

## METHOD TO REDUCE GREEN AND DRY VEGETATION EFFECTS FOR SOIL MAPPING USING HYPERSPECTRAL DATA

C. Kobayashi<sup>a\*</sup>, O. Kashimura<sup>a</sup>, T. Maruyama<sup>b</sup>, M. Oyanagi<sup>b</sup>, I. C. Lau<sup>c</sup>, T. Cudahy<sup>c</sup>, B. Wheaton<sup>d</sup>, D. Carter<sup>d</sup>,

<sup>a</sup> Earth Remote Sensing Data Analysis Centre, 3-12-1kachidoki, chuo-ku, Tokyo, Japan – (kobayashi, kashimura)<sup>@ersdac.or.jp</sup>

<sup>b</sup> Nikko Exploration & Development Co., Ltd., 2-7-10 Toranomom, Minato-ku, Tokyo, Japan - (maruyama, oyanagi)<sup>@tankai.co.jp</sup>

<sup>c</sup> CSIRO Exploration and mining, 26 Dick Perry Avenue, Kensington WA 6151, Australia - (ian.lau, Thomas.Cudahy)<sup>@csiro.au</sup>

<sup>d</sup> Dept. of Agriculture and Food, 3 Baron-Hay Court South Perth WA 6151, Australia  
–(buddy.wheaton, dan.carter)<sup>@agric.wa.gov.au</sup>

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### ABSTRACT:

In this study, to remove the effects of topography and surface roughness to observed spectrum initially, a method using the normalised reflectance (pseudo- reflectance) was employed. Then, we examined the removal of the vegetation effects (such as green vegetation and dry vegetation) and a method to estimate soil pseudo-reflectance spectrum, because the ground surface shows the mixture of soil and vegetation. Using soil pseudo-reflectance, we estimated the fundamental soil properties such as clay mineral content. The results showed higher accuracy for soil pseudo-reflectance data corrected for green vegetation and dry vegetation effects than reflectance data, which demonstrated the effectiveness of our correction method.

### 1. INTRODUCTION

The soil spectrum obtained from satellite remote sensing rarely represents pure soil spectrum but it is often a mixture of soil and vegetation spectra. In order to estimate the fundamental soil properties, it is necessary to separate soil and vegetation and extract the pure soil spectrum.

Furthermore, measured spectra usually contain the effects of topography and surface roughness, and eliminating those effects is not an easy task. And also it is for this reason that accurate conversion of satellite data to reflectance spectra is difficult, because effects of topography or surface roughness are unavoidable even if appropriate atmospheric correction is applied. Reflectance varies depending on the slope gradient and correction by using DEM such as cosine correction algorithm (Iikura & Yokoyama, 1999) needs to be applied to remove those effects. This approach requires not only sufficient geometric correction and accurate DEM, but also time-consuming data processing. Additionally, reflectance changes depending on the surface roughness. Shadowing due to surface roughness causes low reflectance.

In this study, we employed a well-known method to eliminate the effects of topography and shadow before the removal of green and dry vegetation effects, using the normalization technique by band average as proposed by Ono et al., (2002), and using the technique to generate a unit vector by normalization based on the sum of all bands as proposed by ERSDAC (2003). This method allows to produce a similar pseudo-reflectance profile for the same material regardless of the incident light intensity or shadow. Furthermore, the pseudo-reflectance method is insensitive to atmospheric effect (ERSDAC 2003, Ono et al., 2002, etc.).

Using the pseudo-reflectance data obtained by conversion, effects of green vegetation as well as dry vegetation were

removed. Though there are many methods to estimate the amount of vegetation using NDVI or SAVI for eliminating the green vegetation effect, correction of such effect in the dry vegetation (stubble) areas using NDVI or SAVI is difficult because reflectance ratio used for these indices changes due to dry vegetation. To address this problem, we employed a new method to use the absorption depth of water observed near 1200nm in vegetation.

Removal of dry vegetation effect was applied after green vegetation correction. Using the Cellulose Absorption Index (CAI) proposed by Nagler et al., (2003), we investigated the amount of dry vegetation and developed a method for correction.

As described above, we did not use the reflectance itself but converted it to the pseudo-reflectance for analysis. This relatively simple pre-processing allowed effective elimination of both green and dry vegetation effects and extraction of the soil pseudo-reflectance. In this paper, we introduce this pseudo-reflectance method along with those for removing the green and dry vegetation effects.

