Effects of Shortwave Infrared Bands of ASTER and ETM+ for Assessing Vegetative Information

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Abstract: The primary uses of SWIR bands of ASTER data are to analyze geological features. In this study, we are attempting to evaluate the effect of using the narrow band ASTER data for extracting information related to biophysical information of forest vegetation. ASTER and ETM+ data have been obtained simultaneously over the study area in Kyongan-River basin on May 8, 2003. Two data sets were initially processed to reduce atmospheric effects and converted to percent reflectance values, which make them comparable each other. ASTER and ETM+ reflectance were then analyzed by using the field survey data that include forest leaf area index (LAI), cover types, species composition, and stand density. Preliminary results show that ASTER reflectance were not much different to ETM+ reflectance to explain LAI.

Keywords: LAI, forest vegetation, SWIR, ASTER, ETM+, reflectance

1. Introduction

The shortwave infrared (SWIR) or middle infrared (MIR) spectrum (1.3 to 3.0 micrometers) has been primarily known for its sensitivity to discriminate different rock and mineral type. Although the SWIR spectrum is also known for analyzing the moisture content of vegetation, it has been rare to clarify the effects of SWIR bands for such cases. Since the launch of the Landsat-1 in 1972, only a few satellite sensors have comprised spectral bands that are operating at SWIR spectrum. Landsat Thematic Mapper (TM, ETM+) is probably the most well-known sensor that has SWIR spectral bands. In recent years, there has been increasing number of new satellite sensors (such as MODIS, ASTER, SPOT) that include SWIR bands.

Although there have been several parameters in the quantitative aspects of vegetative remote sensing, leaf area index (LAI) has been one of the most useful and important parameters to characterize the vegetation activities from local to global scales. LAI, defined as the sum of the leaf area per unit ground area, can be used to measure the activities (photosynthesis, transpiration, and evapotranspiration) and the production of plant ecosystem [1]. The measurement of LAI on the ground is very difficult and requires a great amount of time and efforts [2]. Since plant canopy is composed of leaves, which is a direct source of the energy-matter interactions in most earth-observing remote sensing systems, LAI has been an attractive variable of interest in vegetative remote sensing. There have been numerous attempts to estimate LAI using various types of remote sensor data since the early stage of space remote sensing [3, 4]. Remote sensing estimation of LAI has been primarily based on the empirical relationship between the ground measured LAI and sensor observed spectral responses [5]. This study initiated to evaluate the effect of adding the SWIR bands for extracting information related to biophysical information of forest vegetation. As a preliminary approach, we are attempting to define the relationship between forest LAI and spectral reflectance obtained from satellite multispectral scanners.

2. Methods

1) ASTER and DTM+ Data Used

The study area covers an area of approximately 500 km^2 of mixed coniferous and deciduous forest in central part of the Korean Peninsula. The temperate mixed forest has diverse group of species composition and stand ages of between 20 to 50 years old and the crown closure is over 80%. For this study, we obtained two sets of satellite data that include visible, near-IR, and SWIR spectral bands. First dataset is Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data acquired on May 8 2003. ASTER is an imaging sensor of ‘terra’ satellite launched in December 1999 as part of NASA's Earth Observing System [6]. The second imagery used was Landsat-7 ETM+ data obtained on the same date. Both ASTER and ETM+ data share about the same spatial and spectral resolutions, except that ASTER have more and narrow spectral bands at SWIR spectrum (Table 1).

Table 1. spectral bands between ASTER and ETM+.

spectrum	ETM+	ASTER
Visible	Band1 (0.450 ~ 0.515)	
	Band2 (0.525 ~ 0.605)	Band1 (0.520 ~ 0.600)
	Band3 (0.630 ~ 0.690)	Band2 (0.630 ~ 0.690)
NIR	Band4 (0.750 ~ 0.900)	Band3 (0.780 ~ 0.860)
SWIR	Band5 (1.550 ~ 0.750)	Band4 (1.600 ~ 1.700)
	Band7 (2.080 ~ 2.350)	Band5 (2.145 ~ 2.185)
		Band6 (2.185 ~ 2.225)
		Band7 (2.235 ~ 2.285)
		Band8 (2.295 ~ 2.365)
		Band9 (2.360 ~ 2.430)

Since both data were obtained about the same time and date, it should be ideal situation to compare the spectral characteristics of surface features without worrying about the discrepancies in phenological variation of leaf development and other environmental perturbations. As seen in Table 2, the two datasets were obtained at only 28 minutes apart and the atmospheric condition and sun angles were almost identical.

