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Spectal Characteristics of Dry-Vegetation Cover Types Observed by Hyperspectral Data

Kyu-Sung Lee†, Sun-Hwa Kim, Jeong-Rim Ma, Min-Jung Kook, Jung-Il Shin, Yang-Dam Eo*, and Yong-Woong Lee*

Inha University, Department of Geoinformatic Engineering, Yonghyun-dong, Nam-ku, Incheon 402-751, KOREA
Agency for Defense Development P. O. Box 35, Yusung, Daejeon, KOREA*

Abstract : Because of the phenological variation of vegetation growth in temperate region, it is often difficult to accurately assess the surface conditions of agricultural croplands, grasslands, and disturbed forests by multi-spectral remote sensor data. In particular, the spectral similarity between soil and dry vegetation has been a primary problem to correctly appraise the surface conditions during the non-growing seasons in temperature region. This study analyzes the spectral characteristics of the mixture of dry vegetation and soil. The reflectance spectra were obtained from laboratory spectroradiometer measurement (GER-2600) and from EO-1 Hyperion image data. The reflectance spectra of several samples having different level of dry vegetation fractions show similar pattern from both lab measurement and hyperspectral image. Red-edge near 700nm and shortwave IR near 2,200nm are more sensitive to the fraction of dry vegetation. The use of hyperspectral data would allow us for better separation between bare soils and other surfaces covered by dry vegetation during the leaf-off season.

Key Words : dry vegetation, crop residue, spectral reflectance, spectroradiometer, hyperspectral sensing, Hyperion.

1. Introduction

Crop residue and dry vegetation are spectrally very similar with background soils in visible and near infrared wavelengths (Daughtry *et al.*, 2004; Streck *et al.*, 2002). In temperate regions where the growing season is relatively short, it is often difficult to accurately assess the surface conditions among soils, croplands, grasslands, and disturbed forests with optical remote sensor data. The spectral similarity between soils and dry vegetation has been major obstacle to correctly classify and evaluate various land cover types with multispectral data that had been obtained during the non-growing seasons in temperature region.

Dry vegetation plays an important role to stabilize agricultural, grassland, and forest ecosystems by reducing soil erosion and increasing organic matter content in soil (Lal *et al.*, 1998). Intensive agriculture, over-grazing and over-exploitation of mountainous

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† Corresponding Author: K. – S. Lee (ksung@inha.ac.kr)

forest have been great concern in several places of temperate region. In particular, the large-scale conversion of mountainous forest to croplands have been a significant impact to degrade the environmental quality. Because of the difficulty to obtain cloud free imagery during the summer when the separation between bare soil and green vegetation can be maximized, there has been very little attempt to monitor the surface conditions of such degraded lands that had not been very productive. The surface coverage of early spring and fall are either bare soil or dry vegetation and, therefore, it is rather difficult to correctly separate between the abandoned croplands (bare soil) and the crop residue coverage after harvest. The inconsistency of land cover classification, particularly for the area of the degraded agricultural area and the cleared forest over North Korea, can be indicative of such problem to correctly classify similar spectral classes on the satellite image data obtained during leaf-off season (Lee *et al.*, 1999).

Hyperspectral image can be an alternative to overcome the limitation of multispectral data for the classification of spectrally similar classes (van der Meer and de Jong, 2001; Ben-Dor *et al.*, 2001). Spectral absorption features in shortwave infrared wavelengths have been known to be effective for assessing crop residue from soil by laboratory spectral measurements (Elvidge, 1990; Kokaly and Clark, 1999; Daughtry, 2001). Spectroscopic approaches to separate crop residue from soil could provide essential information for estimating crop residue coverage using remotely sensed data. The primary objective of this study was to characterize the spectral reflectance of various surface conditions with hyperspectral data over non-irrigated agriculture lands, grasslands, and disturbed forests during the leaf-off season in temperate region. The reflectance characteristics of various surface conditions could provide us essential information for the accurate classification of dry-vegetation covers using newly developed hyperspectral remote sensor data.

2. Methods

This study is based on laboratory experiment measuring spectral reflectance of various samples of mixed soil and dry vegetation. Further reflectance spectra were obtained from EO-1 Hyperion hyperspectral image that were obtained during the leaf-off season.

