

The Impact of Stand Identification Through An Object-Oriented Approach For Forest Management Planning*

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Abstract

Stand boundary identification is an important factor in forest management planning that is dependent on the quality and resolution of the imagery available. We identified stand boundaries on an area within the John C. Stennis Space Center using two sources of multispectral imagery, IKONOS and QuickBird. Forest stands were delineated using eCognition v3.0. Segmentation was performed by initially finding an algorithm to produce objects representing forest stands larger than ten acres. Once this parameter for the algorithm was found, additional parameters (color, shape, compactness, smoothness) were iteratively changed to replicate area estimation. Preliminary results show that main differences in images exist in forest boundary locations. Also, the range of forest stand sizes within the each image type exhibit the largest differences between the images. Future work, analysis of stand boundaries in a forest planning model, will need to be completed to assess the impacts of area estimation.

Key Words: Stand boundaries, area estimation, satellite imagery

Introduction

Technological improvements in data acquisition and management have provided better decision tools for planning forest management activities. One of these tools is remote sensing. Multispectral imaging, for example, can provide quick and accurate data acquisition of managed areas. Multispectral data can be obtained through airborne or space borne sensors. The main differences in the two methods are spectral resolution and calibration. Through the recent development of very-high spatial resolution satellite sensors, such as IKONOS-2 and QuickBird, it is now possible to have image stability of space-borne data and the high spatial resolution capabilities of aerial photography. This offers imagery users the ability to obtain a valuable source of data suited for forest management planning.

Multispectral imagery can be very useful in forest management planning when determining stand boundaries, species composition, feature locations such as forest stands, trees, unique preservation areas, and the detection of stressed or dead trees. Unfortunately, planning may be impacted by how the data are processed. One of these processes is stand delineation. Stand delineation can affect the allocation of silvicultural activities on forest stands as well as the determination of total acres of stand types. The determination of acreage may increase or decrease volume estimates. As a result, the total volume estimate can change future management decisions by impacting harvest schedules. If area estimation is incorrect, the activity schedule may not be optimal for the specific management goals.

The objective of this study is to compare stand boundaries derived from IKONOS and Quick Bird satellite platforms and determine the economic impact of area estimation through the use of a forest planning model. A portion of this study, eCognition v3.0 (Definiens GmbH, Munich, Germany) was used to estimate forest area because of its ability to segment images into real world objects, widespread use, and because of the potential of automating forest stand delineation. This paper will focus on the development of the forest stand boundaries.

Satellite Imagery in Natural Resource Management

With the recent launch of satellites able to capture images having a resolution of less than five meters, relatively coarse spatial resolution is no longer a hindrance to the creation of local stand boundaries. Up to this point, forest managers have not had these sources of data and have relied mainly on aerial photographs and field surveys for the collection of local field data (Kayitakire et al. 2002). Satellite imagery can provide natural resource managers with an invaluable source of information as an alternative to aerial photography that may otherwise be difficult or impossible to obtain or monitor. Also, the detail is comparable to some aerial photography, is easily incorporated into a GIS, and supports multitemporal analyses of natural resources.

At spatial resolutions of about one meter, the per-pixel classification of forested lands should not be conducted without taking into account the spatial context of the information (Aplin et al. 1999). The value of an individual pixel does not provide much information since the objects of interest are often composed of many pixels. Therefore, a per-object classification is needed to correct this problem. A per-object classification should be more accurate even for lower resolution images than that of per-pixel classification (Kilpelainen and Tokola 1999).

Image Interpretation

Typically, stand delineation is accomplished by the use of heads-up digitizing, outlining on photos, or by GPS navigation of stand boundaries. The two former methods require that users can determine differences in stand attributes such as color, texture, shape, size, and context on the image. These characteristics may appear differently to different interpreters. Photo interpretation is a popular way of delineating stands on an image (Naessat 1997). Forest area has historically been interpreted from photo sampling in the USDA Forest Service Forest Inventory and Analysis Program (FIA) (Wynne et al. 2000). However, improvements in computer technology may permit delineation of stands, based on the previously mentioned attributes, without bias of person-to-person differences based on visual perception. One such package, eCognition, may be useful for applications such as stand identification from remotely sensed data through an object-oriented image segmentation approach.

The increased variability of very-high spatial resolution of images requires a stand delineation approach that is based on more than the spectral comparison of pixels. The common ways that have been presented in doing this are through segmenting images based on GIS information (property boundaries, soil types, and land use) or through segmenting from spectral or spatial attributes of the image data. The segmentation of images into unique texture regions is based on criteria such as size, shape, color, compactness, and smoothness followed by the classification of these regions based on the relative homogeneous properties and spectral patterns within each region have shown promising results (Lennartz and Congalton 2004). Aplin et al. (1999) and Kayitakire et al. (2002) noted that using this method may produce more accurate classifications compared to a per-pixel type classification. However, the accuracy of segmenting images in this manner depends on the spatial and spectral resolution of the sensor.

