

# USING eCOGNITION FOR IMPROVED FOREST MANAGEMENT AND MONITORING SYSTEMS IN PRECISION FORESTRY

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## **Abstract**

By using new high-resolution satellite imagery (IKONOS, Quick Bird) it is possible to detect forestland use structure and to assess environmental change more easily than with conventional lower resolution satellite data. However, due to the high spatial resolution, automatic classification of such imagery based only upon the spectral characteristics (tone, color) of the features can become difficult, especially, in spectrally homogeneous areas. Object-based imagery processing techniques overcome this problem by incorporating both spectral and spatial characteristics of objectives. In this research, an object-oriented eCognition's classification scheme (eCognition is designed to segment the image into units of similar spectral and spatial patterns and to classify those segments according to a pre-defined rule base) was developed which used a DTM with IKONOS imagery (one-meter panchromatic sharpened multispectral data) for the initial segmentation and subsequent object classification. In the multi-resolution segmentation process, the influence of the DTM and multi-spectral bands on object generation was controlled by layer weight, scale parameters, the amount of color and shape factors. The accuracy of the results using this approach is promising compared to pixel-based classification. Results indicate that object-oriented approaches have great potential for improved forest management information and monitoring system in decision-making processes for precision forestry purposes.

**Keywords:** precision forestry, monitoring system, IKONOS, eCognition, object-based image analysis

## INTRODUCTION

Forest operational planning is normally based on stands, owners or regional level as the primary unit of treatment. A forest landscape is a spatial mosaic of arbitrary boundaries containing distinct areas that functionally interact (Turner, 1989). Spatial or landscape structure refers to the relative spatial arrangement of patches and interconnections among them (Baskent & Keles, 2005). In recent years, therefore, interest has been directed towards the use of smaller area units such that the formation of treatment units becomes part of the operational planning (Lu & Eriksson, 2000; Martin-Fernandez & Garcia-Abril, 2005).

The very important function of GIS is the ability to answer geographical questions based on the information in digital maps with associated attribute database (Baskent & Keles, 2005). Forests were distributed on precipitous mountain area in Japan. Therefore, the analysis that combined the topography with other various forest attributes is indispensable for forest operational planning. The introduction of GIS through the Japan forest industry has made possible the optimization of current working methods to the extent that GIS has become one of the most essential tools for forest management. There is a business need for a continuous up-to-date inventory of forest resources and monitoring environmental change of land use structure, as well as a requirement for gathering information about the location, condition and sustainable management of these resources (Suarez *et al.*, 2005).

Remote sensing is more cost-effective technique than field survey to conduct long-term and broad area census. Internationally, there have been important scientific advances in remote sensing over the last 30 years that have produced mature techniques ready for implementation in the management of forest resources (Suarez *et al.*, 2005). Recently, high spatial resolution satellite data become commercially available, making possible fine-scale studies over large areas. The commercial IKONOS satellite (Space Imaging, USA), one of several new satellites collecting high spatial resolution data, was launched in September 1999 and provides, on request, effectively global coverage of 1 m panchromatic data and four bands of 4 m multi-spectral data in the blue, green, red and near infra-red portions of the spectrum, respectively (Read *et al.*, 2003; Turner *et al.*, 2003).

High spatial resolution data with fewer spectral bands in aerial photography and new high spatial satellite images (IKONOS, Quick Bird) can create classification problems due to greater spectral variation within a class and a greater degree of shadow (Laliberte *et al.*, 2004). On the other hand, it contains much information in the relationship between adjacent pixels, including texture and shape information, which allows for identification of individual objects as opposed to single pixels. Image segments are a way of summarizing information from a contiguous cluster of homogeneous pixels. Each image segment then becomes a unit of analysis for which a number of attributes can be measured. These attributes can include dozens of measures of spectral response, texture, shape, and location (Benz *et al.*, 2004; Thomas *et al.*, 2003). Ecologically speaking, it is more appropriate to analyze objects as opposed to pixels because landscapes consist of patches that can be detected in the imagery with object-based analysis (Laliberte *et al.*, 2004).

