Land Use and Land Cover Mapping for Watershed Scale Evaluation of Agricultural Practices

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INTRODUCTION

Increasing sensitivity to water quality issues stemming from agricultural production prompted an 80% increase for conservation programs in the 2002 Farm Bill. Many of these programs are focused on watershed level model implementation and require detailed data of hydrology, soil, weather, land use and land cover (LULC). Most models require more specific land use descriptions other than simply "agriculture" or even additional classifications such as row crop, truck crops, or confined animal operations. As an example, row crop can be categorized into cotton, corn, peanuts, etc. and are often the level of detail required by most models. The ability to quantify ground cover is an attribute that many models may also require. The availability of such detailed data at the proper time scale is limited at best.

There are several crop classification data sources where crop spectral signatures have been developed from satellite imagery such as LandSat Multi-Spectral System or Thematic Mapper systems. Spectral signatures from these are suitable for row crop mapping at regional scales. However, these systems do not describe the degree of ground cover, rather only how it is used. Cover is a direct reflection of the current crop condition in a parcel of land under a normal annual cycle. Most satellite systems lack the ability to track the degree of crop or residue cover. This is mainly due to the resolution of images (15 to 30 m) where intense soil reflection overrides any return from a young crop or dead vegetative debris. The ability to develop such data at a watershed scale on a monthly basis would require an imaging system with sufficient ground resolution and rapid turn around time.

In this study the FRWP&PC provides aerial imagery to SEWRL in digital mosaics of selected drainage basis in the Little River Sub-Basin in South central Georgia (Figure 1). This is the first of a multi-year study in which not only timely crop classifications are produced but also evaluations of crop or debris cover. The components of this project are the data acquisition, image processing, and collection spectral signatures.

Figure1. Little River Sub-Basin with research sub-watersheds in black

OBJECTIVES

1. Determine photogrammetry processes necessary in image processing in a production environment
2. Develop methods for creating monthly and semi-monthly LULC from airborne imagery
3. Develop a library of spectral signatures

MATERIALS AND METHODS

Imagery is collected using Spectra-View®, a multi-spectral digital system (Figure 2). It consists of four digital cameras, Inertial Measurement Unit, Differential Global Positioning System, and controlling computer. Each camera collects reflective radiation in a specific wavelength by utilizing a filter over each of the 12.5 mm lens (Figure 3). A "scene" consists of these four images and is saved as a single RAW file. An associative header file is also created and is a collection of navigational and aircraft attitude information at the time of scene acquisition. These data are stored in an on-board removable hard drive. The drive is transferred to the FRWP&PC for image download and processing.

Missions average once a month with two missions in April and May. Each mission is flown to yield one meter ground resolution, 60% front and rear overlap, and 40% side overlap. Missions coincided with SEWRL ground truth windshield surveys.

Processing of the imagery requires two software products. Band Match® is used to align the four bands and export to a geo-referenced Tagged Image File Format (GEOTIFF). Band Match® does a degree of rectification by reading aircraft roll, pitch, and heading information from the header file. Leica Geosystems ERDAS Imagine® is used to judge rectification and mosaic the images. Image distortions are corrected using1999 Digital Ortho-Photographic Quarter Quadrangles as a ground reference This is the most time consuming process.

Spectral Band Wavelength (ηm)

Color	Filter	Range
Blue	460	± 20
Green	560	± 25
Red	660	± 25
Near Infrared	870	± 100

Figure 2. Aerial imaging system consists of the SpectraView® system and a Maule MX-7 aircraft. The system allows for multiple ground resolutions ranging between 0.25 and 2 meters. Such a system allows for quick missions at anytime when conditions are favorable.

Mosaics are used as a source of spectral signatures from "objects" on the ground. Initial signatures are being derived using the Signature Editor in ERDAS Imagine®. Signatures are extracted by plotting feature space where values of two bands are plotted against each other (ratio) creating a scatter plot. Areas within the scatter plot are selected where the spectral values correspond to a selected ground object. The signatures are associated with ground truth data collected in the field and stored in a library of spectral signatures for types of crops, trees, bare soil, and residue cover.

RESULTS AND DISCUSSION

The time required to produce ortho-photographic mosaics on the scale of these study areas, over 8,000 acres each, is contrary to a rapid turn around in LULC data production. Reasons are the specifications of the imaging system itself. The footprint of each image is too small due to the 1024x1024 (9 ηm pixels) sensor despite the 12.5 mm lens. The current watersheds require 450 scenes for one mission. Best estimates of production time for near ortho-photographic quality are 200 scenes per work week. The SpectraView® system was not designed to produce fully ortho-photographic images due to the lens curvature and variances in the Inertial Measurement Unit. Precise production is feasible with single farms or fields. This is the true advantage this system. It offers the ability to quickly collect LULC data for small areas. However, for larger areas such as watersheds other options should be investigated.

The imagery collected from the SpectraView® system is extremely useful if another approach in data development is taken. If field boundaries are available, each field can be classified as to its current crop and/or cover by selecting the dominant spectral signature from the imagery. This approach does not require the intense rectification process and can cut mosaic production time to 16 to 24 hours for a 450 scene mosaic. This approach it assumes homogenous cover conditions within the field boundary. This may not be suitable for cover evaluations. The differences in rectification can be seen in Figure 3.

