST (°C)
River and water bodies	8.57–12.24
Green lands	17.10–21.90
Bare lands	18.01–28.47
Airport	18.84–28.61
Under construction & Bare lands	19.47–29.52
Market area	22.67–25.76
Industry area	21.81–30.34
Constructed area	21.14–27.68

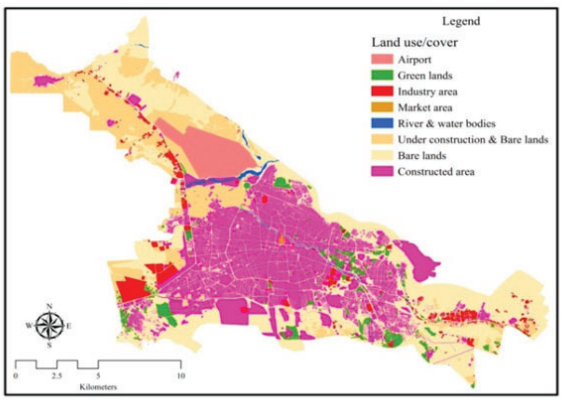

Figure 2. Land use/cover map of Tabriz city

4. DISCUSSION

The results reveal that LST is sensitive to vegetation and moisture. We conclude that LST can be used to detect changes in LUC over time. The population of Tabriz city has been growing dramatically over two decades and LUC changes in this area are significant. It is well known that the increasing population numbers - particularly in developing countries - increases pressure on natural resources [14]. Urbanized and urbanizing landscapes cause significant impacts on local and global eco-systems. Next to other human induced changes, changes in LST are classified as a major urban problem [1]. Urbanization has a great impact on climate through the increase of sealed surfaces, buildings, roads and other mixed types of impervious surfaces [15]. It has been demonstrated that UHI effects are often correlated with LUC changes [16]. Thermal difference, in conjunction with waste heat released from households, transportation and industry, contribute to increasing UHI effects and air pollution [16]. Sealing of vegetated surfaces affects the absorption of solar radiation, surface temperature, evaporation rates, storage of heat, wind turbulence and can drastically alter the conditions of the near-surface atmosphere over urban areas [17]. Green areas are therefore important for environmental services such as rainwater infiltration, soil erosion and can improve climatic conditions within urban areas [18]. This first investigation of the relation between LST and LUC can be used for further urbanization studies and studies on the quality of life in Tabriz city.

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