Automatic Identification of Soil Spectral End-Members from multi-temporal MODIS Imagery in the Western Australian Wheat-Belt

Andrew P. Rodger[1], Graciela Metternicht[1], Henry Smolinski[2] and Greg Beeston[2]

[1] Curtin University of Technology & the CRC-SI, Email arodger@agric.wa.gov.au, g.metternicht@curtin.edu.au
[2] Department of Agriculture Western Australia & the CRC-SI, Email hsmolinski@agric.wa.gov.au, gbeeston@agric.wa.gov.au

Abstract

Using remote sensing data to estimate a fractional vegetation cover requires knowledge of the surface(s) under consideration prior to the analysis taking place. To partially overcome this, a soil spectral library (SSL) of representative soils (e.g. soil end-members) of the WA agricultural region is being constructed. The SSL will be used to model the most likely textural soil type occurring at a given location, based on a comparison of multi-temporal imagery, acquired by the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor on board the Terra and Aqua satellites, and the SSL. An assessment of the approach, presented herein shows that, when combined with a predefined tolerance level, the ability of the proposed method to find soil end-members within the MODIS imagery is possible. It is stressed that the results presented herein represent those of an initial study and that further validation is still required.

Key Words

MODIS, End-member, Soil, Temporal, Spectral, Automated

Introduction

To perform a fractional vegetation analysis the individual surfaces within a MODIS pixel are assumed to be linearly mixed (Settle, 2006). Applying spectral unmixing techniques (Bateson et al, 2000; Haertel and Shimabukuro, 2005) to MODIS spectra allows their respective fractions within the pixel to be estimated. Estimating surface types and fractions in this manner, requires the availability of a spectral library of possible surface types to be encountered. This library is called an end-members library, and contains spectra of individual surfaces. In the agricultural region we make a broad generalization, which states that in a MODIS pixel, covering a cropped area, at some time during the year, the surface is dominated by soil (before seeding and early crop emergence). Although the crops for a given pixel may change from year to year, the soil surface texture is assumed to remain the same. By comparing time-series of MODIS spectral reflectance against a soil's spectral library, it is possible to locate the MODIS spectra that most likely represent a specific soil textural type.

MODIS Data, DAWA Ancillary Property Data, and the Soil Spectral Library

Daily MODIS collections over Western Australia are downloaded and processed to surface reflectance by the Department of Land Information (DLI). The Department of Agriculture Western Australia (DAWA) then downloads the DLI supplied data to an internal storage area. Property boundary data at the DAWA are used to subset individual farms from the MODIS data. The soil spectral library (SSL) is being constructed from representative soil types of the Western Australian agricultural region. Though the SSL is still under construction, a number of representative soil samples have already been collected, including black, yellow, and grey/white sandy soils, red clay, gravel, loamy sand, and sandy clayey soils.

Method

With the MODIS, and ancillary data in place, the approach is implemented as follows:

1. A property of interest is selected and the pixels subset from the available MODIS imagery.

2. At pixel (x,y), at date (t) each MODIS reflectance spectra (ρ_M) is differenced with the SSL reflectance spectra (ρ_{SL}) (1 to L spectra), and the mean sum of the squared differences $\Delta(t,x,y,l)$ calculated over the first 5 MODIS bands.

$$\Delta(t,x,y,l) = \sum_{l=1}^{L}\left(\sum_{n=1}^{5}[\rho_M(t,x,y,\lambda_n) - \rho_{SL}(\lambda_n,l)]^2 \Big/ 5\right) \tag{1}$$

3. At location (x,y) the smallest value of $\Delta(t,x,y,l)$ is identified as being the most likely soil spectra. The MODIS reflectance for pixel (x,y), the corresponding date t, and the value of $\Delta(t,x,y,l)$ is stored.

4. A final threshold value is applied to $\Delta(x,y)$ to account for false-positives.

Reflectance Spectra Normalisation

Since similar or same soils, can have different reflectance magnitudes when viewed under differing conditions the reflectance spectra are normalised (see Eq 2.) in an attempt to remove wavelength independent offsets. Spectral normalisation assumes the differences between any two soil spectra, of the same soil type, are proportionally constant across different wavelengths.

$$\rho_N(\lambda) = \rho(\lambda) \Big/ \sum_{i=1}^{5} \rho(\lambda_i) \tag{2}$$

Only the first 5 spectral bands (459-1250 nm) used due to spurious data corruption in some of the MODIS band 6 data.

