ANALYSIS OF TEMPERATURES DISTRIBUTION OF FOREST TYPE CLASS USING LANDSAT IMAGERY

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ABSTRACT

Many people visit forest for leisure and sometimes for relaxation because it has different temperatures distribution on urban area. Understanding temperatures distribution of forest is important element and estimation of wide forest region using satellite imagery is very efficient. In this study, distributed temperatures to explain the relationship between forest type classes were analyzed by Landsat TM satellite thermal infrared data and digital forest type map. Temperatures were calculated by Landsat imagery and temperatures according to distribution such as forest type, age class and diameter class was estimated effectively by digital forest type map. The results can be used to base data for the urban planning and facilities planning of forest recreations.

KEYWORDS: Temperature Distribution, Landsat Imagery, Digital Forest Map, Forest Type Class, Surface Temperature

INTRODUCTION

Recently, buildings like houses and factories are increasing because of rapid urban growth, on the other hand, forest covered with woods and trees are decreasing. Also, the temperature of downtown area is increasing highly than neighboring area especially forest area because of anthropogenic heat and air pollutants in regions of houses and factories (Kang et al., 2010). This is because day solar insolation is blocked by crowns of trees and transpiration occurred in the surface of leaves, which is absorbed the around the tree in the inside of forest different from the inside of the city. Thus, forest makes a proper climate condition which lower the temperature of average 3~4℃ in summer and raise the temperature of average 2~3℃ in winter compared with the region(area) where there are not trees. Many people go to the forests to enjoy the leisure and to take a rest by the benefit of this climate characteristic. Therefore, it is very important to understand temperature distribution of forests correctly, and it is very effective method to understand temperature using the satellite imagery in wide forest.

In this study, temperature distribution about the each forest type was analyzed using thermal infrared band and digital forest type map. Surface temperature about study site was calculated using satellite imagery, and it was able to extract temperature about each forest types (age class, diameter class, species of trees) effectively using digital forest type map. The results of this study are expected to be utilized basic data about urban planning and creating recreation space inside the forest.

DATA ACQUISITION AND PROCESSING

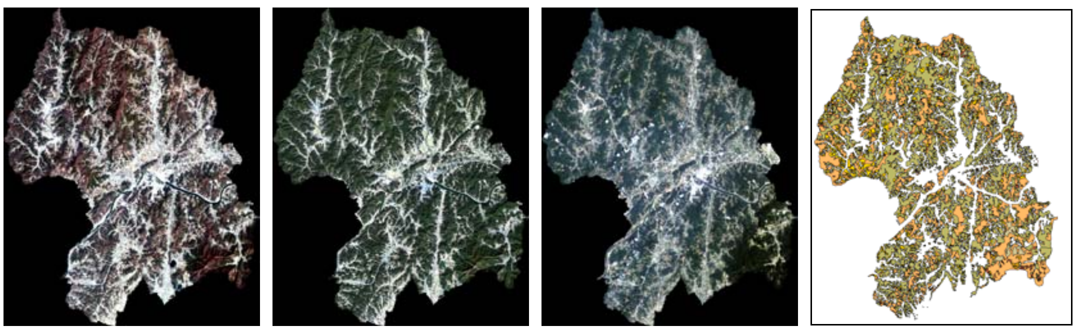
Data Acquisition

In this study, Gongju in South Chungcheng Province, Korea overgrown with a forest around was chosen the study area to calculate temperature each species of tree, age and thickness of the forest using Landsat satellite imagery and was calculated surface temperature using imagery in April 2003, October 2006 and June 2009 and the digital forest cover type map.

Table 1 arranges used Landsat satellite imagery. Fig. 1 shows Landsat imageries masked by study area.

Table 1. Satellite imageries used in this study

	Satellite imagery		
Sensor	Landsat ETM+	Landsat TM	Landsat TM
Date	2003/04	2006/10	2009/06
Spec.	30m	30m	30m
	Multi-Spectral	Multi-Spectral	Multi-Spectral



2003/04 2006/10 2009/06

Landsat imageries Digital forest type map

Figure 1. Landsat imageries and digital forest type map about study area.

Data Processing

Method of Temperature calculation. Based on NASA model, this study calibrates surface temperature from the DN (Digital Number) which represents the absolute radiation of land cover.