1) Laborlatory Spectral Measurements

A laboratory experiment was conducted to measure the reflectance spectra of dry vegetation samples using a portable spectroradiometer. Seven samples of having different level of dry vegetation fraction (0%, 10%, 20%, 40%, 60%, 80%, and 100%) were prepared within the area corresponding to the field of view (FOV) of the spectroradiometer (Figure 1). Dry vegetation was collected from the suburban cornfield at approximately 4 months after the harvest. Corn leaves and stems were almost dried out at the time of measurement and fractured into small pieces. For each sample, the exact fraction of dry vegetation was determined from the vertical photographs obtained by digital camera.

Reflectance spectra were measured using a portable spectroradiometer (GER 2600), which can measure spectral reflectance over the wavelength region between 350nm and 2,500nm. Reflectance spectra were measured at 2m above the sample with a 10 degrees FOV lens. The actual size of the FOV for the spectroradiometer did not exactly correspond to simple trigonometry calculation and it looks an ellipse shape with diameters of about 43cm and 28cm. The samples were illuminated by two 500-W halogen lamps positioned 90cm over the sample. For

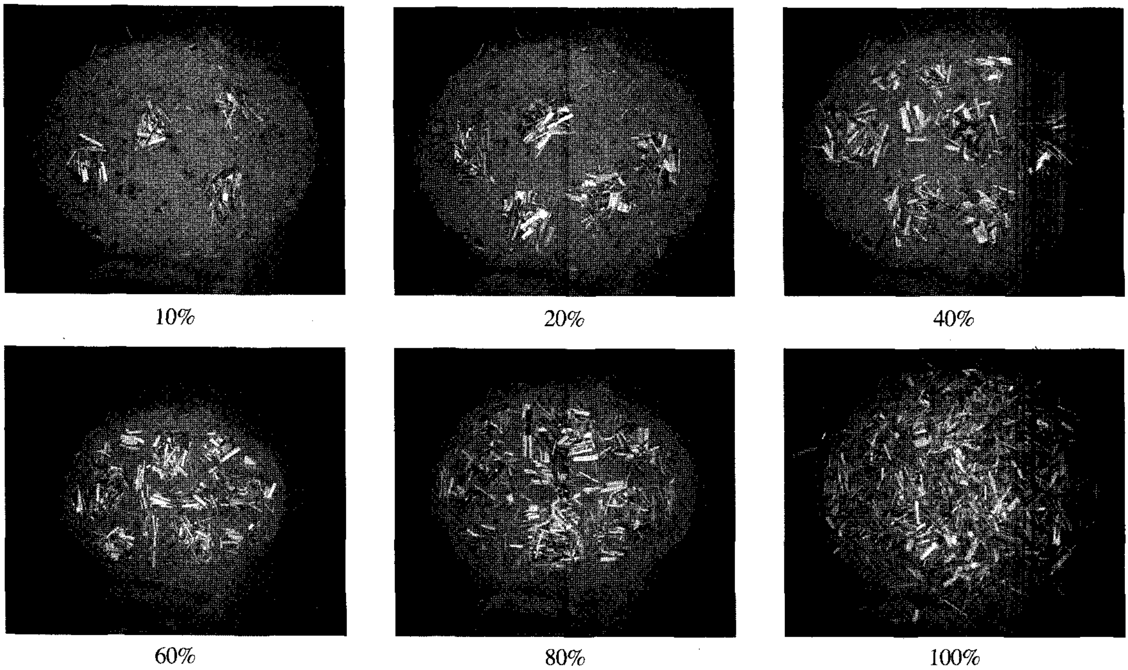

Figure 1. Laboratory spectral measurement samples having 10% to 100% coverage of dry vegetation over the soil background within the FOV.

each sample, spectral reflectance was measured four times and average reflectance were plotted as a function of wavelength. At each measurement, the spectroradiometer actually provides percent reflectance value for 612 continuous bands over the wavelength from 350nm and 2,500nm.

As an initial approach to detect particular spectral absorption features among seven samples, we applied the continuum removal method (Kokaly and Clark, 1999). The continuum removal method allows us to compare absorption features from common baselines. The continuum-removed reflectance is obtained by dividing the original reflectance by the reflectance value on continuum line. As seen in Figure 2, the continuum line was set up to connect local maxima of absorption features, and the continuum-removed

