# EFFECT OF GREEN SPACES ON URBAN HEAT DISTRIBUTION USING SATELLITE IMAGERY

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**ABSTRACT:** Urbanization has transformed the spatial pattern of urban land use by reducing green spaces. An increase of air temperature directly affects forest vegetation, phenology, and biodiversity in urban areas. In this paper, we analyzed the characterization of changing patterns and Urban Heat Distribution (UHD) in Seoul, based on a spatio-temporal assessment. It is necessary to understand green spaces changes, and this understanding is essential for monitoring and assessing green spaces functions. In addition we estimated the effect of green space on urban temperature using Landsat 7 ETM+ imagery and climatic data. Results of the assessment showed that UHD creates differences in the spatial and temporal extent of temperature reducing effects due to differences in urban green space. The ratio of urban heat area decreases rapidly from green space boundary. And it shows that the urban green space plays an important role for mitigating urban heating in central areas. This study demonstrated the importance of green spaces by characterizing the spatio–temporal variations of urban green spaces in cities.

## 1. INTRODUCTION

Cities throughout the world have begun to experience the impacts of climate change. As temperatures and precipitation patterns continue to shift, it is expected that urban areas will encounter an even greater array of challenges (IPCC, 2007). Extreme and/or prolonged high temperatures are increasingly being recognized as posing a serious climate hazard as seen in the severe consequences of recent heat wave events (Gosling et al., 2009). Urban areas in particular are more vulnerable to these effects due to the presence of urban heat islands. Furthermore, projected temperature rise, together with the tendency toward urbanization suggest that the urban thermal environment is likely to become increasingly uncomfortable in the future. This has direct consequences for the urban population and infrastructure (Smith et al., 2009). In urban areas anthropogenic heat is produced from heating and cooling processes in buildings and vehicles. This inadvertent climate modification is called the Urban Heat Island (UHI) (Landsberg, 1981). However, urban green space, such as forests or parks, can ameliorate UHI by preventing incoming solar radiation from heating the surrounding buildings and surfaces, cooling the air by evapotranspiration, and reducing wind speed (Akbari et al., 2001). The cooling effect of green spaces during the hot and humid summer season is especially important, and they are regarded as natural resources available for city planning (Narita et al., 2002). Effects of UHI for many cities, such as Buenos Aires, Argentina, New York City, USA, Lisbon, Portugal, Prague, Czech Republic, and Debrecen, Hungary, have been reported (Choi et al., 2008). In addition many studies have been carried out in other countries on the cooling effect of urban parks or green spaces (Upmanis et al., 1998; Eliasson et al., 2000; Svensson et al., 2002; Wong et al., 2004; Correa et al,. 2006; Chang et al., 2007). However few studies have examined the cooling effects created by urban parks, and the relationship between urban climate and open space planning has not been examined (Lee et al., 2009). This study seeks to close this gap by analyzing whether and how green space reduces the temperature in UHIs, using spatial and seasonal variation analysis.

## 2. MATERIAL AND METHODS

1) Study site description and characteristics of land use

The study area covered in this paper is Seoul, 126˚62′E~127˚48΄E and 37˚25΄N~37˚99΄N. Seoul is located in the Han River Basin, where Han River flows through the central part of the Korean Peninsula. It is characterized as a temperature climate and a terrestrial climate in which the yearly climate difference is largely due to topographical effects. Its yearly precipitation reaches 1488mm and the average temperature is 12.5℃ (the average for last 10 years; 1991-2000) (Seoul Metropolitan Government, 2001). Since the 1960s, Seoul has experienced rapid urbanization, with particular movement of people from rural areas into the city, resulting in population concentration. The current population of the city itself is ten million and that of the Seoul Metropolitan Area is more than twenty million (Lee et al., 2009).

2) Methods
It is necessary to estimate surface temperature in order to establish a climate change impact assessment in urban areas. It is also important to look to inter alia, thermal and forest distributions. All of this can be done via satellite remote sensing, and these systems provide us with the countermeasures for the environmental issues and the prediction methodologies for the natural disasters (Suga et al., 2003). With this in mind, we used Landsat 7 Enhanced Thematic Mapper Plus (ETM+) images in order to extract patterns and detect changes in the spatio-temporal makeup of urban surfaces. All those images covering the scene numbered 116/34 in the Landsat WRS-2 system. In order to analyze the effect of green space on urban temperature we selected satellite imagery in 2002, which is the year that showed the maximum temperatures of AWSs in Seoul for the last decade (Choi et al., 2008).
Based on the variogram analysis, a map for UHD was prepared using kriging analysis. The UHD is graded into the following 5 classes using the natural breaks methods of ArcGIS 9.2: (1) high cooling effect, (2) cooling effect, (2) buffer zone, (4) UHI effect, and (5) high UHI effect. In addition, the study area was zoned by the distance from green space boundary using buffering analysis. Through the relationship between distance from green space boundary and the effect of green space on UHD was analyzed.