When each DN of TM and ETM+ images is given, we can subtract the spectral radiance L_λ (L_λ-TM, L_λ-ETM+) using the official NASA approval ranges $LMIN_\lambda$ and $LMAX_\lambda$ in following formula (1).

$$L_\lambda = \frac{LMAX_\lambda - LMIN_\lambda}{(Q_{cal\max} - Q_{cal\min}) \times (Q_{CAL} - Q_{cal\min})} + LMIN_\lambda \quad (1)$$

Where, L_λ = Spectral Radiance at the sensor's aperture in watts/(meter squared * ster * µm)

$G_{rescale}$ = Rescaled gain (the data product "gain" contained in the Level 1 product header or ancillary data record) in watts/(meter squared * ster * µm)/DN

$B_{rescale}$ = Rescaled bias (the data product "offset" contained in the Level 1 product header or ancillary data record) in watts/(meter squared * ster * µm)

Q_{CAL} = the quantized calibrated pixel value in DN

$LMIN_\lambda$ = the spectral radiance that is scaled to Q_{calmin} in watts/(meter squared * ster * µm)

$LMAX_\lambda$ = the spectral radiance that is scaled to Q_{calmax} in watts/(meter squared * ster * µm)

$Q_{cal\min}$ = the minimum quantized calibrated pixel value (corresponding to LMINλ) in DN

= 1 for LPGS products

= 1 for NLAPS products processed after 4/4/2004

= 0 for NLAPS products processed before 4/5/2004

$Q_{cal\max}$ =the maximum quantized calibrated pixel value (corresponding to LMAXλ) in DN

= 255

a. Spectral radiance estimation in Landsat TM

By the above formula (1). In case of the least post-calibration value Q_{calmin} (DN) is equal to zero, the L_{λ}-TM is able to be calculated by following linear expression formula (2)

$$L_{\lambda-TM} = G_{rescale} \times Q_{cal} + B_{rescale} \tag{2}$$

Table 2 is the example of official dynamic range of post-calibration scale values.

Table 2. TM spectral radiance, Post-calibration $G_{rescale,}$ $B_{rescale}$ dynamic ranges

Band	$LMIN_{\lambda}$	$LMAX_{\lambda}$	$G_{rescale}$	$B_{rescale}$
6	1.2378	15.303	0.055158	1.2378

b. Spectral radiance estimation in Landsat ETM+

In the above formula (1), LPGS (ESO Data Gateway) uses 1 as the least post-calibration value Q_{calmin}, while NLAPS (Earth Explorer) uses 0. Based on this policy, we can get the absolute spectral radiance by the following formula.

$$L_{\lambda-ETM+} = "gain" \times Q_{cal} + "offset" \tag{3}$$

There is no need to rectify the spectral radiance value in ETM+ because the two sub-bands in ETM+ band 6, named Low gain 6-1 and High gain 6-2 are separated always.

Table 3. ETM+ spectral radiance $LMIN_{\lambda}$ and $LMAX_{\lambda}$ "offset" "gain" ranges

Band	Low Gain		High Gain	
	$LMIN_{\lambda}$	$LMAX_{\lambda}$	$LMIN_{\lambda}$	$LMAX_{\lambda}$
6	0.0	17.04	3.2	12.65

In the above formula (1), LPGS (ESO Data Gateway) uses 1 as the least post-calibration value $Q_{\lambda calmin}$, while NLAPS (Earth Explorer) uses 0. Based on this policy, we can get the absolute spectral radiance by the following formula.

As discussed in the above formulas (1) to (3), there is the relationship between the spectral radiance value L_{λ} ($L_{\lambda-TM}$, $L_{\lambda-ETM+}$) and the absolute temperature °K(Kelvin). This can be denoted like following formula.

$$T(°K) = \frac{K2}{\ln\left(\frac{K1}{L_{\lambda}} + 1\right)} \tag{4}$$

Where, T = Effective at-satellite temperature in Kelvin

$K1$ = Calibration constant 1 from Table 3

$K2$ = Calibration constant 2 from Table 3

L_{λ} = Spectral radiance in watts/(meter squared * ster * µm)