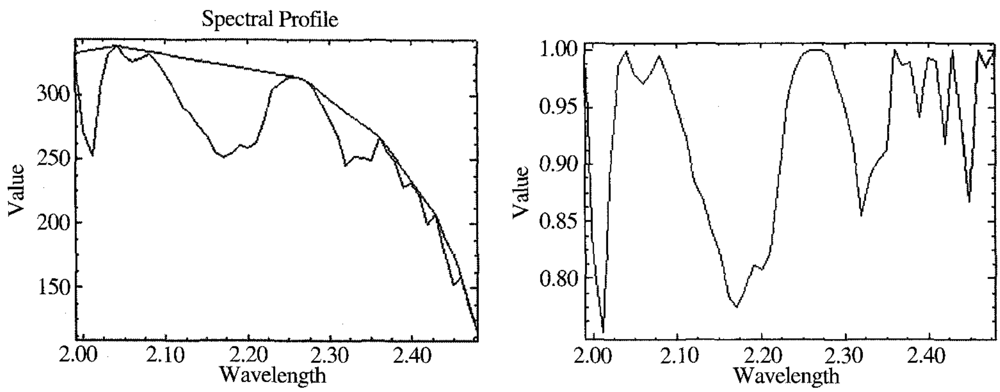

Figure 2. Continuum removal method applied to detect spectral absorption features.

reflectance is equal to 1.0 where the continuum and the original reflectance spectra are the same and less than 1.0 where absorption features occur.

2) Extraction of Reflectance spectra from Hyperion Image

In addition to the reflectance spectra from laboratory measurements, actual ground reflectance spectra were obtained from the EO-1 Hyperion hyperspectral image data. Although EO-1 Hyperion data are known to have relatively poor radiometric quality as compared to airborne imaging spectrometer data, such as the NASA's AVIRIS, they are probably the only satellite hyperspectral data available over the study area (Asner and Heidebrecht, 2003). The Hyperion data over the Kwangju and suburban area in southern part of Korean Peninsula were obtained on November 22, 2002. The original data contain 242 spectral bands, each approximately 10 nm wide, ranging from 356nm to 2,577nm. Of the 242 bands in the full Hyperion dataset, about 70 bands of strong atmospheric water-absorption (near the 1,400nm and 1,900nm) and high instrument noises were excluded.

Figure 3 shows the data analysis procedure to extract reflectance spectra from the Hyperion data. After initial radiometric calibration procedure to reduce inherent sensor noises, the data were georeferenced and converted to surface reflectance. Atmospheric watervapor is a key factor in the atmospheric correction of optical remote sensor data. The atmospheric correction of hyperspectral data has a clear advantage over multispectral data since the intensity of atmospheric watervapor at the time of data acquisition can be directly obtained from a few spectral channels of the data themselves. In this study, we used the ACORN program (AIG, 2002), which was based on the MODTRAN4 radiative transfer code. ACORN used two water absorption channels (940 nm and 1,140 nm) in Hyperion data to estimate the amount of water vapor at the time of data acquisition. Atmospherically corrected Hyperion data having 30m spatial resolution were georeferenced to plane rectangular coordinates using a set of ground control points (GCP) from digital topographic maps.

To build a meaningful relationship between various surface conditions over vegetative areas and reflectance spectra from hyperspectral data, the ground truth collection must be contemporaneous with the date of image acquisition. However, in this study, the ground truth data were not available at the

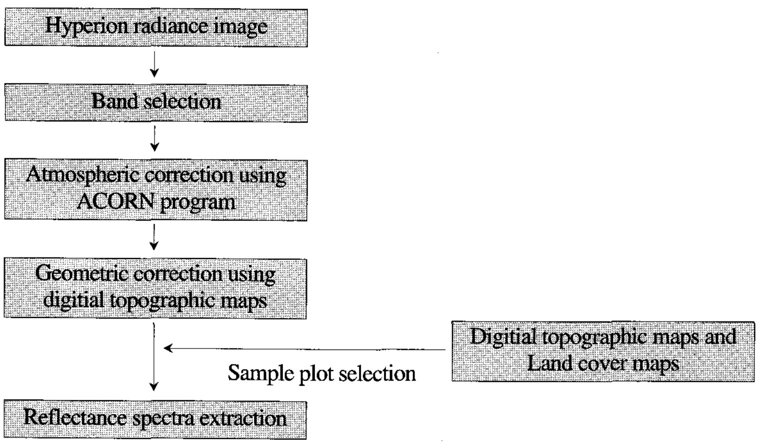

Figure 3. Data analysis procedures to obtain reflectance spectra of dry vegetation covers from EO-1 Hyperion image.

time of data capture. Using various scales of topographic maps and land cover maps, several plots of dry-vegetation surface were selected (bare soil, rice field, non-irrigated cropland, grassland, shrub, deciduous forest, and coniferous forest). Although the exact percent coverage of dry vegetation was not known for each sample plot, the surface conditions of the sample plots varied for the leaf-off season except for the coniferous forests. For each sample plot, average reflectance value was obtained from 2×2 pixels area ($60 \times 60m^2$).

