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IMPACT OF TEMPERATURE DISTRIBUTIONS ON FOREST AND VEGETATION IN JEJU ISLAND WITH REMOTE SENSING DATA

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ABSTRACT

In this study, the temperature distribution of Jeju Island with coastal ocean and its impact for forest and vegetation in Jeju Island, Korea were carried out based on the thermal band of Landsat 7/ETM+ remote sensing data. For the computation of the temperature of the island on the thermal band, we used NASA method which is the 8 bit Digital Number (DN) converted into spectral radiance. The computed results showed that the land temperature variations were from 0 to 12 Celsius degrees, and a good agreement with the observation ones based on the method. However, the ocean surface temperature was not much changed around 15 degree since the water was well mixed between the coastal and the offshore ocean. The interest results were that the temperature distributions of the southern part (Seogwipo City) of Jeju Island were higher than those of the north one (Jeju City) by more than 2 Celsius degree at the same height although the distance between the Jeju and the Seogwipo is only about 35 km in winter season.

Based on the different temperature of the island, we checked the tree and vegetation distributions in island. From the check, we found that at the same height, the coniferous forest are mostly distributed in north part although the deciduous are in south part. As the deciduous are relatively living in warm area comparing to the coniferous, the impact of temperature was important role of distributions of forest and vegetation in the island.

However, we cannot definitively explain to detect a temperature effect related to forest growth which is usually related with soil nutrition and precipitation.

Key Words: Landsat 7/ETM+, Digital Number, NASA Method, Jeju Island, Seogwipo

1. INTRODUCTION

Remote sensing refers to a technique of image collection system to collect environmental data about the earth's surface. Each image from remote sensing is comprised of a series of square pixels or building blocks arranged in a regular pattern of rows and columns (Lillesand and Kiefer, 2000). The intensity at which pixel is displayed is governed by the digital value. The intensity in turn is a representation of the reflected light from that portion of the target which the pixel represents. For example, in grey colour scale, the low digital number is low light intensity that is dark colour, the high number is high intensity that is related to bright one (Jensen, 1996). From the digital value, we can estimate image characteristics of land using image classification technique.

In the remote sensing data, the Landsat satellites have been widely used for the land classification and the image interpretation, respectively. The LANDSAT program was initiated by the U.S. Department of Interior and NASA under Earth Resources Technology Satellites (ERTS) that was changing the program designation to LANDSAT (USGS, 2000). LANDSAT ones have varied as technologies have been improved and certain types of data proved more useful than others. Particularly, Landsat TM (Thematic Mapper) images have been widely used for land classification with supervised and unsupervised techniques, respectively. The Landsat 7/ETM+ developed after the Landsat TM is a multispectral satellite measuring electromagnetic energy in eight spectral bands ranging from the visible to the Pan images. Landsat 7 are also useful for image interpretation for a wide range of applications like Landsat TM since the data provide 8 satellite images, blue band (band 1), green (band 2), red (band 3), near infrared band (bands 4, 5, 7), thermal band (band 6) and Pan image (band 8). Particularly, the thermal band is widely used in vegetation stress analysis, soil moisture discrimination and thermal mapping (Jo et al., 2001, 2002).

Sugal et al. (2000) provided a verification study on the surface temperature derived from the thermal infrared image data of Landsat 7 for the estimation of thermal condition around Hiroshima city and bay area based on NASA method. Barsi et al. (2003) estimated the on board thermal calibration of Landsat 7 through the ground measurements and showed validation of the temperature values of the Landsat 7. From these studies, we found that the thermal band proposed the reasonable temperature distribution of land and water.

Gillies and Carlson(1995) outlines a method for the estimation of regional patterns of surface moisture availability and fractional vegetation in the presence of spatially variable vegetation cover with NOAA (Advanced Very High Resolution Radiomete). In the study they pointed the surface radiant temperature to a vegetation index (computed from satellite visible and near-infrared data). However, NOAA data usually can not estimate the impact between temperature and vegetation distribution. Whitlock and Barthen(1997) studied the relationship between vegetation and climate change in north west America. In the stduy, they showed the climate can effect the vegetation distribution in the area.

In this paper, the thermal band of Landsat 7 was applied to Jeju Island to estimate the temperature distribution impact for the vegetation and forest types of the area. The calculated results of Landsat data will be also compared to the observation data supported by KMA (2003).