### 2. METHOD

#### 2.1 Data used

We used the data collected by HyMAP, an airborne hyperspectral imaging scanner, in December 2006 over Toolibin area located in the south of wheat belt region in Western Australia (Fig. 1). The land use of Toolibin area consists of Toolibin Lake, conservation forest, pasture land and agricultural land. Originally Toolibin Lake had freshwater, but recently the lake and surrounding area have been harmed by salt. In conservation forest appearing black color in Figure 1, there are trees such as Eucalyptus and Acacia. And also, saltwort

such as Common Glasswort grows around Toolibin Lake. In agricultural land, wheat and canola are cultivated. But in December, all crops are harvested and stubbles (dry vegetation) remain in agricultural land. We developed the method to remove the effects of these green and dry vegetation, using the data of this area.

For HyMAP data, the wavelength between 450nm-2500nm was covered in 126 bands with spatial resolution of 3 m. Products made by HyVISTA that applied the atmospheric correction (using ATCORR software) to convert to the reflectance values were used for analysis.



Figure 1. Natural color HyMAP image around Toolibin area

### 2.2 Pseudo-reflectance

Pseudo-reflectance method is an approach proposed by ERSDAC (2003) and used in the Pseudo-SAVI (PSAVI) method. The method generates a unit vector from reflectance spectrum and uses it as the pseudo-reflectance. With this method, even when shadow is included in the measured spectrum, a similar pseudo-reflectance profile can be obtained

for the same material regardless of the incident light intensity, which means that the effects of shadow or terrain relief can be neglected with the use of pseudo-reflectance.

Pseudo-reflectance is expressed as:

$$PR_n = \frac{R_n}{\sqrt{\sum_{n=1}^{126} R_n^2}} \tag{1}$$

where PR = Pseudo-reflectance,  
R = Reflectance  
n = HyMAP band number.

### 2.3 Green vegetation removal

We describe here a method to estimate the impact of green vegetation to observed spectrum and its correction using the pseudo-reflectance. Reflectance in the visible and near-infrared regions is changed by the presence of dry vegetation (stubble) on the surface, and it is difficult to correct the green vegetation effect using NDVI or SAVI for areas covered with dry vegetation. For this, we developed a new correction method based on the water absorption by vegetation near 1.2 μm. This absorption is only observed for vegetation and not seen for soil or dry vegetation usually (Clevers et al.,). As the conversion to the pseudo-reflectance is performed for analysis, we did not use the conventional method to calculate the vegetation cover ratio but determined the “impact of green vegetation” as an index to show how much effect the vegetation has on the pseudo-reflectance.

In our proposed method, the angle of reflectance at 1.114 μm, 1.202 μm and 1.244 μm was used as an index to show green vegetation impact. Large green vegetation impact yields a sharp angle, while small impact produces an angle that approximates a straight line (180°) (Fig. 2).

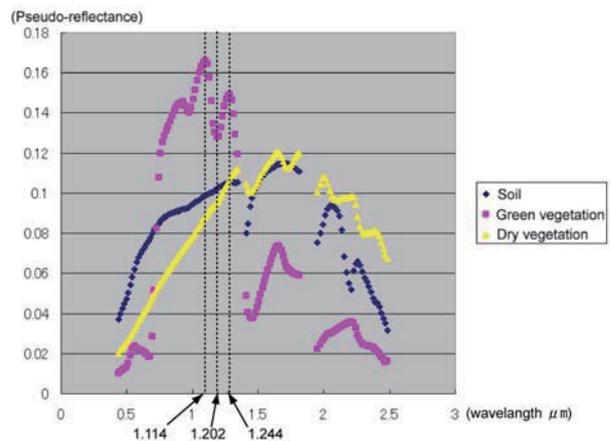


Figure 2. Water absorption in vegetation seen around 1.2 μm

The impact of green vegetation is given by:

$$\begin{aligned} & \frac{(OPR_{1202} - VPR_{1202} * X) - (OPR_{1114} - VPR_{1114} * X)}{1202 - 1114} \\ & = \frac{(OPR_{1244} - VPR_{1244} * X) - (OPR_{1202} - VPR_{1202} * X)}{1244 - 1202} \end{aligned} \tag{2}$$

where OPR = pseudo-reflectance of soil, green vegetation and dry vegetation mixture,  
 VPR = pseudo-reflectance of green vegetation  
 X = "impact of green vegetation"

Pseudo-reflectance of green vegetation was determined by calculating SAVI and converting the reflectance of a point that maximized SAVI.