Table 4. TM and ETM+ Thermal Band Calibration Constants

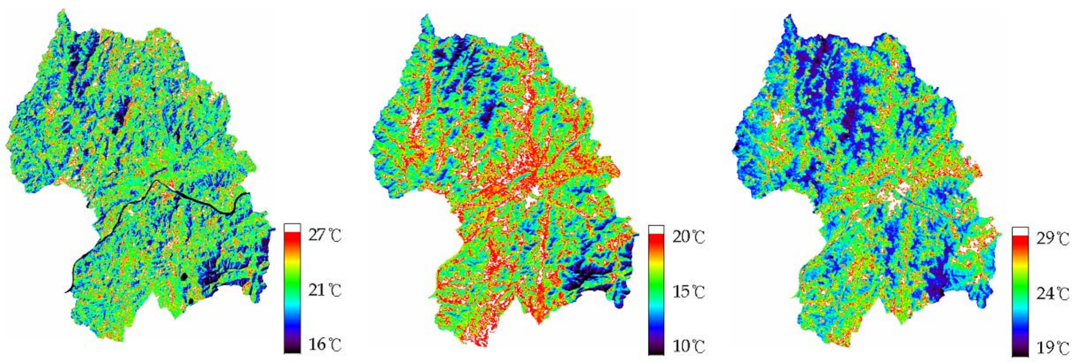
	K1 - Constant 1 watts/(meter squared * ster * μm)	K2 - Constant 2 Kelvin
Landsat 5 TM	607.76	1260.56
Landsat 7 ETM+	666.09	1282.71

Temperature obtained by formulas (4) is absolute temperature °K. So

As the temperature obtained by using equation (4) is absolute temperature (K), subtract 273.15 from T(K) like equation(5) in order to convert to centigrade.

$$T(°C) = T(K) - 273.15 \quad (5)$$

The periodic temperature is calculated from equation for surface temperature calculation. Figure 2 show calculated results in April 2003, October 2006 and June 2009.



2003/04 2006/10 2009/06

Figure 2. Surface temperature about study site.

Temperature calculation by forest type. In this study, satellite image processing program was used to extract the surface temperature and then digital forest type map was used to calculate the surface temperature about the type of each forest type (age class, diameter class, and species of trees). Digital forest type map is produced in a map scale of 1:25,000 using plotter after aerial photograph interpretation, and is constructed by scanning forest type map inputting all stand boundary by vector and entering the properties information. In this study, it was used digital forest type map about the city of Gongju which is provided in WAter Management Information System (www.wamis.go.kr).

Table 5. Forest type

Diameter Class	**Age Class**	**Species of Trees**
Xsmall(diameter <6cm)	1(age 1~10years)	Conifer
	2(age 11~20years)	
Small(diameter 6~16cm)	3(age 21~30years)	
Middle(diameter 18~28cm)	4(age 31~40years)	Deciduous
	5(age 41~50years)	
Large(diameter >30cm)	6(age 51years)	

Mask bands about age class, diameter class, and species of trees were produced by using the digital forest type map of Gongju and three season imageries were masked. Pure forest land area by forest type about the study site is 605.67km^2, it is about 64.35% in the whole area of the city. The results of diameter class which represents the economic value and condition of growth are as follows. Area of young tree is 11.67km^2 and 1.93% among whole forest land area, small tree is 40.06km^2 and 6.61%, middle tree is 537.0km^2 and 88.67%, large tree is 16.87km^2 and 2.79%.

The results of age class which represents age are as follows. Area of class 1 is 8.22km^2 and 1.35% among whole forest land area, class 2 is 43.26km^2 and 7.10%, class 3 is 345.60km^2 and 56.76%, class 4 is 196.52km^2 and 32.28%, class 5 is 13.08km^2 and 2.15%, class 6 is 2.17km^2 and 0.36%. The results of forest physiognomy which represents type are as follows. Area of conifer is 257.75km^2 and 51.90% among whole forest land area and area of deciduous is 238.89km^2 and 48.10%.

RESULTS AND ANALYSIS

In this study, masking is carried out about each of the forest type class to figure out temperature distribution of the forest type class, and the temperature is calculated about the results. Masking is carried out about obtained temperature results of each forest type class throughout the city. All the changes in temperature are checked by graph obtained from results. When temperature of the study site is compared with the whole city, all of the mean temperature of the study site in 2003, 2006, 2009 are about 1℃ lower than the mean temperature of near Gongju. Figure 3 shows the average temperature of Gongju city and forest site.