Study Area

The John C. Stennis Space Center (SSC), operated by the National Aeronautics and Space Administration (NASA) is being used for this study. The SSC is located in Hancock County, in southern Mississippi, and east of the Pearl River. Over half of the SSC land is used for testing facilities, laboratories, offices and other operational services. The main focus of the SSC is to conduct research on NASA's rocket propulsion systems for the Space Shuttle and future space vehicles. Research is also being conducted through federal, state, private and academic organizations for space, ocean, environmental and national defense programs. The forested areas are currently being managed by the United States Army Corps of Engineers.

Data

The IKONOS and QuickBird imagery, both taken in February of 2001, was obtained from NASA at the SSC. The imagery was received in raw tagged image format (TIF) and was subsequently stacked and mosaicked in Leica ERDA Imagine 8.6. The projection used for georeferencing was Universal Transverse Mercator (UTM), Zone 16 North WGS 1984 Datum. These images were imported into Imagine for visual inspection and data preparation. The study area of SSC to be delineated was identified and clipped from the full scene. This was done to reduce the amount of data needed to be processed and the spectral confusion of land outside of the study area.

The IKONOS satellite platform was launched in September 1999 and has a sun-synchronous orbit with an approximate three day repeat cycle. The satellite can provide

panchromatic images at a resolution of one meter, and multispectral images with blue, green, red, and near infrared bands at a resolution of four meters (Dial and Grodecki 2003). Typically delivered images are 11 km square.

The QuickBird satellite platform is the highest spatial resolution commercial Earth-observation satellite available. Also, the satellite provides a swath width of 16.5 km. The satellite has 61 cm panchromatic and 2.44 m multispectral resolution and can provide four band multispectral images (blue, green, red, and near infrared) and a panchromatic image. The satellite was launched in October 2001 and has approximately a three and a half day repeat cycle (DigitalGlobe 2003).

A GIS of the study area was also obtained from SSC to populate the objects created in eCognition with forest stand types. The GIS was created in a recent inventory for SSC and was used as a reference when stand typing. The inventory was used in conjunction with tax map information for Hancock County, MS to create the GIS. When the GIS were overlain with the objects from eCognition it was then possible to assign the proper stand type.

Methods

The primary goal of this study is to assess the impacts of area estimation using two types of imagery through a forest planning model. A portion of this study, in order to develop forest stand boundaries, used an object oriented process to identify stand boundaries. This study took the approach of iteratively changing a segmentation algorithm to simulate different area estimations and analyze these results through a forest planning model.

eCognition allows users to input five separate categories to define how objects are created. The software uses a bottom-up approach to merge objects of similar heterogeneity, which is subject to a defined scale parameter and the defined heterogeneity criteria. The scale parameter allows users to define the maximum heterogeneity allowed from the resulting objects. The heterogeneity criteria are defined by color, shape, object compactness, and object smoothness. The color and shape criteria are linked to allow users to apply weights, from 0 to 1, in order to control which criteria is more important. The color criterion is basically the standard deviation of each objects spectral values and is used along with the user defined weights to determine the acceptability of merging two objects. The shape criterion is defined by the object compactness and object smoothness. The objects smoothness and compactness allows users to define what the “ideal” object would be by using weights from 0 to 1. The more weight applied to the smoothness criteria will result in objects with smoother edges. Alternatively, objects will be more compact and have a more fractal shaped border when more weight is applied to the compactness criteria.

eCognition v3.0 was used to segment both image types. All four bands of both images (blue, green, red, and near infrared) were used in the segmentation and were weighted equally. The settings were initially defined in order to find a segmentation that would produce “forest” regions larger than 10 acres. This size limitation was determined to be the lowest acceptable forest management unit. The process to determine this “minimum mapping unit” was as follows:

1. The color, shape, compactness, and smoothness criteria remained the same as the default found in the segmentation algorithm.
2. The size parameter was iteratively adjusted from 100 to 200 in increments of 10.
3. Shapes were exported into GIS and overlaid with an existing GIS of the SSC populated with current classifications of forest cover types and use zonal majority algorithm to assign stand types to objects from eCognition.

4. The acres were queried for each object from eCognition (beginning with smallest size criteria) to determine the acres of each forest unit.
5. If any forest units were found to be less than the minimum mapping unit desired, the segmentation was rejected and steps 3 and 4 were repeated.

Results

It was determined that an initial size parameter for each image would have to be obtained because of the sensor attributes of each image type. After several iterations, a scale parameter for each image that produced forest stands greater than 10 acres was identified. An example of both the IKONOS and QuickBird images being segmented using this can be found in Figure 1. These images were segmented using the initial size parameter to produce forest stands greater than 10 acres and the color, shape, smoothness, and compactness on the default settings.