Then, using the obtained impact and pseudo-reflectance of green vegetation, the pseudo-reflectance of mixed soil and dry vegetation was calculated:

$$MPR = OPR - VPR * X / (1 - X) \tag{3}$$

where MPR = pseudo-reflectance of soil and dry vegetation mixture

Following this correction, MPR was converted to the normalized pseudo-reflectance by setting the sum of the pseudo-reflectances to be 1:

$$N\_MPR_n = \frac{MPR_n}{\sqrt{\sum_{n=1}^{126} MPR_n^2}} \tag{4}$$

where N\_MPRn = Normalized pseudo-reflectance of soil

As a result of a series of calculations, effects of green vegetation were removed and the pseudo-reflectance of mixture of soil and dry vegetation was defined.

**2.4 Dry vegetation removal**

To isolate the soil reflectance from the mixed soil and dry vegetation pseudo-reflectance, the dry vegetation coverage and the typical reflectance of dry vegetation are needed. In this study, we focused on a characteristic absorption band of cellulose in the short-infrared region to examine the dry vegetation (fig. 3). Cellulose can be quantified by this diagnostic absorption band and the Cellulose Absorption Index (CAI) using this absorption band is proposed in Nagler et al., (2003). We applied this approach to the pseudo-reflectance and investigated the amount of dry vegetation cover and the correction method.

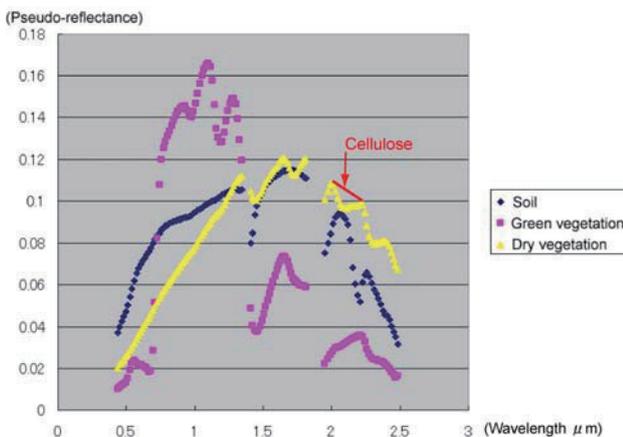


Figure 3. Cellulose absorption

CAI is expressed as:

$$CAI = 0.5(N\_MPRa + N\_MPRc) - N\_MPRb \tag{5}$$

Here, we used the pseudo-reflectance at 2.01 μ m, 2.101 μ m and 2.206 μ m for N\_MPRa, N\_MPRb and N\_MPRc, respectively.

In the analysis that involves conversion to the pseudo-reflectance, CAI values do not correspond to the dry vegetation cover ratio. For correction of stubbles using CAI, correction curve showing the influence of CAI on the pseudo-reflectance for each bands is required. The correction curve was attained using the statistical approach in the following steps:

- (a) Calculate CAI from HyMAP data using the equation (5).
- (b) Multiply CAI by 10000 and most data should range from -100 to 100. Divide the data into about 20 groups based on the values (CAI\*10000, intervals of 10), and calculate the average pseudo-reflectance for each group (fig. 4).
- (c) Assuming the least CAI value to indicate the area of no stubbles set the pseudo-reflectance of such area to be 1 and normalize the pseudo-reflectance.
- (d) Construct a correction curve for each band (126 bands in total) using the normalized pseudo-reflectance. The obtained correction curves can be approximated by the quadratic curve (Fig.5).

As a result, if CAI is given, we can find how many folds the observed pseudo-reflectance for each band is increased compared to the soil pseudo-reflectance by applying the CAI value to the correction curve of respective band. We then estimated the pure soil pseudo-reflectance by performing the inversion.