The aim of this study is to explore the viability of the object-oriented image analysis for the formation of treatment units in order to appropriate forest operation

using the high spatial resolution satellite image (IKONOS) and the digital elevation model (DEM). For this paper, we used eCognition software (Definiens, 2000) to produce the image segments.

## MATERIALS AND METHODS

### Study site

The study area consists mostly of artificial forests in Miyagawa of Mie prefecture, is located in Central Japan (Fig 1, 34°19'N, 136°15'E) and covers about 1600 ha. Elevations range is between 200 and 1000 m, and topography is precipitous (slope gradient about 10-70°). The forest is an artificial forest characterized by coniferous tree species (cedar and cypress).

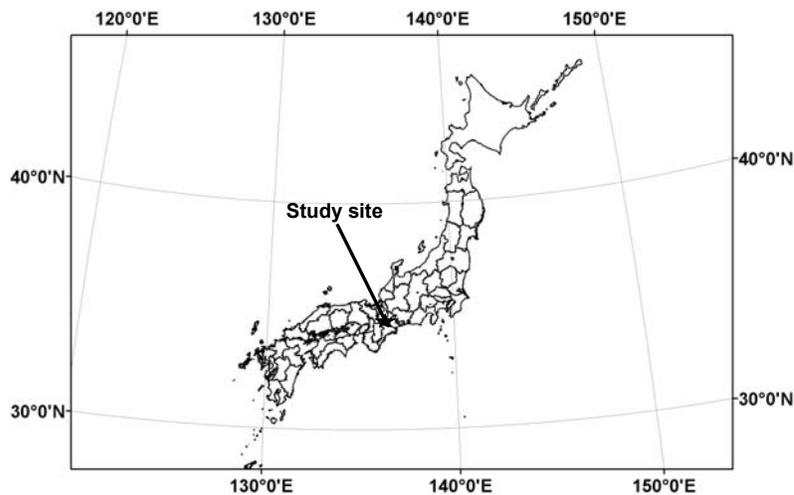


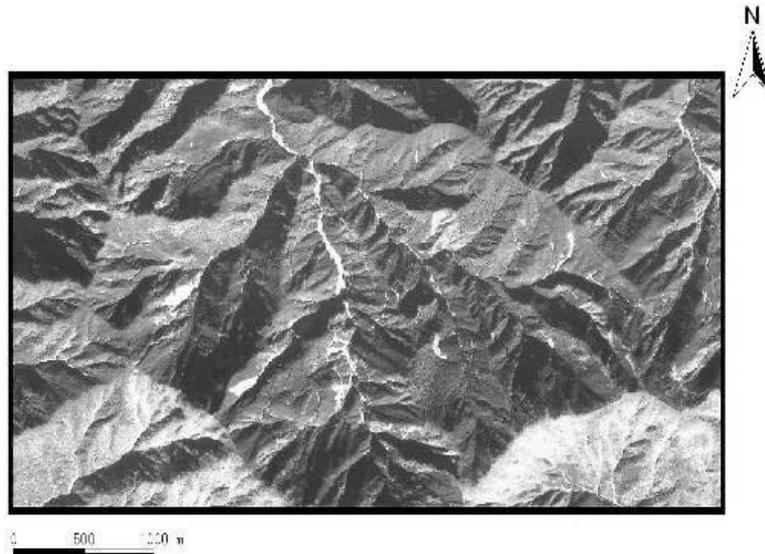
Fig 1. Location of the study site: Miyagawa of Mie prefecture

### Data source

We used IKONOS satellite (Fig 2, Space Imaging™ processing level: standard geometrically projected) multi-spectral (4 m / pixel) data for about 1600 ha study area. The data were acquired on 23 November 2004. In this study the red, blue and green bands were used for a false-color composite image, which was an available image format (Erdas Imagine image) in the eCognition. Near infra-red and red bands were used to calculate a normalized difference vegetation index (NDVI). NDVI is expressed as

$$NDVI = \frac{NIR - red}{NIR + red}$$

where NIR is the reflectance measured in the near infra-red band and red is the reflectance in the red band (Ustin, 2004). Calculated NDVI was also image format (Erdas Imagine image).