2. DATA AND RESEARCH SITE

In this study, Landsat 7/ETM+ data (2898 x 1897 Landsat pixels) from the cloud-free day of January 6, 2003 was selected. The study area, Jeju Island is a volcanic island located off the southern coast of Korea, the shape of the island is flat and oval-shaped (approximately 126 05′ 10″ N to 126 58′ 37″ N and 33 06′ 31″ E to 33 35′ 55″ E) with high mountain Halla (Figure 1). In the figure, the green lines represent contour line of elevation, the line interval is 100 m. Black lines are roads. Blue lines are county of Jeju Island. Hill side areas of 200-300m above the sea level are gently sloped but most of them are idle land or meadows. The coastal area (less than 200m above sea level) is 1,013.5 ㎢. It occupies 54.9% of the whole area and is mainly used for farm land or residential areas. A high mountain, called Mt. Halla (height 1950 m) is located at the center of the island. Given this difference in elevation, the fluctuations of temperature and climate on the island are strong. Consequently, the environment of the island has a diversity of ecosystems.

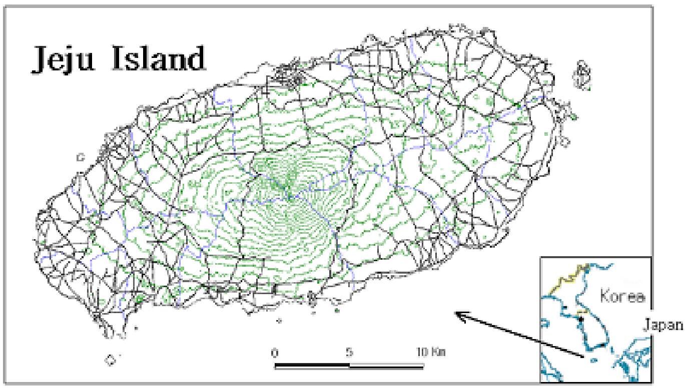

Figure 1. The study area of Jeju Island. Green line is contour line of the Jeju Island with Mountain Halla.

To analyze the ocean surface and the land temperature distributions in the study area based on Landsat 7 data, Image Analyst software was used, that was developed by Inergraph company. Using the software, we extracted the surface temperature from the value of the radiance of DN (Digital Number) in band 6 which is called thermal band. At the same time, we implemented image rectification using the 1:25,000 digital map.

3. METHODOLOGY

Usually, the satellite image needs to be the image rectification process since the orignal image was distorted by the satellite and its sense inclinations at the image capturing stage. To solve the distortion of the image, we used Affine transformation technique with 1/25,000 digital map, which is most widely used in satellite image rectification process. The calculated result shows that the error of the image rectification is less than 0.5 pixel size. Therefore, the results can be accepted to estimate the temperature distribution in Jeju Island.

For calculating the temperature distributions of Jeju Island using thermal band of Landsat 7/ETM+ thermal band, the following equations were used (Jo et. al, 2002)

$$T = \frac{K2}{\ln\left(\frac{K1}{L_\lambda} + 1\right)} \qquad \text{------------------------------(1)}$$

where

$$L_\lambda = gain * DN + offset, \quad gain = \frac{L_{max} - L_{min}}{Q_{max} - Q_{min}}, \quad offset = L_{min}$$

The equations are also known as NASA method. The gain and the offset values are provided by Barsi, et al. (2003), that were calculated by continually monitoring the ground surface temperature observation. The estimated parameters are shown in Table 1 which can be also derived from Landsat 7 project database system (USGS, 2000).

Table 1. ETM+ spectral radiance range and thermal constants

L_{max}	L_{min}	Q_{max}	Q_{min}	K1	K2
17.04	0.0	255	0.0	666.09	1282.71

4. THE TEMPERATURE DISTRIBUTIONS OF JEJU ISLAND

As the calculations of the temperature of Jeju Island using Eq. (1), we can estimate the generally temperature distributions of the island with the coastal ocean. Figs. 4.1 and 4.2 show the computational and the observational results of the temperature distributions of Jeju Island. The four observation areas were selected for temperature estimation in Jeju Island. The comparison between the observations and the computations was shown in Table 4.1 and Figure 4.1, respectively.

From the Figure 4.2, we know that the calculation results are a good agreement with the observation ones although the observation and the computations are a little bit difference in Sungsan area. The quantitatively estimated accuracies are shown in Table 4.1.

Figure 4.2 shows the results of spatial temperature patterns of the island based on Landsat 7/ETM+ in January 2003. In the figure, we know that the temperature variations are from 0 to 15 Celsius degree. Around top of the Halla mountain is less than 0 degree, and the coastal ocean is about 15 degrees that is almost the same temperature distribution in the ocean since the horizontal and the vertical mixing process in the coastal ocean.