Results

The results shown in Figure 1 correspond to a property in the WA agricultural region and highlight the ability of the AUTOSEM to separate and identify differing soil types. Figure 1 shows AUTOSEM spectra selected, a RGB composite, and a broad image classification of the selected property. The spectral curves mostly represent different soil textural types, with a small number of spectra showing chlorophyll features at approximately 550 nm.

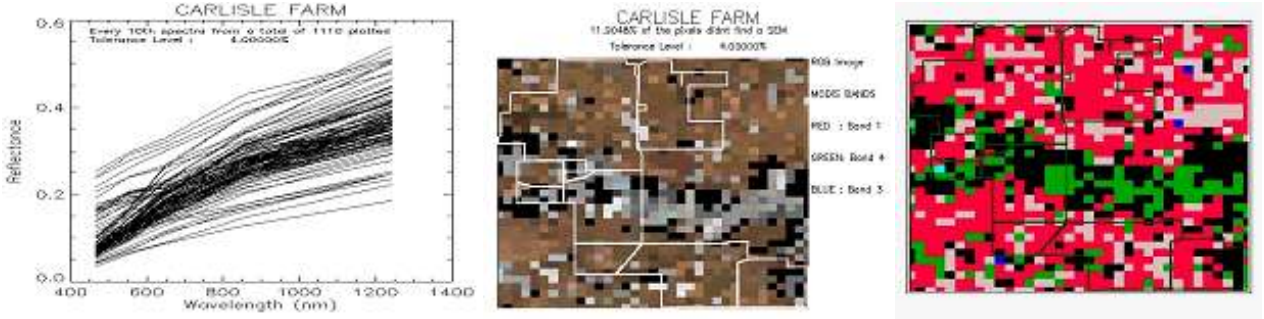

Figure 1. The left hand plot shows the MODIS reflectance spectra selected by the AUTOSEM as being the most likely soil spectra. The central plot is a RGB colour composite of the AUTOSEM selected spectra (note the river running through the middle of the property). The right hand figure is a classified MODIS image using AUTOSEM, where MODIS spectra is matched to the closest spectral library (green is sandy soils, red/pink is clayey soils).

To validate the AUTOSEM results in the absence of in-situ soil spectra corresponding to the months on which MODIS spectra were collected, the AUTOSEM (figure 2a) results are compared against the NDVI time-series of the property (figure 2b). The results show the AUTOSEM selected spectra as primarily coming from the months of November and December while the NDVI time series shows that during theses months the NDVI was close to zero, thus indicating minimal vegetation cover. The AUTOSEM does not currently narrow the date range, but by using NDVI time traces it will be possible to reduce computing overhead and processing time by limiting the search to months in which the NDVI is minimal.

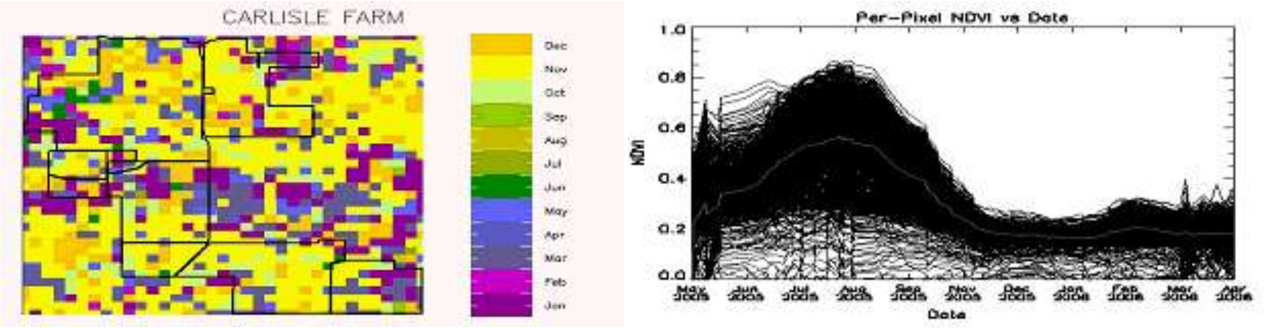

Figure 2. The months corresponding to the AUTOSEM selection (left), and a NDVI time trace of the property (right). The AUTOSEM months correspond well with the minimum NDVI values of the NDVI time trace.

References

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