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Estimating regional forest cover in East Texas using Enhanced Thematic Mapper (ETM+) data

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Abstract

The USDA Forest Service, through its Forest Inventory and Analysis (FIA) program, periodically estimates forest/non-forest area at the county level using aerial photographs. Satellite-based remotely sensed data and digital image processing techniques could substantially reduce the time required to generate this information. Satellites collect data on a repeat basis and with higher frequency than the aerial photos that are currently used for this purpose. In addition to the forest cover estimates, the USDA could use satellite data to generate maps depicting the spatial distribution of forest cover. However, few studies have tested the utility of medium-resolution satellite data for FIA purposes. We tested the potential for using LANDSAT satellite data to obtain forest cover estimates for a six-county region in East Texas. Satellite data were processed using a combination of image classification techniques that could be repeated in other regions of the USA. Results were compared with the results of traditional photo-based estimation techniques and were comparable within a 95% confidence interval. Based on this study we recommend that medium-resolution satellite data can be used for obtaining county-level forest cover estimates.

Keywords: USDA Forest Service; Forest inventory; FIA; LANDSAT; East Texas

1. Introduction

The US Department of Agriculture-Forest Service (USFS) has periodically estimated and published the extent of forest cover and timber resources in the United States as part of its Forest Inventory and Analysis (FIA) program (USFS, 1992; Frayer and Furnival, 1999; Reams and van Deusen, 1999). This information, published since the 1930s, is used by state forest agencies, private timber companies and individual foresters for planning and decision making. In addition to this, FIA results are used for assessing sustainability of forest management practices and predicting the effects of global change (USFS, 2004). The FIA program uses a variation of the double

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sampling method for collecting data about forest resources. In the first phase, points are placed on aerial photographs and are classified as either forest or non-forest. In the second phase, detailed information about forests is collected by visiting a predefined number of photo-points on the ground. The estimates obtained in the first phase are refined based on the ground information and standard errors are computed (McWilliams and Bertelson, 1986; Kelly et al., 1992; Hansen and Wendt, 1999; Reams and van Deusen, 1999). This information is used for periodically publishing statistical estimates of forest cover at the county level (Wynne et al., 2000; McRoberts et al., 2002).

Wayman et al. (2001) and McRoberts et al. (2002) summarize the limitations of aerial photographs for FIA purposes. Interpretation of the photos is a labor-intensive and time-consuming process. Photographs are expensive and cumbersome to handle, store and transfer. Also, obtaining current aerial photographs for FIA purposes is often difficult. Reams and van Deusen (1999) identified the inability to produce maps using county-level estimates. County-level estimates cannot be used to capture the spatial variability of forest cover within each county. In addition, it takes approximately 8 years for the FIA program to update estimates for the southern region (13 states, Puerto Rico and the Virgin Islands) of the US.

Satellite-based remotely sensed data in combination with semi-automated digital processing could reduce the time required to generate forest and non-forest estimates (Lannom et al., 1995; Cooke, 1999; Czaplewski, 1999; Wayman et al., 2001). Orbiting satellites collect data more frequently and regularly on a global basis than do aerial photography programs. Currently, satellites from the US (LANDSAT-http://landsat.usgs.gov), France (SPOT-http://www.spotimage.fr) and India (IRS-http://www.nrsa.gov.in, http://www.antrix.org) provide medium-resolution multispectral data. These satellites collect information in the green, red and infrared regions of the electromagnetic spectrum that is useful for discriminating vegetation. The current LANDSAT satellite (ETM+) developed an anomaly (Scan Line Corrector malfunction) in May 2003 that reduces its utility, but data from an earlier LANDSAT satellite (LANDSAT 5) are nearly identical in character and are still available for use. Plans are underway to include the next LANDSAT sensor in a NOAA satellite scheduled for launch in 2009. Should LANDSAT TM5 fail before 2009, data collected by the IRS and SPOT satellites could be used for forest estimation using methods similar to those described here.

In addition to forest and non-forest estimates, information about forests could also be produced from satellite data in a variety of formats including maps (Dymond et al., 2002). Among other applications, these maps could be produced at regular time intervals and would improve the spatial accuracy and precision of forest cover estimates, provide spatially explicit estimates of changes in forest cover and condition, fuel availability and wildlife habitat among others (Beaubien, 1994; Wayman et al., 2001).

The 1998 Farm bill recommended that the USFS and NASA work together to integrate satellite-based remotely sensed data for the forest inventory program. This bill also mandated that the USFS sample 20% of the plots in a state every year, a substantial increase in sampling density (Wayman et al., 2001). In addition, the FIA was one of several federal government programs reviewed by a study commissioned by the Office of Science and Technology Program (OSTP). One of the recommendations made by this study was to incorporate satellite data in general and LANDSAT Thematic Mapper data in particular into this process to reduce the dependency on aerial photographs for FIA purposes (Peterson et al., 1999).

In order for the USFS to incorporate satellite-based estimates into its FIA program, additional research is required to address the following issues: transferability of image processing and classification methods for other regions, sources of misclassification related to landscape pattern, and precision of the estimated area for each thematic class that incorporates uncertainty. Only comprehensive studies will enable the USFS to evaluate the usefulness of satellite-based estimates in comparison to traditional photo-based estimates. This paper describes such a study where the utility of LANDSAT data to map and estimate forest resources was tested in East Texas.

Satellite image processing and classification of forest resources involves assigning the pixels in the image to predefined forest types. Methods such as unsupervised or supervised classification or a combination of these two are available for grouping pixels into forest or non-forest classes (Lillesand and Kiefer,