Table 4.1. The temperature difference between the observations and the computations (Unit: ℃) in January 6, 2003

Obs. Period	Jeju	Sungsan	Gosan	Seogwi
Jan. 6, 2003	0.2	0.9	0.4	0.3

The ocean surface temperature is almost 3 degrees higher than the highest temperature in Jeju Island. Because of the high temperature effect of the ocean, we can expect that Jeju Island air temperature can be relatively warm in winter season. The interesting thing of the figure is that the temperature of the north part of the island is relatively lower than that of the south at the same height. Based on the height contour of the Figure 4.3, at the height of less than 400 m, the temperature difference between the north and the south is about 3 degrees. However, at the area of the higher than 800 m, the temperature is almost same between the north and the south as 5 degrees.

Figure 4.4 shows the viewshade of sunshine and shade areas in the island. In the figure, we can easily find out that the area of south viewshade(sunshine) is larger than the north (shade). Comparing temperature distributions of Figure 4.2 to the sunshine of Figure 4.4, we can easily find out that the temperature distribution is strongly related with viewshade area.

From the results, we can assume that the non-symmetric temperature distribution is related with the geographic characteristics and viewshade during winter seasons.

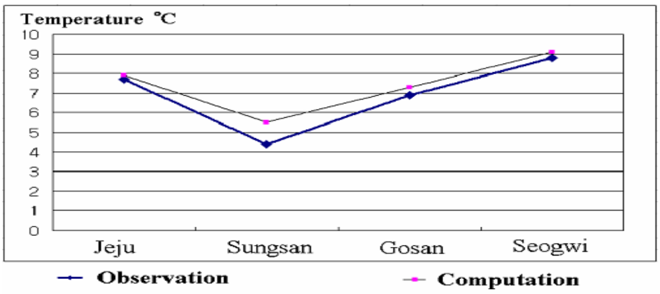

Figure 4.1. The comparison of the calculation and the observation data at four areas such as Jeju city, Sungsan, Gosan and Seogwipo city.

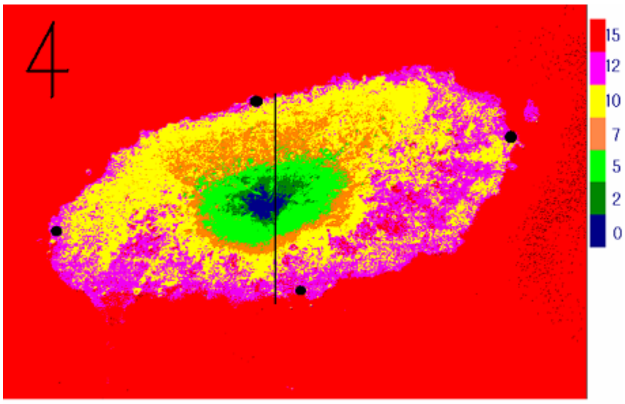

Figure 4.2 The temperature distributions of Jeju Island and around ocean using Landsat 7 image. The black spots showed the observation ones.

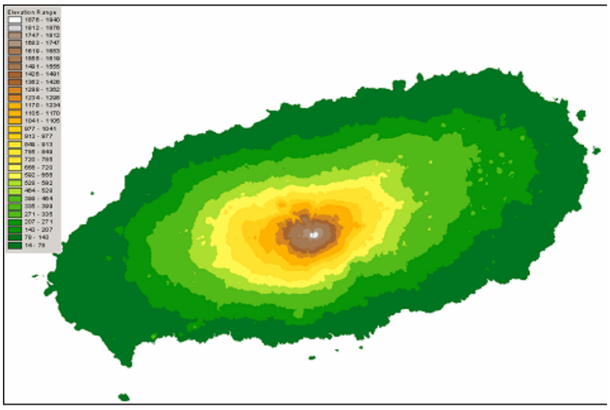

Figure 4.3 The elevation contour of the Jeju Island using 1/25,000 digital map.