**Fig 2. IKONOS data of the study area**

DEM was delivered from Geographical Survey Institute in Japan. Spatial resolution was 50 m / grid. DEM was interpolated by the bilinear interpolation method to 4 m / grid in order to coordinate with the IKONOS data. The slope and the aspect were calculated by using GIS (Arc View 3.2a / ESRI, USA). Calculated topography data was 4 m / grid, which was an available grid format (ESRI ASCII GRID) in the eCognition. The output unit of the slope was a degree. The aspect assigned eight aspects to 1-8 after having output a unit with a degree, which was clockwise from the north. The flat assigned 0.

### **Analysis procedure**

In order to form treatment units for appropriate forest operation, a false-color composite image, a calculated NDVI image, grid data of slope and aspect were used. A false-color composite image and NDVI image were used to obtain land cover information. Grid data of slope and aspect were used to obtain estimation of topographically adequacy for forest operation. Based on these data, the forest treatment units were segmented by eCognition.

The eCognition segmentation algorithm creates image or grid data segments based on three criteria: scale, color and shape (smoothness and compactness), where color and shape parameters can be weighted from 0 to 1. Within the shape setting, smoothness and compactness can also be weighted from 0 to 1. In the case of grid data, each value of grid was treated like color. These criteria can be combined in numerous ways to obtain varying output results. Scale is the most important parameter and affects the relative size of output polygons, although there is not a direct relation between the input scale and the number of pixels per polygon.

Scale is heterogeneity tolerance within a segment. Color, smoothness, and compactness are all variables that optimize the segment's spectral homogeneity and spatial complexity. The balance at which these criteria are applied depends on the desired output. Assigning a high weight value to color (spectral information) with no weight on shape information resulted in highly jagged polygons with

narrow spectral range. In contrast with that, when shape information was strongly emphasized rather than color, the resulting polygons were amorphous and did not closely follow feature boundaries. A high weight for compactness also outputs amorphously shaped feature polygons that do not adhere to major features. Emphasizing smoothness rather than compactness allows for polygons that follow natural features more naturally (Benz *et al.*, 2004; Definiens, 2000; Laliberte *et al.*, 2004; Thomas *et al.*, 2003).

**Table 1 Segmentation parameters used for the analysis**

Segmentation Level	Scale	Color	Shape	Shape setting	
				Smoothness	Compactness
Level 1	10	0.8	0.2	0.5	0.5
Level 2	50	0.8	0.2	0.5	0.5

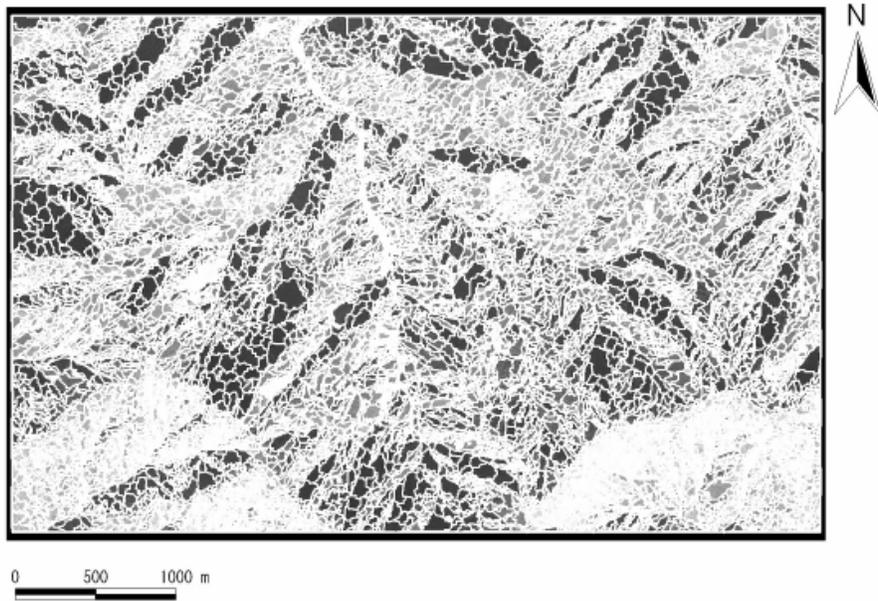
Table 1 shows segmentation parameters used in this study. The segmentation used in eCognition is a bottom-up region merging technique. In subsequent steps, smaller image objects are merged into larger ones based on the set scale, color, and shape parameters, which define the growth in heterogeneity between adjacent image objects. This process stops when the smallest growth exceeds the threshold defined by the scale parameter. A larger-scale parameter results in larger image objects (Benz *et al.*, 2004).