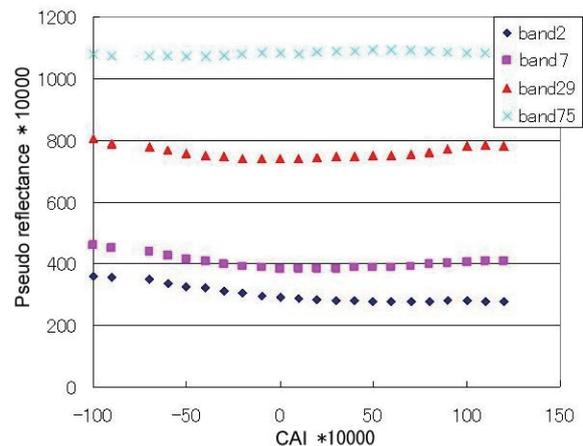


Figure 4. Relation between CAI and Pseudo-reflectance

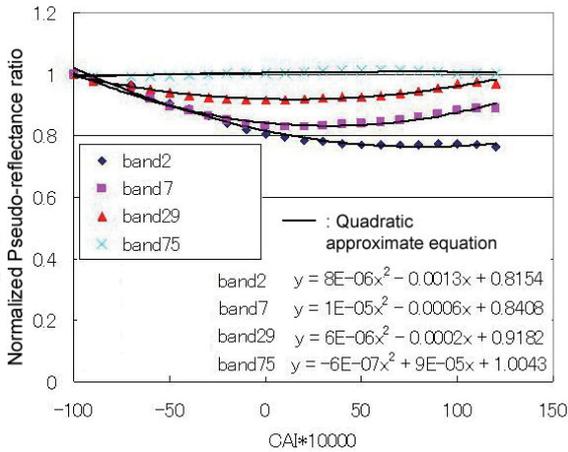


Figure 5. Correction curve using the normalized pseudo-reflectance

### 3. RESULT

#### 3.1 Validation of pseudo-reflectance method

We validated the results with the spectral data acquired from an ASD FieldSpec at the Mullewa wheat area of WA in Australia from February to March 2010.

Spectral profiles obtained in the area without and with the impact of stubble shadow are shown in Figures 6 and 7, respectively. Pure soil and pure dry vegetation spectra were obtained from field measurements. While the spectrum in Figure 6 could be derived from two end-member spectra, soil spectrum and dry vegetation spectrum, it was impossible to determine the obtained spectrum under the influence of shadow from any combination of mixture of the two-end member spectra as demonstrated in Figure 7.

In contrast, by using the pseudo-reflectance, a spectrum almost consistent with the observed pseudo-reflectance profile was obtained by combining the soil and dry vegetation end-member data (Fig. 8) because the effect of shadow at the time of data acquisition could be neglected. The spectral form for 60% dry vegetation cover matched the actual spectrum as shown in Figure 8.