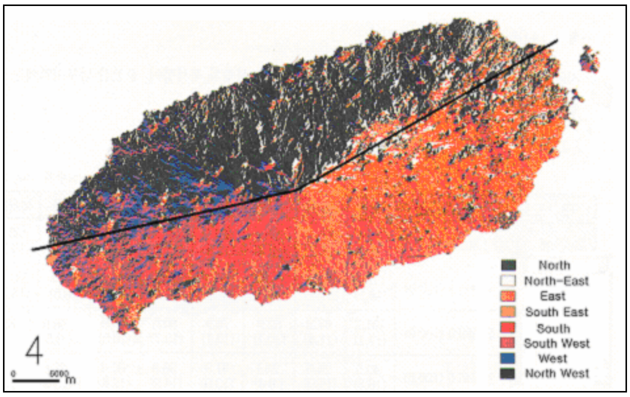

Figure 4.4. The estimated areas of the sunshine and the shade of Jeju Island. The straight black line pointed the boundary between North and South viewshade.

To check the detail temperature difference between the north and the south, we estimated the temperature changes not only from south coast to the top of the mountain but from north to the mountain according to black center line based on Figure 4.2, respectively. The results were shown in Figure 4.5. In the figure, the horizontal line is the temperature and the vertical one the height of Jeju Island, respectively. In the figure, the temperature difference between the north and the south from the bottom to the top of the mountain is about 2 ~ 3 degrees.

This results can be explained that the temperature of south part of Jeju Island during winter season is higher than those of the north part by the geographic effect. To find out the reason of the difference, we check solar radiation energy between the north and the south. Figure 4.6 shows the monthly solar irradiation variation between the north part (Jeju city) and the south (Seogwipo city) supported by KMA during 2003. Horizontal line is time variation (months) and the vertical line is solar irradiation values. The figure identified the solar energy variation pattern at the north and the south parts, respectively.

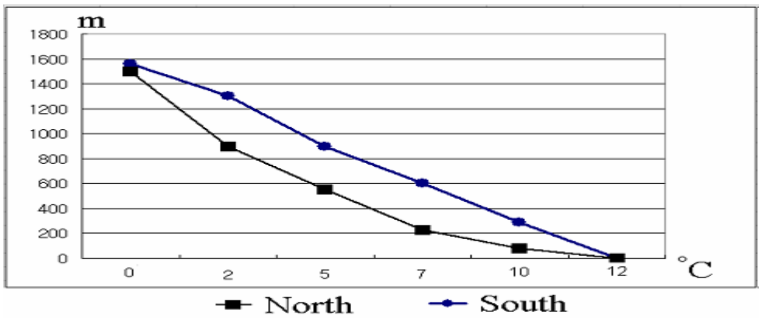

Figure 4.5 The temperature variation between the north and the south along the black straight line of the Jeju Island in Figure 4.2.

In the figure, from January to March and September to December, solar irradiation of the south area is higher than that of the north.

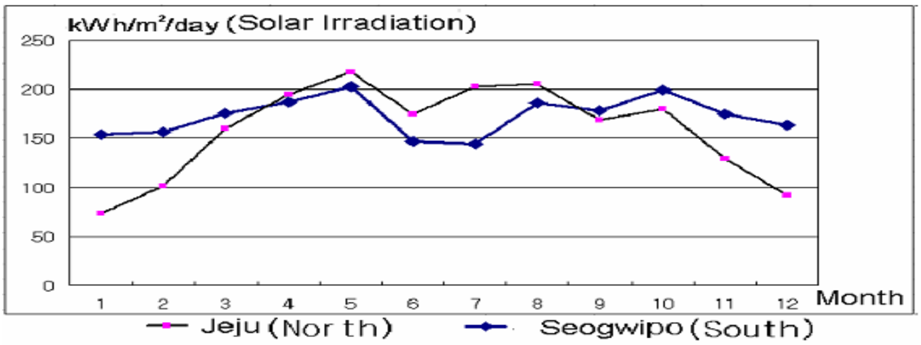

Figure 4.6 Solar irradiation between Jeju city (North) and Seogwipo (South) city.

However, from April to August, the north is higher than the south. Since the effect of solar irradiation, the temperature distribution of south area of the Halla mountain is higher than that of the north one at the same height of the mountain. This result can be explained that the solar irradiation was an important role of the temperature distributions in Jeju Island between the north and the south areas.

5. VEGETATION AND FOREST DISTRIBUTION

In previous section, our analysis showed the strong correlation between solar irradiation and surface temperature and viewshade with the height of the island. From the results, we check the relationship between the temperature and the vegetation and trees types. To do this, we propose a hypothesis that is, the different temperature distributions of the island will affect the vegetation intensity and diversity. Based on the hypothesis, we check the distribution and species of the forest based on the temperature distribution in the island.