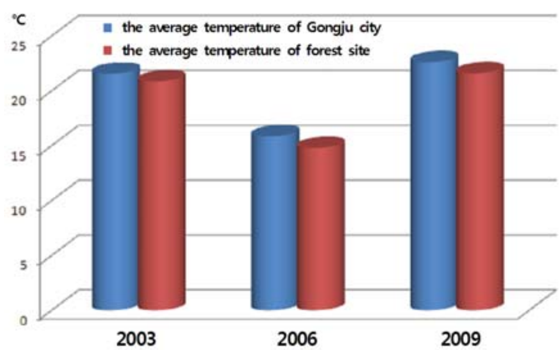


Figure 3. Average temperatures.

Temperature Distribution of Diameter Class

According to calculated temperature of diameter class from imagery in April 2003, the mean temperature of the Xsmall diameter class is 21.93℃, the Small is 21.20℃, the Middle is 20.82℃ and the Large is 20.10℃. In October 2006, the mean temperature of the Xsmall diameter class is 15.86℃, the Small is 15.01℃, the Middle is 14.77℃ and the Large is 13.78℃. In June 2009, the mean temperature of the Xsmall diameter class is 21.83℃, the Small is 21.79℃, the Middle is 21.59℃ and the Large is 21.04℃.

Table 6 is list of calculated temperature of diameter class. And Figure 4 is graph on the table. According to the result, the lower the mean temperature is obtained in the large diameter trees area.

Table 6. Temperature distribution of diameter class

Diameter Class	2003/04	2006/10	2009/06
Xsmall	21.93℃	15.86℃	21.83℃
Small	21.20℃	15.01℃	21.79℃
Middle	20.82℃	14.77℃	21.59℃
Large	20.10℃	13.78℃	21.04℃

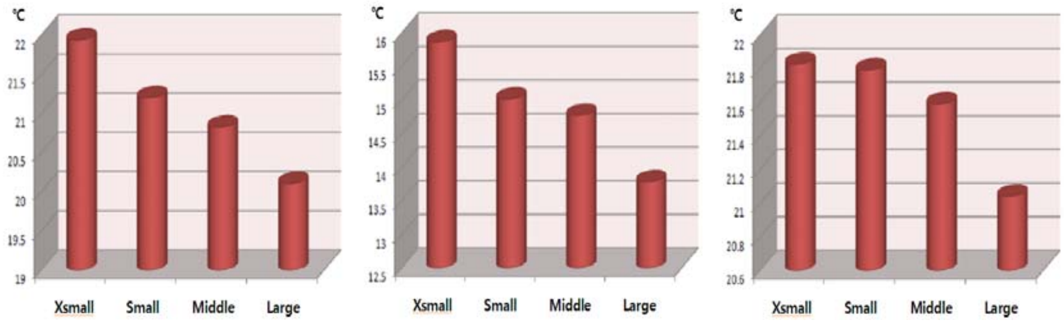


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Figure 4. Temperature by diameter class.