Talbe 2. Data acquisition of ASTER and ETM+

	ETM+	ASTER
Data acquisition (local time)	May 8, 2003 (11:00 AM)	May 8, 2003 (11:28 AM)
Sun elevation angle	61.5°	66.2°
Sun azimuth angle	129.6°	143.9°

Both ASTER and ETM+ images were georeferenced, radiometrically calibrated, and converted to surface reflectance value. Initially, ASTER data were georeferenced to the local plane rectangular coordinates by using a set of ground control points obtained from the 1:5,000 scale topographic maps. Although the ASTER and ETM+ data were provided as 8-bit depth grey level data, their digital number values are not quite comparable because of the different radiometric calibration procedures between two sensor systems. Both ASTER and ETM+ data were atmospherically corrected by MODTRAN radiative transfer code using a standard atmospheric model. Table 3 shows the correlation coefficients among the spectral bands, calculated using the spectral reflectance values extracted from the same targets after the atmospheric correction. The spectral reflectance between ASTER and ETM+ are very similar at each wavelength band. As listed in Table 1, however, the correlation between the two datasets declined slightly at the SWIR band, in which the bandwidth and band position between two sensors is not quite corresponding each other.

Table 3. Correlation coefficients between ASTER and ETM+ spectral reflectance after the atmospheric correction.

	ETM1	ETM2	ETM3	ETM4	ETM5	ETM7
ASTER1	0.89	0.91	0.90	-0.46	0.42	0.67
ASTER2	0.89	0.91	0.92	-0.56	0.38	0.66
ASTER3	-0.56	-0.48	-0.59	0.91	0.15	-0.25
ASTER4	0.33	0.36	0.30	0.27	0.85	0.70
ASTER5	0.74	0.71	0.70	-0.27	0.73	0.87
ASTER6	0.71	0.69	0.67	-0.22	0.75	0.87
ASTER7	0.74	0.72	0.70	-0.26	0.73	0.87
ASTER8	0.76	0.74	0.72	-0.31	0.70	0.87
ASTER9	0.79	0.76	0.75	-0.36	0.65	0.85

2) Field LAI Measurements

The study area includes 390km² area of forest lands, in which about one third of them are plantation pine stands (*Pinus koraiensis, Pinus rigida, and Larix leptolepis*). The remaining two third of forests are mixed deciduous species. During the growing season of 2003, 30 ground sample plots were selected and species, LAI, stand density, and stand height were measured. Each plot has an area of 20 x 20 m² and includes five subplots for LAI measurement within it. All subplot measurements were averaged to provide a single value for the LAI at each plot. Plot locations were determined using a differential global positioning system (GPS).

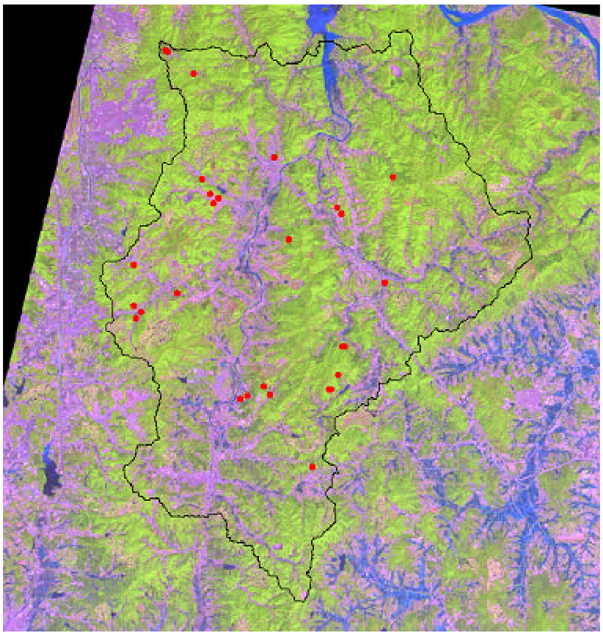

Fig. 1. Distribution of 30 ground plots of LAI measurements within the study area of the Kyongan Watershed

LAI values were measured indirectly using an optical device (Li-Cor LAI 2000) at 30 ground plots during the summer of 2003. To minimize any discrepancies due to the phenological variation of leaf development, the field measurements were conducted as close to the date of satellite data acquisition. Although the May 8th of satellite data acquisition is slightly earlier than the field measurement (late June to early July), we believe that it did not cause any serious problem since the leaf development status of 2003 started very early and the canopy condition between May and June was not much different. LAI values of the plantation conifer stands were higher than the natural stands of mixed deciduous stands. However, the LAI variation was very low at the mixed deciduous stands.