Figure 5.1 shows vegetation distribution of Jeju Island. Along boundary line of sunshine direction in the figure, the south forest area is larger than the south in the island. Figure 5.2 shows the three forest types as the coniferous, the deciduous and the mixed types. In the figure, we can easily find out that the most part of forest are charged by the deciduous not coniferous. However, the top of the island is mostly covered by coniferous as low temperature. The other part is most affected by deciduous forest. From the results, remote sensing data showed a strong correlation with solar radiation and forest characteristics. Given the vegetation distribution between the coniferous and the deciduous it is not surprising the effect of solar radiation to vegetation will strongly related with vegetation diversity and distribution in the Jeju Island. Finally, we can conclude that the different distribution between the coniferous and deciduous forest is that the coniferous of the north part is relatively abundant than that of the south.

To check also the growth of the trees related with temperature distributions, we used the tree diameter data supported by KRISH(1997). Figure 5.3 shows the tree diameter characteristics of the island. In the figure, 30 cm larger sizes of the trees are mostly grown in the south part of the mountain. However, the small size of the tree also grows in south part. The reason is not found. We just expected that since the area is mostly composed of rocks and stones, the growth of the plant was restricted by nutrition and precipitation.

Up to now, we tried to set up our hypothesis of the effect of temperature to the forest distribution based on solar radiation, the tree species and the tree size. From the data, we detected that the temperature distribution is related with the Jeju Island forest types such as coniferous and deciduous. However, we can not definitively explain to detect a temperature effect related to forest growth which is related with soil nutrition and precipitation.

In the past, most researcher argued that the vegetation distribution in Jeju Island is only affected by the height of the mountain since they assumed the temperature only changed by the height of the island. However, from this study, we can propose the new idea for the vegetation distribution that can be affected by viewshade and solar radiation of the island.

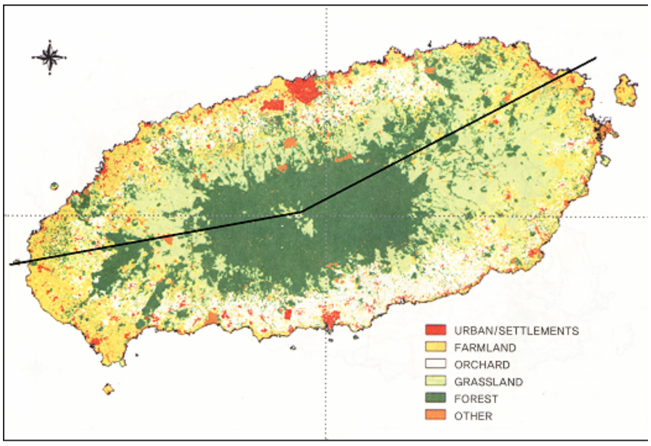

Figure 5.1 Vegetation distribution of Jeju Island.

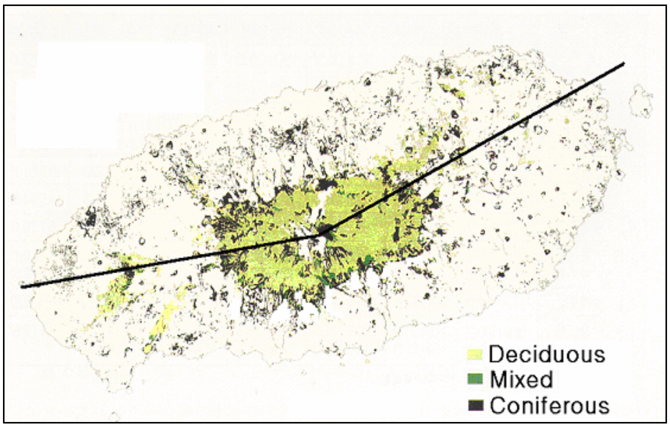

Figure 5.2 Forest distribution of Jeju Island.

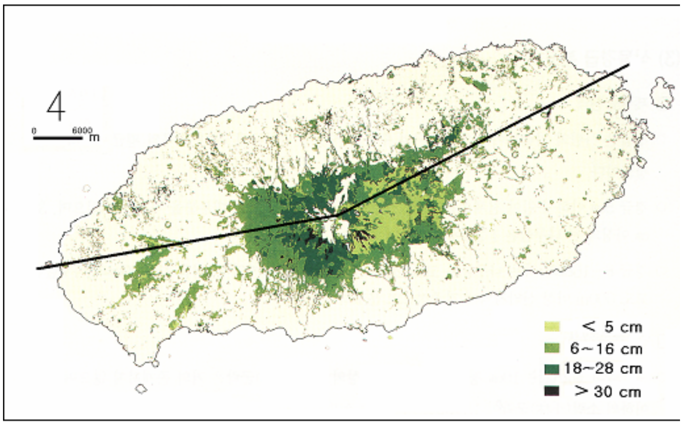

Figure 5.3 The tree diameter characteristics of Halla mountain in Jeju Island.