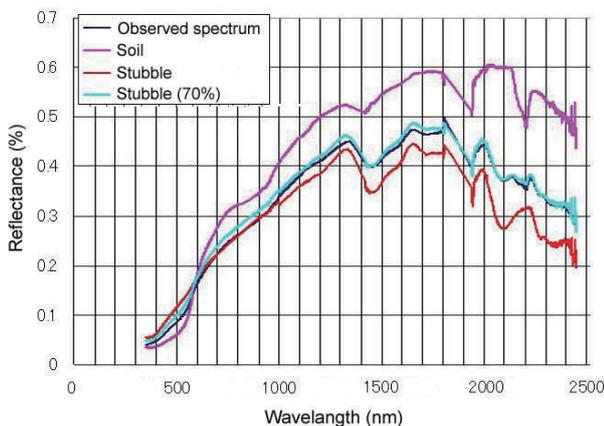


Figure 6. Reflectance obtained in the area without shadow effect of stubble

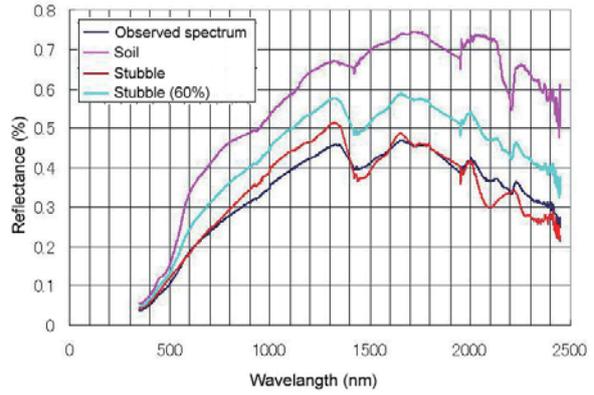


Figure 7. Reflectance obtained in the area with shadow effect of stubble

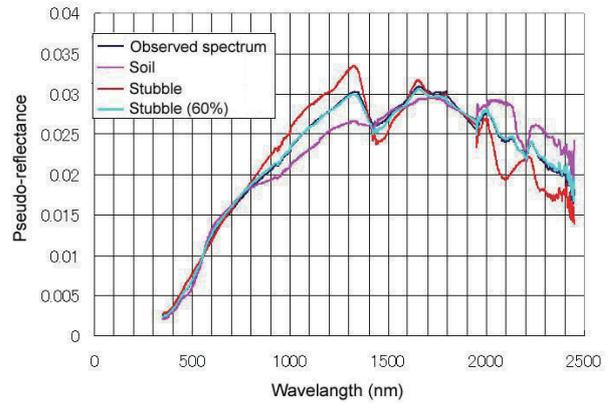


Figure 8. Pseudo-reflectance calculated using same data as fig.7

#### 3.2 Validation of the method to reduce vegetation effects

We validated the results of the method to reduce vegetation effect using ASD FieldSpec data. Measured spectrum of soil and stubble mixture is shown in blue color in Figure 9. Pure soil spectrum measured on the ground is shown in red color. And estimated pure soil spectrum is shown in yellow color. Estimated spectrum profile corresponds with measured one, except for VNIR region (0.6-0.9  $\mu$  m). Especially at the wavelength over 2  $\mu$  m where is important for mineral estimation, the profile of pure soil spectrum is well estimated.

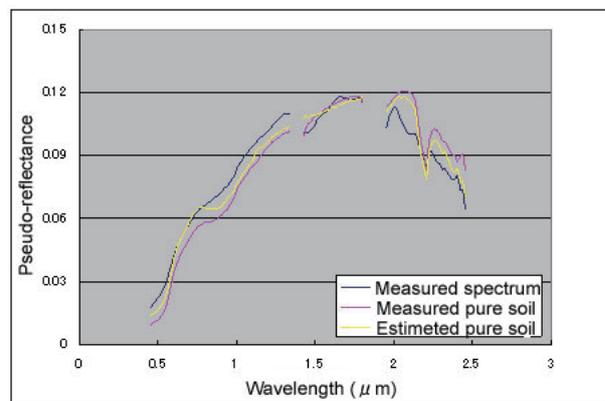


Figure 9. Estimated pure soil spectrum and measured pure soil spectrum

### 3.3 Estimation of soil property

Clay minerals were estimated using the corrected pseudo-reflectance. Total clay content data were available from the field sampling in Toolibin in November 2009, and we examined the correlation between the absorption depth at 2200nm and clay content in this study.

Figure 10 displays the relationship between total clay content and the absorption depth at 2200nm of pseudo-reflectance data after green and dry vegetation corrections. Meanwhile, the relationship between total clay content and the uncorrected data, or the absorption depth at 2200nm of the continuum removed reflectance data, are shown in Figure 11. Correlation was found in Figure 10 (corrected data) except for four points in dried-up lake (red points in Fig. 10 and 11), but no correlation was observed even for other points than the four points in dried-up lake in Figure 11 (uncorrected data) with a very poor  $R^2$  of 0.1561. Comparison of these results demonstrated the effectiveness of the method using the pseudo-reflectance by green and dry vegetation corrections. Two possible reasons considered for the lack of correlation for the lake points were distribution of different vegetation from the surroundings such as Common Glasswort, and the potential unavailability of accurate total clay content estimation due to different clay mineral types. Figure 12 shows the clay mineral content map created using the correlation equation derived from the corrected pseudo-reflectance.

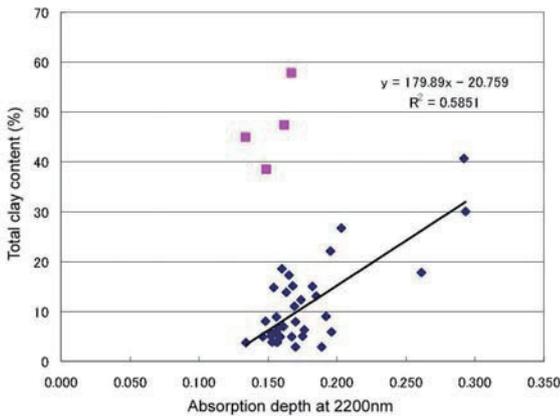


Figure 10. Relationship between total clay content and the absorption depth at 2200nm of pseudo-reflectance