Image A is shows both idle fields (cyan) and active winter cover (magenta). During idle periods previous cropping patterns can be noted in some of the post harvest fields by darker bands from debris. This is also an indication of the BMP such as conservation tillage. Images B and C in Figure 3 contain examples of how crop signatures change within a growing season. One of the problems with using imagery is that despite an actively growing crop it will not be spectrally unique until the canopy has developed enough to influence the signature of the soil. This is the same issue with satellite imagery but scale allows a more precise measure and detection. With many crops there are always "holes" in the field. Holes can be due to too much or insufficient water, disease, or even lightning strikes. This is shown in image C in field "b" where there is water damage in the western portion of the field. No-till BMP shows in fields labeled "c". This is evidenced by the active winter cover in January, the dead vegetation in early May and crop signatures later in the growing season. The post harvest debris was also noted in D.

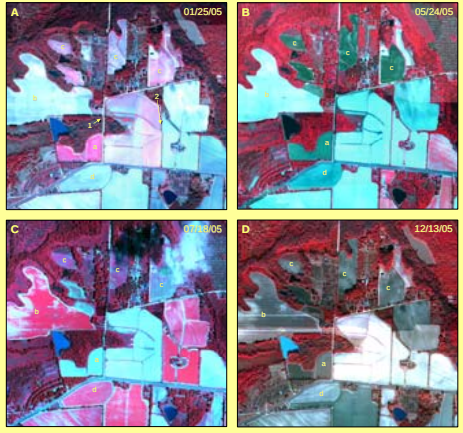

Figure 3. Comparison of speed versus accuracy. Image A is part of a minimally rectified mosaic. Note the offsets at numbers 1 and 2. Image D is a more intensely rectified mosaic. Image B shows cotton field "b" being mowed and peanut field "d" under irrigation. In January field "a" is under active growth, winter cover, while it is fallow in December. Images B and C illustrated the influence crop canopy cover on crop signature. Fields that appear to be bare in May return the crop spectral signature once a canopy develops.

Feature Space is a method of classifying images using the band ratio approach. Some success has been achieved in separating distinct crops and more importantly in sub-dividing ground cover. The images suggest two types of ground cover one where bare soil is covered by dead vegetative debris or actively growing crop. Figure 4a show a typical feature space plot of bands 3 and 4 (red and near infrared). Areas are delimited on the scatter plot that coincide with the spectral values that occur in the image. Values in these areas are stored in the library and use for classification. The resulting classification shows bare soil with debris (lightest greens) and the active vegetation (reds and browns). This classification has yet to separate dense peanuts from thin cotton and dense cotton from scrub vegetation and some trees.

The other aspect of this study is the quantification of debris over bare soil. Classification of the current data is possible when using the NIR band in association with other bands. Only then does the bare soil separated into classes. Classification with bands 1, 2 and 3 yield little variation on bare soil because these bands values are at the maximum of the imaging systems capability. Regardless of this there are distinct differences in the cover in these bare areas (Figure 4) and can be use in developing signatures. Work continues on developing these signatures to refine the crop signatures and include other LULC categories.

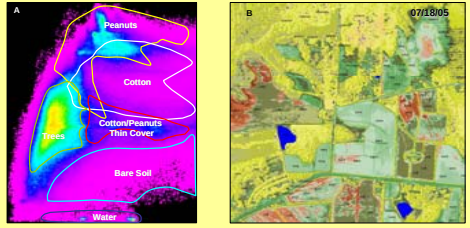

Figure 4. Graph A is a feature space plot of bands 3 and 4 with some values isolated as to crop signature. As the color moves from magenta to blue to yellow to red the number of values with that band e and band 4 combination increases. Note the overlap in some classifications. Image B is a product of the feature space. Light green areas are either bare ground with some cover. Darker green are peanuts, Olive green is cotton. Yellow s are trees and scrub, Red and brown areas are completely bare soils in active growth areas.

CONCLUSIONS

This approach to rapid development of LULC data has proven to be challenging in many respects. With regard to the imaging system, it is suggested that such an approach is feasible with modifications. The most important of these is the use of a larger sensor and longer focal length lens. Simply changing the senor size to 2048x2048 can drop the number of images to process by 75%. Longer focal length lens would reduce degree of rectification where automated processing would be possible and provide ortho-photographic quality. Missions could be changed to reduce the amount of forward/rear overlap but this would limit the mosaic process by reducing the area available for seams and would possibly create "holes" of missing data that are gaps between scenes.

Developing spectral signatures of LULC objects is currently underway. Results show great potential for mapping crops and ground cover. Some modification were made in the 2006 missions to compensate for the "over exposure" of bands 1, 2, and 3 in bare soil. This will change the band ratio and force additional development of signatures. Regardless of these issues, the ability to classify the imagery into LULC including crops and ground cover will greatly aid in the next portion of the work where data are linked to surface water quality samples.

From these data one can see many potential uses. The most obvious is mapping of crops for statistical purposes. One such potential use is to develop an evaluation system for crop damage due to drought or too much water. This system could be used as an evaluation of BMP in specific areas.

Future work include the processing of the 2006 imagery and acquiring the 2007 imagery. This include processing and classification. SEWRL will also link the LULC and cover data from these images to the water data sampled with in the study watersheds.

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