6. SUMMARY AND CONCLUSIONS

In this study, the estimation of the relationship between the surface temperature and the vegetation distribution of Jeju Island with coastal ocean was studied. Tod do this, we used the thermal band of Landsat 7/ETM+ and the vegetation field observation data supported by KRIHS(Koreas Research Institute for Human Settlements). For the computation of the temperature of the island and the coastal ocean based on the thermal band, we used NASA method which is the 8 bit DN converted into spectral radiance. The computed results showed that the land temperature variations are from 0 to 12 Celsius degree and were a good agreement with the observation ones based on the method. The ocean temperature is almost 3 degrees higher than the highest temperature in Jeju Island. Because the high l effect of the ocean, we can expect that Jeju Island air temperature can be relatively warm in winter season.

The interesting thing of the temperature distribution is that the temperature of the north part of the island is relatively lower than that of the south at the same height. The temperature difference between the north and the south from the bottom to the top of the mountain, respectively is about 2～3 degrees. It means that the temperature of south part of Jeju Island during winter season is about 2～3 degrees higher than those of the north part at lower area although the distance between two cities is only about 35 km. However, at the area of the higher than 800 m, the temperature is almost same between the north and the south as 5 degrees. To find out the reason of the difference. we checked solar radiation energy between the north and the south during 2003 between the northern part (the Jeju City) and the southern (the Seogwipo City). The result shows that the north solar irradiation is higher than the south one during the winter season only.

We also found that since the different effect of seasonal variations of the solar irradiation between the north and the south parts, the temperature distribution of south area of the Jeju Island at lower area (less than 800 m) is higher than that of the north one at the same height. It means that the solar irradiation and the island geographic characteristics were an important role of the temperature distributions between the north and the south areas.

Based on the temperature data, we tried to set up our hypothesis that is the temperature will influence the forest distribution, forest types and the tree size. To do this, we compared the temperature and viewshade to forest types(deciduous and coniferous) and its diameter.

From the comparison, we can propose the new idea for the vegetation distribution in Jeju Island. The vegetation and forest types can be affected by not only the height of the island but the viewshade and solar radiation. Up to now, most researchers argued that the vegetation distribution in the island is only affected by the height of the mountain since they assumed temperature only changed by the height of the island. Finally, we can draw a conclusion that the temperature distribution is related with the tree species such as the coniferous and the deciduous forests in the Jeju Island.

However, we can not definitively explain that the temperature distribution is related to the forest growth which is strongly affected by soil nutrition and precipitation.

7. ACKNOWLEDGEMENTS

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REFERENCES

Barsi, J.A., Schott, J.R. Ralluconi, F.D., Helder, D.L., Hook, B.L., Chander, G. and O'Donnell, E.M., 2003. Landsat TM and ETM+ thermal band calibration, Canadian Journal of Remote Sensing, 28, 141-163.

Jensen,J.R,. 1996. Introductory digital image processing, Prentice-Hall, Englewood Cliffs, New Jersey, 316p.

Jo, M-H., Lee, K.-J. and Jun, B.-W., 2001. The spatial topographic analysis of urban surface temperature using remote sensed data and GIS, 22nd Asian Conference on Remote Sensing Proceedings, Asian Association on Remote Sensing (AARS), 127～131.

Jo, M.-H., Kim, J.-B. and Kwon, B.-K., 2002. Correlation analysis of surface temperature and physical feature in mountainous area using RS and GIS, 23rd Asian Conference on Remote Sensing Proceedings, Asian Association on Remote Sensing (AARS), 25～33.

KMA, 2003. Monthly Weather Forecast Data. http://www.kma.go.kr.

Lillesand, T.M. and Kiefer, R., 2000. Remote sensing and image interpretation (4th edition), John Wiley & Sons, 724 p.

Sugal, Y., Yoshimura, M., Takuchi, S. and Oguro, Y., 2000. Verification of surface temperature from Landsat7/ETM+ Data, AARS 2000 Proceedings.

USGS, 2000. Landsat 7 Science Data Users Handbook. 560 p.

Whitlock, C. and P.J. Bartlein. 1997. Vegetation and climatechange in northwest America during the past 125 kyr. Nature 388. 57~61.