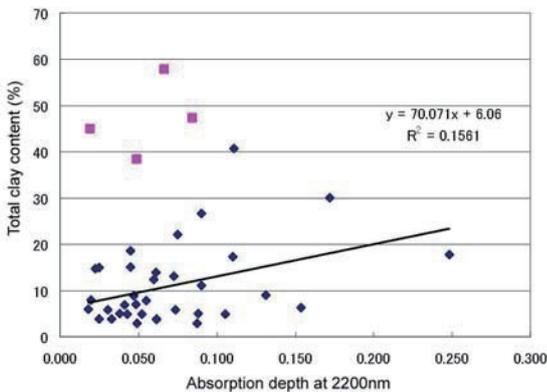


Figure 11. Relationship between total clay content and the absorption depth at 2200nm of reflectance (uncorrected)

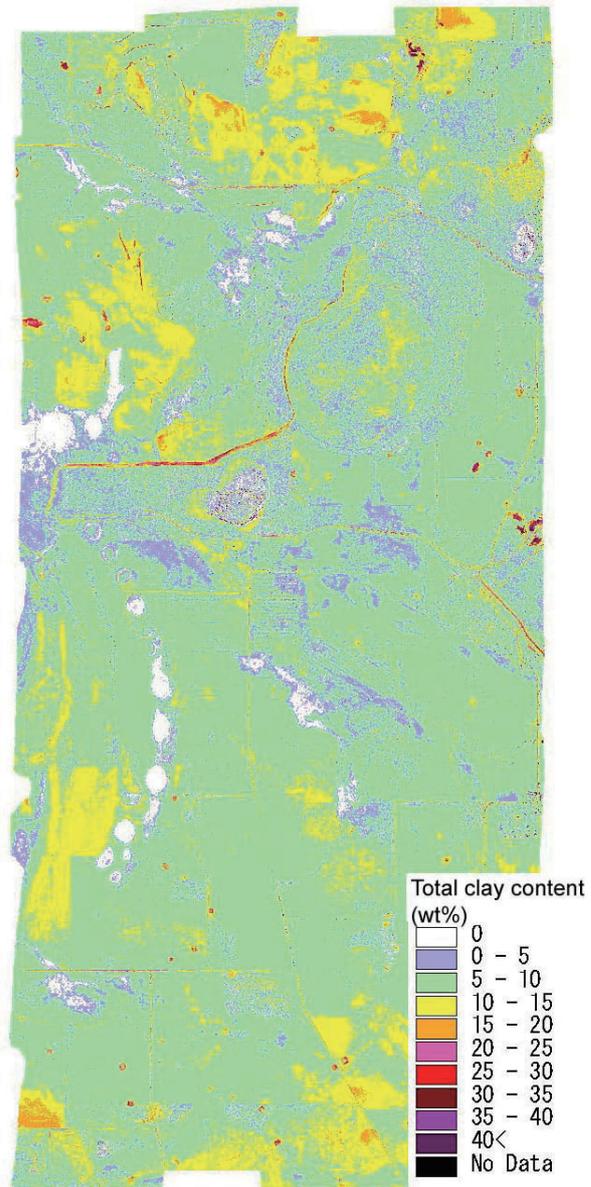


Figure 12. Total clay mineral content map

### 4. CONCLUSION

We proposed here a method to extract information using the pseudo-reflectance. This method is not affected by topographic relief, shadow, or soil/vegetation brightness. These differences do not appear in green vegetation correction curve or in dry vegetation correction curve, because SAVI and CAI are represented as green vegetation impact and dry vegetation impact, respectively. For this reason, green vegetation correction amount can be uniquely determined from SAVI of the obtained pseudo-reflectance. Similarly, dry vegetation correction amount can be uniquely defined from CAI of the obtained pseudo-reflectance. And extracted spectrum profile of pure soil corresponds with observed spectrum.

This method assumed that each of green and dry vegetation in the study area was represented by a respective single pseudo-reflectance profile. However, plant species vary by region and the pseudo-reflectance of vegetation changes to a certain degree.

This variance leads to the estimation error in determining the soil pseudo-reflectance. Whether this error is within the acceptable range or not in estimating the soil properties needs to be investigated in the future.

The soil pseudo-reflectance can be estimated from the impact of green vegetation and dry vegetation pseudo-reflectance if they are estimated accurately. The reflectance shows some variation in reality even for homogenous vegetation areas, and the estimated soil pseudo-reflectance becomes inaccurate in the case of increased vegetation cover. This error should also be examined to determine the upper limit for the soil pseudo-reflectance estimation.

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