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Distinguishing blueberry bushes from mixed vegetation land use using high resolution satellite imagery and geospatial techniques

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ABSTRACT

Blueberry orchards for commercial production are increasingly common in Georgia and other southeastern states. The blueberry bushes grow closer to the ground compared to pine trees and other forest plants. It is, therefore, difficult to distinguish blueberry bushes from other trees and shrubs in a farm scenario where tall grasses are abundant and pine trees are in close proximity. The goal of this study was to apply advanced image processing techniques with high resolution multispectral imagery to distinguish blueberries in mixed vegetation. We used high resolution 2.15 m multispectral QuickBird imagery along with high end image processing techniques to identify blueberry bushes of a small orchard, located in Pike County, Georgia. Principal component bands of multispectral QuickBird images, taken on May 22 and June 6, 2006, were classified using an unsupervised ISODATA classification technique and the WARD minimum variance method. Four classes, including forest, blueberry bushes, tall grasses, and cut or dwarf grasses were extracted from the classified images for ground truth and subsequent delineation of spatial cells that represented the blueberry bushes. For the image taken on May 22 the blueberry bushes were distinguished with a 53% producer's accuracy, a 100% user's accuracy, and a kappa statistic of 0.24. This low accuracy was attributed to mixture of the blueberry bushes and the tall grasses that were not cut when the image was acquired. However, the June 6 image proved to be more suitable for distinguishing blueberry bushes from the pine forest and grasses. The producer's accuracy was 100%, the user's accuracy was 94% and the kappa statistic was 0.65. Based on the results from this study it can be concluded that high resolution imagery and high end image processing techniques can be used to help distinguish mature blueberry bushes from a forest and grass land cover if the area is well maintained. The study also suggests that commercial or large scale blueberry orchards can easily be micro-managed with the use of remotely sensed images and geospatial technology.

1. Introduction

Site-specific crop management (SSCM) has become very common and is widely being used for precision management of maize, wheat, rice, cotton, soybeans, and other row crops (Casanova et al., 1998; Panda, 2003; Magri, 2005; Baez-Gonzalez et al., 2005; Lobell et al., 2005). However, precision agriculture for non-traditional crops, such as fruit crops, is still not very common. Fruit and nut crops, including peaches, pecans, apples, grapes and blueberries, are an important component of the agricultural production system, and they are high value crops for which precision management might have potential for increasing net returns and optimizing resource use.

Several studies have been conducted over the years to delineate or classify forests or shrubs from satellite and aerial Landsat images (Haapanen et al., 2003; Franco-Lopez et al., 2001; Li et al., 2000; Holmgren and Thuresson, 1998). However, very few studies have been conducted to distinguish orchards from a mixed forested land use. Remotely sensed images are a quick and sound means to access those fruit trees or orchards. Torres et al. (2008) conducted a study to distinguish olive tree orchards using remote sensing images by clustering assessment techniques. Scientists in the Space Application Center of the Indian Space Research Organization (ISRO) successfully used low resolution IRS LISS III and IRS AWiFS (23 m and 55 m, respectively) images to characterize apple orchards in India (Sharma and Panigrahy, 2007). O'Connell and Goodwin (2005) have used remotely sensed imagery to identify the tree canopy of a peach orchard to facilitate their study of forecasting orchard yield and crop water requirements. However, in all these cases, the authors worked with commercial or large scale orchards, which could easily be distinguished through remotely

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sensed imagery because of their homogenous nature in the land use map.

Remote characterization of orchards at a small farm scale and among forested land use is a challenging task. The challenges of distinguishing blueberry bushes in southern Georgia are of similar proportion. Blueberry is a high value crop that is produced by mostly small producers in Georgia and other southeastern states and the management of these blueberry bushes is one of their main concerns. It is postulated that remote sensing and geospatial technology could help blueberry producers with a more effective management. There is also potential for other applications, including regional landuse assessment or for crop insurance.

The application of high resolution remote sensing data, e.g., satellite imaging, along with Global Positioning Systems (GPS) and Geographic Information Systems (GIS) is the first step towards the goal of SSCM in fruit and nut crops (Sevier and Lee, 2005). Utilizing spatial data for decision making for a cultivated blueberry orchard can be a valuable tool for determining fruit yield, minimizing the applications of inputs, such as fertilizers and irrigation, while maximizing profits. Precision farming of blueberries would require plant canopy and leaf color and obtaining spatial soil samples for detailed analysis, as well as many other factors. As a preliminary step of this SSCM, it is essential to obtain plant vigor to be able to predict plant yield.