## RESULTS

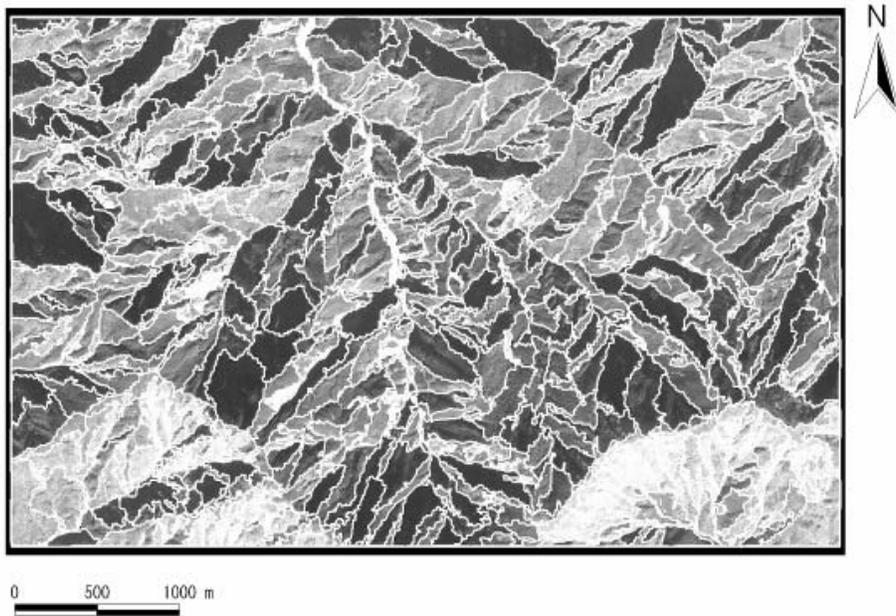
The study area was segmented by using a false-color composite and NDVI images at a lower level (Fig 3) and at a higher level (Fig 4) based on the image object hierarchy. The number of the objects that was obtained was 11898 (the mean area was 1289.73 m<sup>2</sup>) in the lower level. In the higher level, it was merged to 732 (the mean area was 20963.45 m<sup>2</sup>, Table 2). According to my observation, the segmentation which used the parameter of level 2 was more suitable for land cover than level1.

**Table 2 Unit area by using each levels and attributes**

Segmentation Level		Attribute used for segmentation		
		R, G, B, NDVI	Slope, Aspect	All
Level 1	No. of Segmentation	11898	6120	-
	Mean Area (m2) ± S.D.	1289.73 ± 1501.47	2537.98 ±1599.68	-
Level 2	No. of Segmentation	732	383	585
	Mean Area (m2) ± S.D.	20963.45 ± 20833.32	40554.61 ± 25896.17	26030.41 ± 23442.12



**Fig 3. Segmentation of study area by level 1 using a false-color composite image, a NDVI image**



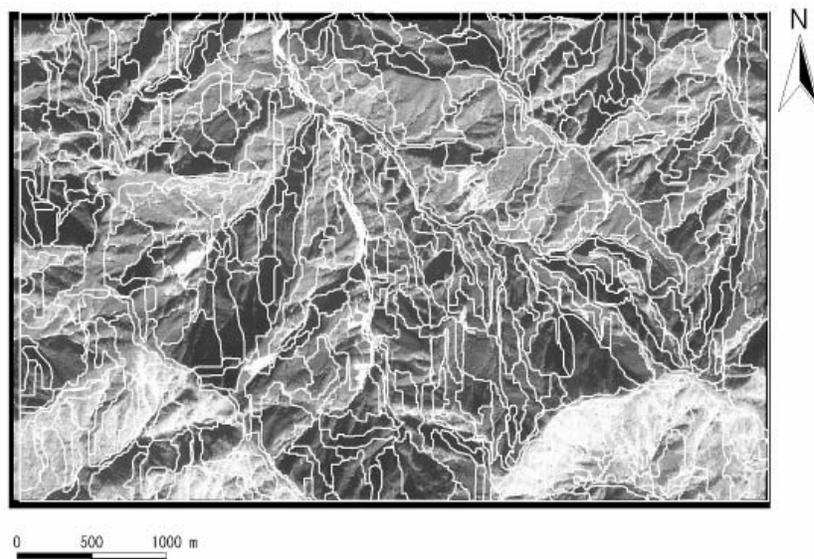
**Fig 4. Segmentation of study area by level 2 using a false-color composite image, a NDVI image**