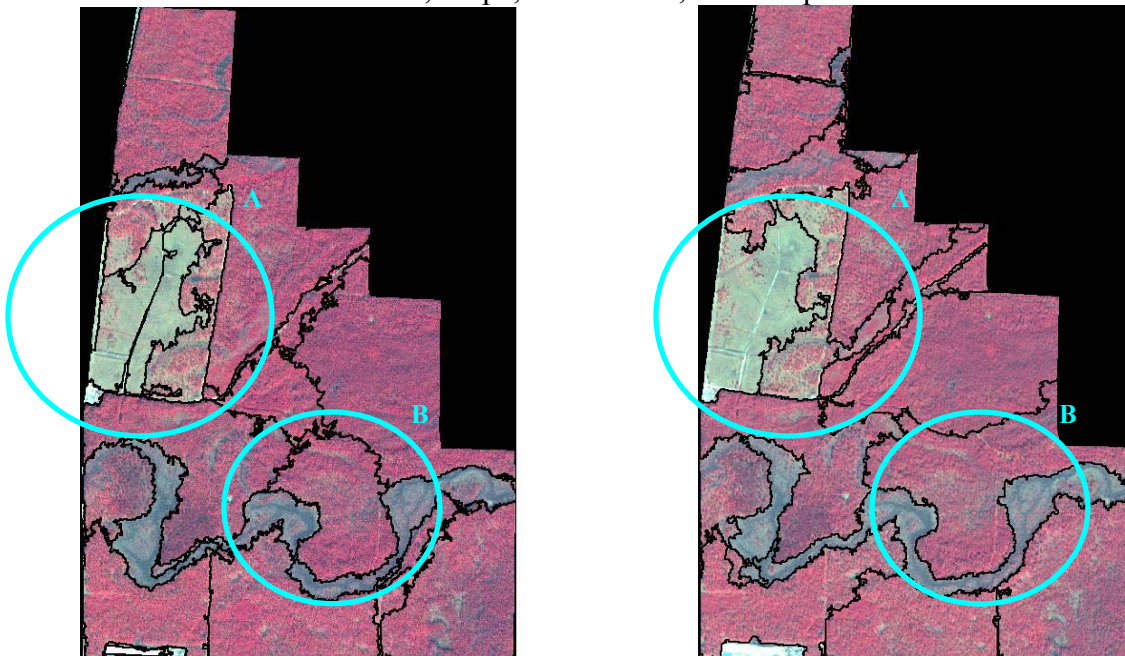


Figure 1. A multispectral QuickBird (left) and IKONOS (right) segmented image of forest stands within a portion of the John C. Stennis Space Center, Hancock Co., MS. illustrating the differences in the boundary locations of “unique” areas A and B.

One segmentation process for each image was analyzed for simple statistical exploration. The segmentation algorithm used to explore this data was consistent between each image, excluding the size parameter. The total number of stands identified was 98 and 104 for the QuickBird and IKONOS images, respectively (see Table 1). It is worth noting that the smallest (minimum) stand identified for each image was less than five acres. This is a direct result of “island” stands surrounded by roads. It was determined that since there were such a high number of stands over an operational high threshold, over 100 acres, further splitting of stands will be conducted to allow further analysis in a forest planning model. Nelson (2001) found that splitting polygons according to a multiple pass splitting routine, dependent on minimum and maximum polygon sizes, resulted in operationally acceptable areas in the development of strategic and tactical forest plans. A routine similar to the methods Nelson (2001) presented will be used in this research to split the forest polygons appropriately to eliminate areas greater than 100 acres.

Descriptive Statistics	QuickBird	IKONOS
# of Stands	98	104
Acres Mean	68	64
Acres Range	352	213
Acres Std. Deviation	62	50
Acres Minimum	4	2
Acres Maximum	355	215
Stands greater than 100 acres	23	21

Table 1. Descriptive statistics from segmentation of the QuickBird and IKONOS images using eCognition (Definiens GmbH, Munich, Germany).

Future Work

More research is necessary to completely quantify possible differences in imagery types. Analysis of data will involve several different steps to determine the impacts of the image segmentations. To further analyze forest area estimation, the segmentation parameters (color, shape, compactness, and smoothness) will be changed iteratively. This will result in approximately 200 layers produced. This will also add several additional steps to the analysis of the images mentioned in the methods sections previously.

To quantify the possible differences between the two types of imagery, a forest planning model will be developed. Management prescriptions will also be developed for each stand. These prescriptions will include regeneration costs, site preparation costs, intermediate costs throughout the rotation, thinning revenues, and harvest revenues. Also timing of thinning, harvesting, prescribed burning, and planting will be determined using the program WINYIELD v1.11. The forest planning model will be developed with Woodstock (Remsoft) to determine the best management plan for each of the stand types. Spatial restrictions, green-up periods and adjacency constraints, will be analyzed using Stanley (Remsoft) and objective function values will be compared to determine the impacts of area estimation on forest management decisions.

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