1999 BigFoot ETM+ Analysis: AGRO Land Cover and LAI

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1. Purpose

The purpose of this analysis was to produce 1999 land cover and leaf area index (LAI) surfaces for the AGRO site from ETM+ imagery.

2. Study Area

The core AGRO study site is a 5x5 km area centered on UTM coordinate 389764, 4328742 (zone 16 north) near Bondville, IL, USA. The study area is a midwestern cropland dominated by corn and soybeans, with additional cover types consisting of barren land, urban, residential homesites, water, and road networks.

3. Data and Preprocessing

An ETM+ image dating from July 29, 1999 was used in the analysis. This source image was acquired from the MODIS Land Team Validation website (http://modarch.gsfc.nasa.gov/MODIS/LAND/VAL/). Source image characteristics include level 1G processing, a cell size of 30 meters, and UTM (WGS84) projection.

The COST radiometric correction model (Chavez, 1996) was applied to convert the source image digital counts to reflectance. Pixels falling in deep cloud shadow were found to be the darkest scene elements. These pixels were used as dark objects in the radiometric calibration algorithm, and were assumed to have 2% reflectance based on published estimates of shadowed vegetation reflectance (Adams et al., 1995; Hall et al., 1995).

The positional accuracy of the image was assessed by direct comparison with USGS digital orthophoto quadrangles (DOQ’s) in a 9x9 km area centered on the AGRO study site. A systematic, local shift of -37.5 meters in the x, and -127.5 meters in the y was applied to lock the ETM+ image directly to the DOQ’s. The reflectance image was then cubic convolution resampled to 25 meter resolution, and clipped to a 7x7 km area centered on the AGRO site. The 7x7 km area was chosen to provide a buffer for subsequent comparisons with 1 km resolution MODIS terrestrial ecology products.

Land cover calls and LAI measurements that were collected by the BigFoot field effort on July 27, 1999 were used as reference for image analysis (http://mercury.ornl.gov/servlet/ornldaac). Additional reference consisted of the DOQ’s, 1:12,000 scale aerial photography, and ground reconnaissance performed by the BigFoot remote sensing group in the summer of 2000.

4. Methods and Results

Land cover mapping was performed using an unsupervised clustering of the six ETM+ reflectance bands in the 7x7 km analysis area. A K-means approach was used, with 30 clusters being initialized along the principal axis of variation within the six-dimensional reflectance space. The algorithm produced a set of 30 stable clusters, with a 98% convergence rate over the course of 20 iterations.

Clusters were assigned to five classes: water, urban & built, barren & sparsely vegetated, corn, and soybean (figure 1). This assignment was performed with reference to the DOQ’s, air photos, interpreter knowledge, and spectral characteristics examined in bivariate frequency distributions. Crop types noted in the 1999 field survey were not used to label clusters, but were reserved exclusively for subsequent error characterization. Some confusion was apparent in the cluster map, most notably between the urban & built and barren & sparsely vegetated categories. Additionally, minor confusion within crop types occurred, for example where localized drainage features reduced the separability of soybean from corn in more moist (lower
Validation of the classification was limited by the small number of cover types sampled during the 1999 season, a situation which has been rectified for subsequent analyses at the site for 2000 and 2001. A total of 100 observations were collected across three cover types: corn (n=67), soybean (n=31), and urban/built (n=2). However, the majority of these observations occurred within only a few discrete areas (i.e., fields, residential units). To minimize pseudoreplication and spatial autocorrelation, a single validation point was selected at random from within each distinct cover type area. The final validation set consisted of the following breakdown: corn (n=8), soybean (n=7), and urban/built (n=1) (table 1).

<table>
<thead>
<tr>
<th></th>
<th>Urban/Built</th>
<th>Corn</th>
<th>Soybean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban/Built</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Corn</td>
<td>0</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Soybean</td>
<td>0</td>
<td>1</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 1. 1999 AGRO land cover classification error matrix.
LAI modeling was stratified between the corn and soybean crop types. A canonical correlation analysis (CCA) was performed, producing a multispectral LAI index for each of the two cover types (Figure 2). The LAI indices were then used as predictors in a traditional linear regression context to generate predictive models for corn and soybean leaf area index (Table 2). Due to the small number of LAI measurements in corn (n=48) and soybean (n=18), all available samples were used to build the regression models.

![Figure 2. Standardized ETM+ loadings derived from CCA for AGRO 1999 LAI modeling.](image)

<table>
<thead>
<tr>
<th>Regression Model</th>
<th>n</th>
<th>R²</th>
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<tbody>
<tr>
<td>Corn</td>
<td>48</td>
<td>0.25</td>
</tr>
<tr>
<td>7.69 - 0.73 * corn LAI index</td>
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<td></td>
</tr>
<tr>
<td>Soybean</td>
<td>18</td>
<td>0.6</td>
</tr>
<tr>
<td>4.05 – 0.9 * soy LAI index</td>
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Table 2. Regression summaries for corn and soybean LAI models.
The ETM+ data were transformed using the corn and soybean CCA loadings, and the appropriate regression equations were applied to produce the corn LAI (Figure 3) and soybean LAI (Figure 4) surfaces.

Figure 3. 1999 AGRO corn LAI surface, 7x7 km area.

Figure 4. 1999 AGRO soybean LAI surface, 7x7 km area.
Estimates of error in the regression predictions were obtained using cross-validation. That is to say, an independent prediction for each observation was calculated by applying a unique regression equation generated after leaving that observation out of the sample (Efron and Gong, 1983). This technique provides a reasonable estimate of prediction error when a small sample size makes data splitting impractical (Neter et al., 1989).

Figure 5. Cross-validation results for 1999 AGRO corn and soybean LAI modeling.

References