## 3. RESULTS AND DISCUSSION

Temperature variation distributions of urban surface temperature differed greatly depending on land use and land cover patterns of surrounding areas. This is in line with the spatial and temporal variability pattern of climatic factors in Seoul (Choi et al., 2008).
In order to identify which urban areas have a statistically significant influence on urban temperature and effects of temperature decrease within urban green areas. The examination shows that the best-fit variogram model for our study is the spherical variogram model. Spatial autocorrelation existed within a range of about 4.6km to 14.2km in hot seasons, respectively. Moreover, spatial autocorrelation in urban green space ranges are larger than that of urban areas, especially from 4km standards. The variation of the UHD in green space, as characterized by spatial pattern showed strong spatial continuity as indicated by the high proportion of each sill showing spatial structure. The range of green space was 4.2km to 7.3km, whereas that for urban area was only 3.6km to 18.6km. However, it does not show any specific spatial differences in the summer season. This suggests that spatial variation is decreasing and that summer is getting warmer in Seoul.
We employed kriging analysis as in Figure 1 in order to determine the spatial extent of green space in regards to temperature reducing effects. It shows that lower temperature zone resulted in high-elevation forests and water areas. The higher zone is formed in a built up area. Especially, the UHI effects were clustered towards the center built up area-Jung-gu and Gangnam-gu.

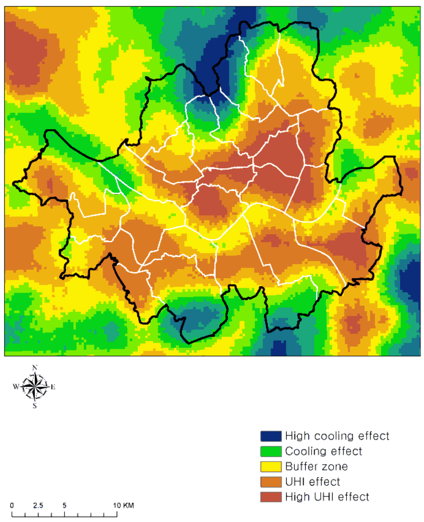

Figure 1. Effect of green space on UHI

UHI distribution in Seoul that relatively warm regions extend in the east–west direction, and relatively cold regions are located near Mounts Bukhan and Gwanak. Near the borderline of Seoul, the temperature is, as would be expected, relatively low, except near the southwestern and southeastern borderlines, where the sprawling expanse of urbanization is already in progress. And these results come from the transformation of downtown Seoul; we observe that the center of the Han River, the Gangbuk area, became a pinpoint for downtown development in the late 1960's according to the Land District Adjustment Plan (Song et al., 2005). Gangnam shows great differences in its history of land use, land development pattern, and the space management form in comparison to another area, specifically, Gangbuk. In addition, the reduction of air temperature from green space can reach around 4km. The ratio of urban heat area decreases and urban cooling area increases with closing green space (Figure 2). It shows that a strong relationship exists between urban thermal excess and distance, as well as built up ratio.

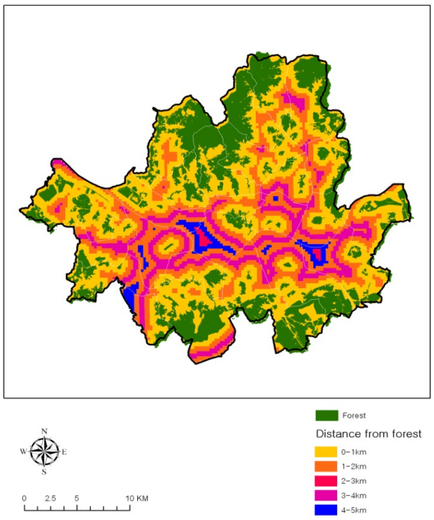


Figure 2. Area of green space UHI reduction effect

## 4. CONCLUSION

This study examined the effect of green space on urban heat distribution in Seoul, using satellite imagery data and near-surface air temperature data measured at 31 AWSs – the spatial and temporal structure of the urban heat island in Seoul. It was found that UHI deviates considerably from concentric heat island pattern, and warm areas were attributed to the location of densely built-up commercial and industrial neighboring sectors. In addition, spatial autocorrelation existed within a range of about 5km to 10km in hot seasons, respectively. Moreover, spatial autocorrelation in urban green space range is shown as larger than urban area, especially at distances higher than 4km. However, it does not show any spatial differences in the summer period. We also found that the temperature of green space is quite different from the urban area. The effects of temperature decrease within urban green areas can reach around 4km. The ratio of urban heat area decreases and urban cooling area increases from green space boundary. The analyses showed that urban green space plays an important role for mitigating urban heating in central area. Consequently, we suggest that a green space area within 4km would reduce temperatures in urban areas. This kind of research is expected to provide additional observational evidence for the theoretical modeling study (Baik et al., 2001), suggesting that urban green space plays an important role for mitigation and temperature reduction to UHI in central areas.

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