Blueberry is a wax-leaved shrub that grows closer to the ground compared to pine trees and other forest plants in the southeastern USA. However, the blueberry bushes grow above the wild grasses that are much closer to the ground. Blueberry bushes are known to be strong forward scatterers, where as soft-leaved dwarf shrubs are backscatters (Peltoniemi et al., 2005). At the same time, pines and other coniferous plants are both forward and backscatters. Thus, the total reflectance of a forest canopy is the combination of illuminated and shaded components of the tree crown as well as the background because of the bidirectional behavior of the forest canopy (Peltoniemi et al., 2005). With advanced image processing techniques and the use of high resolution multispectral imagery, it should be possible to distinguish blueberries from the mixed vegetation of tall forest trees and dwarf grasses or other small shrubs. Spectral signatures of blueberries suggest that the shrub has a very low reflectance as compared to forest trees and grasses because of its medium stature and because it mixes easily with the shadows (Rao, 2007). Blueberry is distinguishable at the 680–700 nm (Red) band width and the 800–900 nm (NIR) band width range (Peltoniemi et al., 2005; Rao, 2007).

To extract digital information from remote sensing images and to correlate this with crop precision management scenarios, one must use image processing techniques and build models (Panda, 2003). Image processing techniques generally involve classification and algebraic manipulation to determine the spatial variability in the image (Senay et al., 1998). High resolution images can contain an enormous amount of information and can, therefore, be computationally intensive when analyzed. Thus, it is desirable to reduce the dimensionalities of the image data while at the same time extracting relevant and significant information. This process could be challenging when dealing with images of agricultural fields that are mixed with the forest cover. Unsupervised clustering is one of the desirable techniques for image segmentation, because of its associated advantages (Eastman, 1999). Clustering, i.e., grouping data with similar characteristics is a data mining technique that has been used for several years to segment images and extract information about types of land use (Jain et al., 1999). Three visible bands, i.e., red, green, and blue, in multispectral imagery contain digital information about the land uses which differ significantly because each band has a different reflectance pattern. Therefore, it is essential to use all three bands to extract pertinent information about land use land cover types from remotely sensed images (Jain et al., 1999).

Since 1978, scientists working in remote sensing have argued that the vegetation dynamics can be detected with the red and infrared bands of the electromagnetic spectrum (Deering, 1978). However, vegetation such as shrubs can be easily distinguished with the green band along with the red band. In many cases, classified individual (R, G, and B) band images show poor classification accuracy because the data from all of the spectral bands involve a certain degree of redundancy (Fung and LeDrew, 1987). The principal component analysis (PCA) approach is one of the best techniques to analyze correlated multidimensional data so that all the multispectral band information regarding the vegetation reflectance would be intact (Byne et al., 1980). The iterative self-organizing data analysis (ISODATA) unsupervised clustering technique is commonly preferred over supervised classification methods for classification of images (Eastman, 1999). The unsupervised classification method overcomes the inconvenience of choosing training sites for a large number of images and makes the classification process simpler and less time consuming (Anderberg, 1973). The ISODATA classification technique along with the WARD minimum variance algorithm classifies the images with a high accuracy and is commonly used in precision agriculture (Dobermann et al., 2003). The objective of this study was, therefore, to use high resolution remotely sensed data along with advanced image processing techniques to distinguish blueberry orchards in mixed vegetation for site-specific crop management.

2. Methodology

2.1. Data acquisition and preparation for image analysis

Two sets of single scene QuickBird (Digital Globe Inc., Longmont, CO) multispectral (MUL) images were acquired on May 22 and June 6, 2006. An example of the raw false color composite (FCC) image for May 22, 2006 is shown in Fig. 1. The resolution of the MUL image was 2.15 m. The collected images were larger than the study area because the blueberry orchard covered only a few hectare. The images were geometrically corrected to the ground control points (GCP) earmarked in the area that covered the images. A radiometric correction was applied to each image after it was acquired by the satellite.

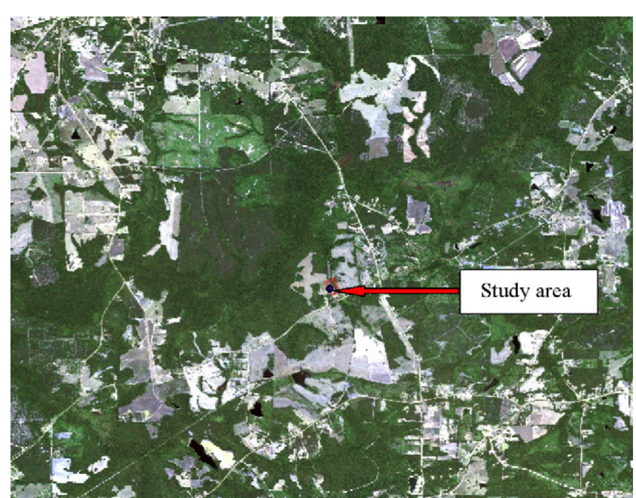

Fig. 1. False color composite (FCC) multispectral QuickBird imagery of the study area obtained on May 22, 2006.