

# Understanding the LST (Land Surface Temperature) Effects of Urban-forests in Seoul, Korea

Sung-Ho Kil and Young-Jo Yun\*

*College of Forest and Environmental Science, Kangwon National University, Chuncheon 200-701, Republic of Korea*

## Abstract

Urban development and population have augmented the increase of impervious land-cover. This phenomenon has amplified the effects of climate change and increasing urban island effects due to increases in urban temperatures. Seoul, South Korea is one of the largest metropolitan cities in the world. While land uses in Seoul vary, land cover patterns have not changed much (under 2%) in the past 10 years, making the city a prime target for studying the effects of land cover types on the urban temperature. This research seeks to generalize the urban temperature of Seoul through a series of statistical tests using multi-temporal remote sensing data focusing on multiple scales and typologies of green space to determine its overall effectiveness in reducing the urban heat. The distribution of LST values was reduced as the size of urban forests increased. It means that changing temperature of large-scale green-spaces is less influenced because the broad distribution could be resulted in various external variables such as slope aspect, topographic height and density of planting areas, while small-scale urban forests are more affected from that. The large-scale green spaces contributed significantly to lowering urban temperature by showing a similar mean LST value. Both of concentration and dispersal of urban forests affected the reduction of urban temperature. Therefore, the findings of this research support that creating urban forests in an urban region could reduce urban temperature regardless of the scale.

**Key Words:** urban temperature, urban green-space, landscape spatial pattern, biotope

## Introduction

Due to the recent rapid urban development and the occurrence of air pollution, the temperature over the city is higher than the surrounding area (Kang et al. 2010). The high temperature of these cities is attributable to urban heat island phenomenon. Urban heat island phenomena occur as farmland and vegetation areas are replaced by impervious areas such as concrete and asphalt (Buyantuyev and Wu 2010). These changes prevent the heat generated in the city from escaping, thereby increasing the amount of surface heat energy in the city. In order to solve these

problems, landscape architects and city planners have been carrying out various researches such as enlargement of green areas, increase of water resources area, green space network, formation of barrier road (Kim et al. 2004; Cha et al. 2007). Although the use of green spaces and water resources is an important factor for the elimination of urban heat island phenomena, the water resources researches are relatively few compared to those related to green space expansion. The purpose of this study is to investigate the tendency of temperature distribution according to changes of pond and lake area in main parks and public institutions in Seoul.

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\*Corresponding author: Young-Jo Yun

College of Forest and Environmental Science, Kangwon National University, Chuncheon 200-701, Republic of Korea  
Tel: +82 332508341, Fax: +82 332505618, E-mail: [yyj@kangwon.ac.kr](mailto:yyj@kangwon.ac.kr)

## Materials and Methods

### Study scope

The target area of this study was Seoul city, the capital of the Republic of Korea. Seoul has the oldest biotope map in Korea, and it is easy to analyze by acquiring satellite images at multiple times.

### Study methods

#### 1) LST (Land Surface Temperature) output

The 6th band of Landsat TM / ETM image data is thermal infrared region, and LST is extracted by equations (1) and (2)

$$L(\lambda) = L_{\min} + (L_{\max} - L_{\min}) \times (Q_{\text{dn}} - Q_{\min}) / (Q_{\max} - Q_{\min}) \quad (1)$$

where  $L(\lambda)$  is the spectral radiance at the sensor's aperture ( $\text{W m}^{-2} \text{sr}^{-1} \mu\text{m}^{-1}$ );  $L_{\max}(\lambda)$  is the TOA radiance scaled to  $Q_{\max}$  ( $\text{W m}^{-2} \text{sr}^{-1} \mu\text{m}^{-1}$ );  $Q_{\text{dn}}$  is the DN value for the analyzed pixel of the TM/ETM image;  $Q_{\min}$  is the lowest point of the rescaled radiance in DN; and  $Q_{\max}$  is the highest point of the rescaled radiance in DN.