3. Results and Discussions

Figure 4-a shows the laboratory-measured reflectance spectra of seven samples representing 0% to 100% fractions of dry vegetation. Although two primary water absorption bands near 1,450nm and 1,950nm are distinct, the reflectance spectra are almost proportional to the percent coverage of dry vegetation. Beside two water absorption bands, the other absorption features were found near 650-700nm and 2,200nm. In spectroscopic studies, these absorption bands are known to have close relationship with cellulose and lignin, which are the main compounds of dry vegetation (Curran, 1989). The relatively dark soil (0% fraction) has the lowest reflectance and the 100% fraction sample shows the highest reflectance. The reflectance spectra of other fraction samples are more likely the spectral mixture of these two extreme spectra, in particular at wavelength shorter than 1,900nm. The addition of dried corn residues over the dark soil background increases the reflectance value. However, such proportional increase of the reflectance reversed beyond the wavelength near the 2,200nm. Adding more dry vegetation decreases the reflectance at these spectral bands, which corresponds to several previous studies (Streck *et al.*, 2002).

Once the continuum line is divided by the original reflectance, the resulted reflectance is equal to 1.0 where the continuum and the original reflectance spectra are the same and less than 1.0 at the absorption features. In the continuum-removed spectra, several absorption features are more apparent than in raw reflectance spectra (Figure 4-b). Again, the absorption features are mostly found in two water absorption bands of 1,450 and 1,950nm. Although these two primary water absorption bands show the most distinct separation among the bare soil and dry-vegetation covers, they are not very useful because these wavelength bands are usually excluded from most imaging sensors. Beside these two distinct absorption features, we could observe other absorption features in 650-700nm, 1,550nm, and 2,200 nm. The establishment of a continuum line is a key step that can vary the outcome of continuum-removal analysis. Further refining on the determination of continuum line may provide us better distinction of absorption features to separate different fraction level.

Unlike the laboratory-measured spectra, the reflectance spectra obtained from the hyperspectral image had mixed nature of soil, dry vegetation, and other surface materials due to the 30m ground resolution of Hyperion image data. Figure 5 shows the Hyperion reflectance spectra and the continuum-removed spectra of ground sample plots having various surface conditions of the leaf-off season on November 22. Except for the coniferous forest, the sample plots were surely covered by certain amount of dry vegetation. The coniferous pine forest (*Pinus rigida* and *Pinus thunbergii*) was very dense canopy closure and might be very little influence of spectral reflectance by dry vegetation. The reflectance curve of the coniferous forest shows a classic form of green vegetation with strong water absorption features at

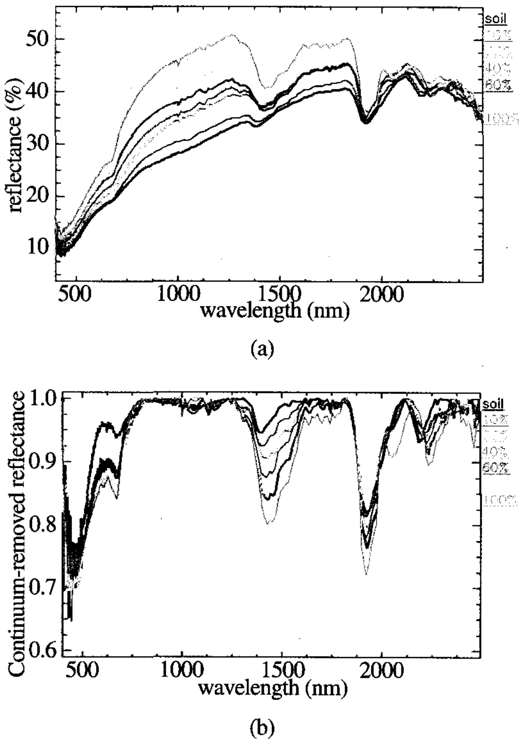

Figure 4. Laboratory measured reflectance spectra (a) and continuum-removed reflectance spectra (b) of seven samples representing 0% to 100% fractions of dry vegetation.