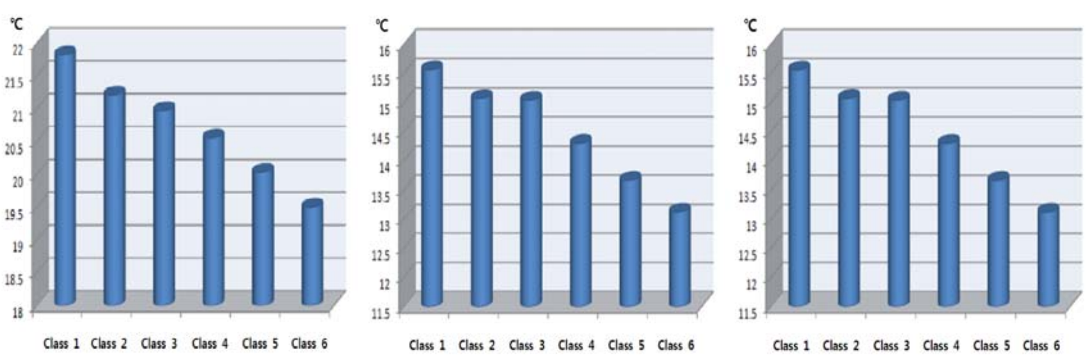
Temperature Distribution of Age Class

According to calculated temperature of age class from imagery in April 2003, the mean temperature of Class 1 is 21.82℃, Class 2 is 21.21℃, Class 3 is 20.97℃, Class 4 is 20.56℃, Class 5 is 20.03℃ and Class 6 is 19.50℃. In October 2006, the mean temperature of Class 1 is 15.56℃, Class 2 is 15.07℃, Class 3 is 15.04℃, Class 4 is 14.30℃, Class 5 is 13.66℃ and Class 6 is 13.12℃. In June 2009, the mean temperature of Class 1 is 21.90℃, Class 2 is 21.81℃, Class 3 is 21.79℃, Class 4 is 21.22℃, Class 5 is 21.02℃ and Class 6 is 21.00℃.

Table 7 is list of calculated temperature of age class. And Figure 5 is graph on the table. According to the results, the lower the mean temperature is obtained in the older trees area.

Table 7. Temperature distribution of age class

Age Class	2003/04	2006/10	2009/06
Class 1	21.82□	15.56□	21.90□
Class 2	21.21□	15.07□	21.81□
Class 3	20.97□	15.04□	21.79□
Class 4	20.56□	14.30□	21.22□
Class 5	20.03□	13.66□	21.02□
Class 6	19.50□	13.12□	21.00□



2003/04 2006/10 2009/06

Figure 5. Temperature by age class.

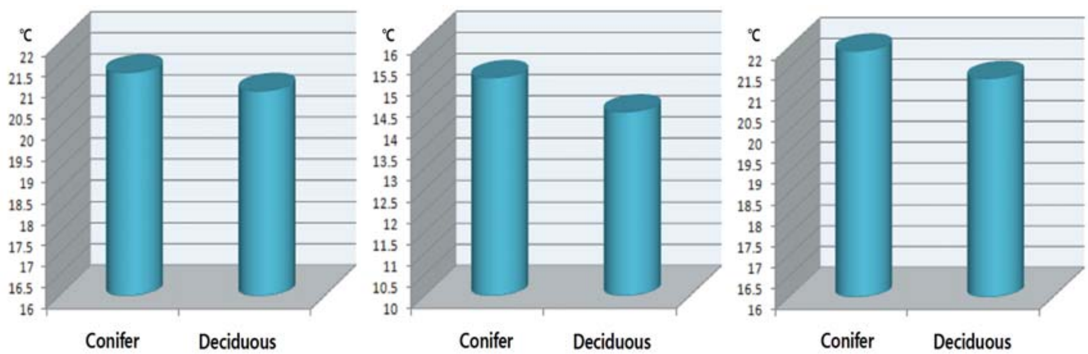
Temperature Distribution of Species of Trees

According to calculated temperature of species of trees from imagery in April 2003, the mean temperature of Conifer is 21.29℃ and Deciduous is 20.85℃. In October 2006, the mean temperature of Conifer is 15.14℃ and Deciduous is 14.33℃. In June 2009, the mean temperature of Conifer is 21.91℃ and Deciduous is 21.25℃.

According to the result, the lower the mean temperature is obtained in the broader leaves area. And Figure 6 is graph on the table. According to the results, the lower the mean temperature is obtained in the older trees area.

Table 8. Temperature distribution of species of trees

Species of Trees	2003/04	2006/10	2009/06
Conifer	21.29℃	15.14℃	21.91℃
Deciduous	20.85℃	14.33℃	21.25℃



2003/04 2006/10 2009/06

Figure 6. Temperature by species of trees.

CONCLUSIONS

In this study, the followings are conclusions by analysis of temperature according to the forest type of the area using multi-temporal satellite imageries and digital forest type map.

First, forest area has low temperature about 1℃ than the other study areas. Based on this finding, it is concluded that forest area influences temperature decreases.

Second, forest area with large diameter and high age showed lower temperature than any other areas. And deciduous area shows slightly lower temperature than conifer area.

Third, it is expected that information provided by satellite imagery and digital forest type map will be convenient and useful to urban planning and afforestation.

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