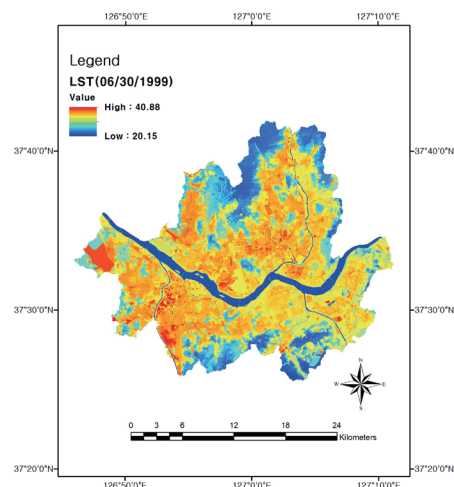
The next step was to convert the spectral radiance to the brightness temperature at the sensor. The following equation (2) was used (Chander and Markham 2003; Landsat Project Science Office 2002)

$$T_i = \frac{K_2}{\ln\left(\frac{K_1}{L(\lambda)} + 1\right)}$$

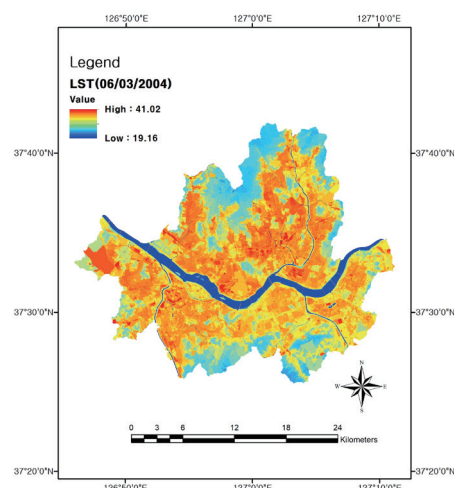
where  $T_i$  is the surface temperature in Kelvin;  $L(\lambda)$  is the computed band radiance from Equation (1) ( $\text{W m}^{-2} \text{sr}^{-1} \mu\text{m}^{-1}$ );  $K_1$  and  $K_2$  are calibration constants for Landsat 5 TM,  $K_1 = 607.76$  ( $\text{W m}^{-2} \text{sr}^{-1} \mu\text{m}^{-1}$ ) and  $K_2 = 1260.56$  K; and for Landsat 7 ETM+,  $K_1 = 666.09$  ( $\text{W m}^{-2} \text{sr}^{-1} \mu\text{m}^{-1}$ ) and  $K_2 = 1282.71$  K.

#### 2) Retrieved LST

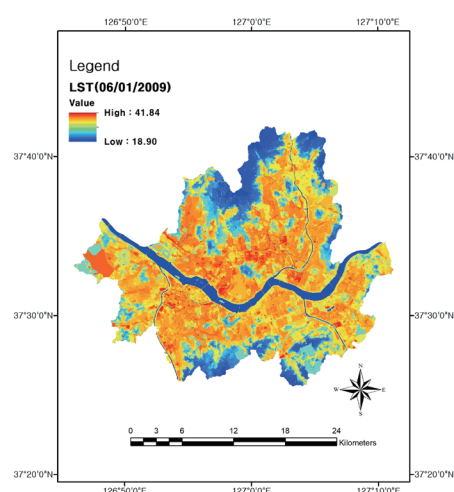
The LST retrieval method selected for this study was the mono-window algorithm, because it has been widely applied in previous studies (Liu and Zhang 2011; Sobrino et al. 2004; Zhang et al. 2006).



a) LST\_1999



b) LST\_2004



c) LST\_2009

Fig.1. LST by each year.

## Results and Discussion

### *LST distribution*

The LST as of June 30, 1999, ranged from 20.15 to 40.88°C; the average value was 30.46°C. The LST as of June 3, 2004, ranged from 19.16 to 41.02°C; the average value was 31.86°C. The LST as of June 1, 2009, ranged from 18.90 to 41.84°C; the average value was 31.30°C. The average temperature of commercial land during the three periods was about 33.870°C, which was the highest average temperature compared to other land cover. On the other hand, the average temperature of Forest land was about 26.951°C, which was the lowest average temperature. The average temperature difference between the two was about 7°C. The second highest average temperature was the traffic land of about 33.84°C. The highest temperature among the three periods was 34.193°C for commercial land in 2004. On the other hand, the lowest temperature among the three periods was 26.901°C in 2009 Forest land. The wide range of mean LST in each area showed the difference of around 20°C in all images.

The LST of green space and water resources in the city is lower than the mean LST of all land cover and plays a role in reducing the LST (Kong et al. 2014). Thus, the expansion of forest and water resources contributes to urban average LST reduction and can contribute to urban heat island reduction.

## Conclusion

This study was verified for needs to closely examine the change of LST distribution of the small area for each land-cover. Increasing the green-area rate reduces the urban temperature, while increasing the building-to-land rate has the opposite effect. Furthermore potential variables including building density, albedo, three-dimensional green area richness and green-area fragmentation would be necessary to consider a more specific examination in the future research.

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