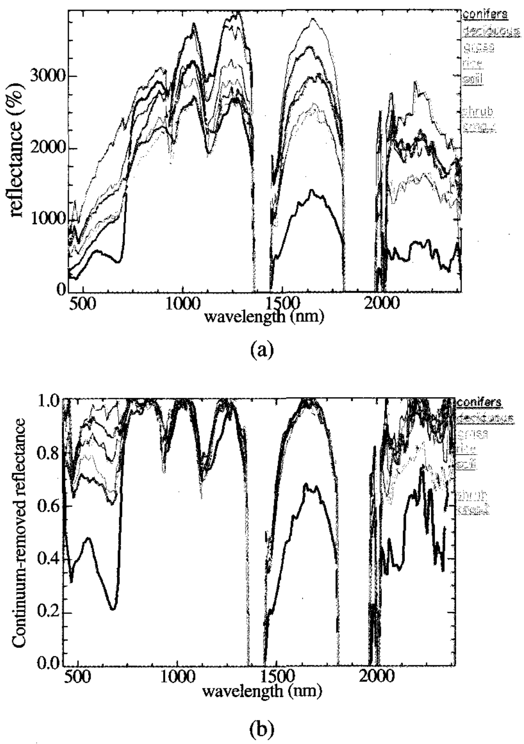

Figure 5. Reflectance spectra of field plots having various surface condition, which were obtained from EO-1 Hyperion data during the leaf-off season: (a) - percent reflectance, (b) - continuum removed reflectance.

wavelengths near 940nm, 1,100nm, 1,400nm, and 1,900nm. Unlike to the relatively dark soil sample used in the lab measurement, the bare soil plot was very bright site and assumed no dried vegetation residues.

The other six reflectance-spectra were extracted from the sites of rice field, non-irrigated cropland, grassland, and shrub. It was somewhat unusual to see the relatively high reflectance of the dry vegetation classes in near-IR and SWIR region. In wavelength longer than 1,100nm, the dry vegetation sites showed much higher reflectance than the evergreen forest. Probably, the deciduous oak forest and shrub had the largest amount and fraction of dry vegetation as compared with other classes. However, the other classes of grassland and cropland show the lowest reflectance near 2,200 nm. Although the exact amount and fraction of dry vegetation was not known for each ground plot, these sites had different type and fraction level of dry vegetation. In this preliminary analysis of comparing the reflectance spectra, we tried to find particular wavelength bands that might show the maximum separation among these classes.

The continuum-removed reflectance spectra (Figure 5-b) clearly show several absorption features. Excluding the green vegetation of coniferous forest, the main spectral absorption features were found in red-edge (650-700nm) and the second shortwave IR (2,050-2,200nm) wavelengths. Because of relatively high level of signal noise of Hyperion data, it was not clear to define specific narrow absorption bands.

However, the maximum difference among the dry vegetation classes can be achieved in these two wavelength regions. The broad absorption band in red wavelength might come from the different type of vegetation and soil background. Spectral characteristics of various surface conditions during the non-growing season are dependent upon soil type, chemical constituent of dry vegetation, and moisture conditions of soil and vegetation.

From both laboratory measurement and EO-1 Hyperion image-derived spectra, a few spectral absorption features in red-edge and SWIR region can be used to separate dry vegetation cover types from the bare soil. Without knowing the exact status of the surface condition at the time of the Hyperion data acquisition, it would be premature to make a certain conclusion. Further spectral analysis on the interaction of these factors could provide us better understand of spectral reflectance on dry vegetation.

4. Conclusions

Because of the difficulty of obtaining cloud-free remote sensor data during the growing season, it has been rather difficult to assess the surface condition and to correctly classify land cover types over the vegetative area in temperate region. The spectral characteristics of mixed soil and dry vegetation may provide us to solve such problem.

Based on the reflectance spectra obtained from both lab measurement and satellite hyperspectral data on several types of dry vegetation samples, the following conclusions can be made. The reflectance spectra of bare soil, which is a typical surface condition of abandoned and no-longer productive cropland, could be distinguished from the other surfaces covered by dry vegetation using hyperspectral data. The classification of such abandoned croplands in mountainous area may be greatly dependent upon the spectral variability of background soils. Red-edge and shortwave IR wavelengths, in particular at wavelength near 2,200nm, are more sensitive to the fraction of dry vegetation. Similar patterns were found from both laboratory measured spectra and Hyperion image spectra, except for more distinct absorption features at visible wavelength with Hyperion data. Although relatively poor radiometric resolution of Hyperion data was problematic to derive noise-free reflectance spectra, future development of satellite hyperspectral sensor can be a great potential to monitor vegetation coverage even during the non-growing season.

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