Mineralogy, Pedology and Remote Sensing: A Multi-scaled Approach to Potassium Deficiency Risk in California Vineyards

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Objectives

1. Develop and modifying map of benchmark sites on landscapes for sampling.
2. Collect soil samples, characterize, and measure reflectance within stratified landscapes of Woodbridge-Lodi Wine Grape District (WLWGD).
3. Analyze spectral data and compare to collaborators' x-ray diffraction and potassium fixation analyses.
4. Classify images, when available, by applying spectral models within GIS-stratified images of WLWGD and Carneros District.
5. Additional soil characterization with validation samples collected within image classes.
6. Analyze spectral data of validation samples, refine spectral predictive models for minerals and potassium fixation.
7. Repeat image classification in both districts with refined models.

Objectives 1 to 3 were addressed in 2007 with objectives 4 to 7 to be addressed during 2008 through acquisition of hyperspectral images of the wine districts. The results to date have demonstrated a spectral relationship to the minerals within the geomorphic regions and the predictive ability of mineral spectroscopy for potassium fixation.

Approach and Procedures

Collaborators O'Geen, Pettygrove, Southard, and Minoshima modeled the landscape according to the response of soil to the K-fixation potential within the Lodi-Woodbridge study sites. These sites were separated into five geomorphic positions: a) young terraces composed of fine texture, b) young coarse texture soils, c) Old lower terraces, d) Old higher terraces, and e) volcanic parent material. X-ray diffraction (XRD) (Minoshima, personal communication, December 2007) and mineral spectroscopy (Ben-Dor et al. 1999; Mustard and Sunshine 1999; Whiting et al. 2005) techniques were used to identify the minerals in soil surfaces and profile horizon samples. Multivariate modeling estimated the amount of vermiculite, the principal mineral responsible for K-fixation.

Results

Mineral light absorptions determined the various amount of smectite, kaolinite, illite, and vermiculite minerals within the soil samples by the band-depths (Clark and Roush 1984) at characteristic absorption centers in the short wave infrared (SWIR, 1,200 to 2,500 nm) reflectance region (table 1 & fig. 1a). The presence and absence of the minerals were

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independently shown in the XRD intensity values (fig. 1b). A comparative analysis of the XRD and spectroscopy supports a geomorphic stratification into two classes: 1) young fine and coarse texture, and 2) old lower-higher terraces and volcanic parent material. Thus, two models based on the geomorphic stratification were utilized to identify significant factors in the clay-size fraction of soil using stepwise linear regression. Furthermore, stepwise linear regression analysis of vermiculite band-depth (apportioned to clay-size fraction) was highly correlated to K-fixation analysis in class 1 sample sites (fig. 2), while there was no correlation in class 2 sites due to the lack of vermiculite minerals.

Discussion

Stratification of the study sites by age and position geomorphology improved the estimation of mineral abundance. Since there was such a clear distinction between the classes in potassium fixation as well as the lack of vermiculite mineral, as identified by XRD and spectroscopy, the elimination of class 2 sites from the regression models reduced the number of zero fixation samples.

Within image and field spectral measurements, the soil contains various amounts of clay mineral and moisture, which reduces the contrast of the vermiculite adsorptions. Unlike most mineral spectroscopy of oven-dried pure clay fractions, this study demonstrates the utility and accuracy of absorption band-depth measurements for predicting K-fixation of air-dried soil. It was necessary to account or apportion the vermiculite abundance using band depths to the amount of water and clay fraction within the soil. In this preliminary analysis using a sequence of two multiple regressions, we demonstrated the capability of combination of band depths for water, secondary clay minerals and vermiculite to estimate the vermiculite contents more accurately. The methodology and results of the study to date lends promise to improving the precision of identifying K-fixation potential within the landscape model using hyperspectral imagery of bare dry soil.

During the second half of the project funding, the spectral models will be refined with the application of the models to available hyperspectral imagery. The imagery has lower spectral resolution (10 nm from 1 nm), with high spatial resolution of 4 m for mapping the vermiculite abundance and K-fixation potential. The robustness of K-fixation prediction will be determined by additional analyses of field and imager spectral data and soil samples in the Carneros regions of southern Napa County.

GIS modeling provides a tool to improve the perspective on spatial sequences and generating recommendation models. Remote sensing can increase the precision in soil management. The Kearney Foundation Mission recognizes this pattern in anticipating the ability to model soil behavior and functions from the sample locations and upscaling to predict successful management practices over field and regional areas. Output maps of the surface mineral contents should improve site-specific farm management and our understanding of the productive behavior of soil.
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References


Table 1. Absorption centers in the short-wave infrared (SWIR) for minerals in the study areas.

<table>
<thead>
<tr>
<th>Mineral Species</th>
<th>Absorption center (µm)</th>
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<tbody>
<tr>
<td></td>
<td>Primary</td>
</tr>
<tr>
<td>Quartz</td>
<td>Flat Line</td>
</tr>
<tr>
<td>Montmorillonite</td>
<td>2.200</td>
</tr>
<tr>
<td>Kaolinite</td>
<td>2.200</td>
</tr>
<tr>
<td>Illite</td>
<td>2.230</td>
</tr>
<tr>
<td>Vermiculite</td>
<td>2.320</td>
</tr>
<tr>
<td>Serpentine</td>
<td>2.320</td>
</tr>
</tbody>
</table>

Figure 1. (a) Continuum removed reflectance of two soil samples with kaolinite, smectite, and vermiculite minerals, and their characteristic absorption centers in the SWIR; (b) Continuum removed and smooth X-ray diffractogram of the clay size fraction of soil sample 3-3 that identified the kaolinite, smectite, and vermiculite minerals (Minoshima 2006).
Figure 2. K-fixation potential versus estimated abundance of vermiculite mineral by multivariate analysis for class 1.

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