Once a vector file of the 30 ground plots was overlaid to the georectified ASTER and ETM+ imagery, three or four pixels spanned by the boundary of each plot were extracted and their reflectance values were averaged. Due to the high spatial autocorrelation, the variation of adjacent pixels was very low to overcome the problem of the sub-pixel error distance of the geometric registration.

3. Results and Discussions

Surface reflectance values from ASTER and ETM+ data were extracted for every location of ground sample plot. Field measured LAI was initially analyzed by its correlation with calibrated reflectance values. Correlation coefficients between the spectral reflectance and the field measured LAI were very low for all plots combined (Table 4). Forest LAI varies by several factors of stand structural parameters, such as species, stand density, crown closure, DBH, and tree height [7]. Considering the diverse groups of species composition in the study area, such low correlations would not be surprising.

When we calculated the correlation coefficient separately for each of two species groups of coniferous and mixed deciduous forest, the absolute value of correlation coefficients increased at the coniferous forest. The plantation coniferous stands are rather homogeneous in species composition. The variation of LAI in these stands is mainly due to the tree size and stand density. It is rather unusual to see the negative correlations between LAI and spectral reflectance in all wavelengths except at the near infrared bands. The negative correlation at the northern boreal forest has been reported by a previous study [8] and could be explained by the shadow effects and understory vegetation that has relatively high reflectance.

Table 4. Correlation coefficients between field measured LAI and spectral reflectance of ASTER and ETM+ bands.

	all	conifer	deci.
ASTER1	-0.160	-0.278	0.002
ASTER2	-0.224	-0.491	0.229
ASTER3	0.111	0.372	-0.167
ASTER4	-0.054	-0.142	0.014
ASTER5	-0.128	-0.357	0.116
ASTER6	-0.076	-0.321	0.158
ASTER7	-0.165	-0.392	0.106
ASTER8	-0.091	-0.422	0.243
ASTER9	-0.104	-0.423	0.286

	all	conifer	deci.
ETM1	-0.114	-0.320	0.056
ETM2	-0.097	-0.302	0.070
ETM3	-0.287	-0.560	0.055
ETM4	0.086	0.296	-0.179
ETM5	-0.233	-0.277	-0.286
ETM7	-0.270	-0.574	-0.075

No significant correlations were found at mixed deciduous stands, except for ASTER band 8 and 9 of longer SWIR spectrum. Unlike the plantation coniferous stands, the mixed deciduous stands showed very little variation in the field measured LAI value (mean=4.33, std=0.78). The subtle differences in the actual LAI values were thought to be the cause of such relatively low correlation.

The primary difference between ASTER and ETM+ spectral bands is that ASTER has more and narrow bands in SWIR spectrum. In overall, correlation coefficients were similar between ASTER and ETM+. Although there are a few exceptions where the narrow band ASTER reflectance has slightly higher and lower correlation than the ETM+ reflectance, the narrow band characteristics of ASTER does not show any significant advantage over the broadband ETM+. In the coniferous forest, strong correlations were mostly found at the red spectral bands and the longer SWIR bands (ASTER 8 and 9, ETM+ 7).

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4. Conclusion

From this early analysis on the relationship between the field measured forest LAI and ASTER/ETM+ reflectance, it would be premature to derive any solid conclusions. When we combined all forest sample plots regardless the species composition, no significant correlations were found between the field measured LAI and ASTER/ETM+ reflectance. Significant correlations were only found at the plantation coniferous stands. The spectral reflectance of SWIR bands might improve the strength of the LAI estimation model. Further analysis on the topographic effects is planned. Variation of solar illumination by the terrain slope and aspect has certain impact on the satellite reflectance.

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