Considering topography is important to estimate of appropriateness of forest operation, since forest area in Japan is the steep and complicated landform. The study area was segmented by using topography data at a lower level (Fig 5) and at a higher level (Fig 6) as well as above IKONOS image data. The number of the objects that was obtained was 6120 (the mean area was 2537.98 m<sup>2</sup>) in the lower

level. In the higher level, it was merged to 383 (the mean area was 40554.61 m<sup>2</sup>, Table2). The segmentation which used the parameter of level 2 was more suitable for forest operations than level1 as a result of my observation.

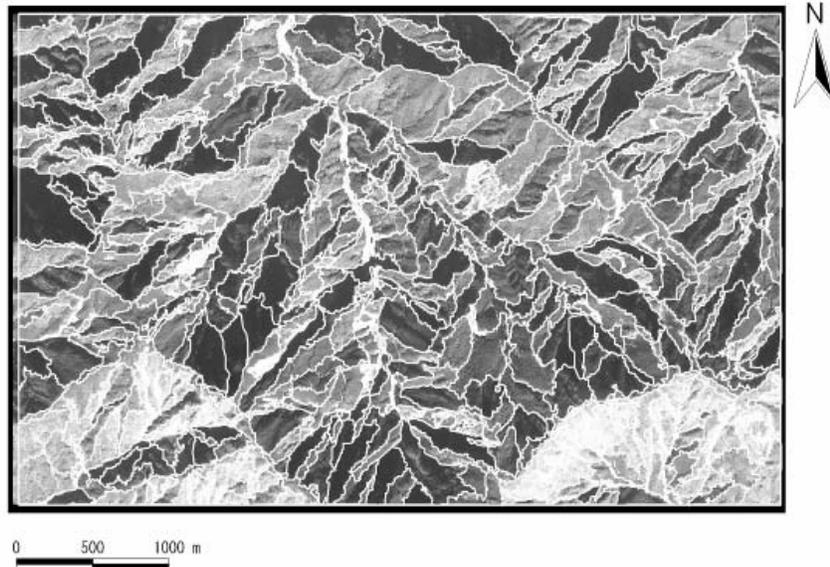


**Fig 5. Segmentation of study area by level 1 using geography data**



**Fig 6. Segmentation of study area by level 2 using geography data**

For the formation of treatment units in order to appropriate forest operation, the study area was segmented by using a false-color composite image, NDVI image and topography data (slope and aspect). It was recognized that level 2 suited the segmenting of this area by above-mentioned analysis. Therefore, after the study area was segmented at a lower level, it was segmented at a higher level (Fig 7) based on the object hierarchy. The number of the objects that was obtained was 585 (the mean area was 26030.41 m<sup>2</sup>) in the higher level.



**Fig 7. Segmentation of study area by level 2 using a false-color composite image, a NDVI image and geography data**

## **DISCUSSION**

The importance of concepts in sustainable and nature-oriented forest management has become increasingly recognized in recent years. In addition to governmental institutions, non-governmental organizations such as the Forest Stewardship Council (Forest Stewardship Council, 1994) have developed new, nature-oriented forest management and certification standards (Mrosek, 2001). Therefore, we should depart from the traditional management method by units of stands, owners or regional level.

The use of object-oriented image analysis was proved to be advantageous in this study. Treatment units to appropriate forest operation were generated smaller area compared to that of the stand base planning. The segmented result was the aggregation of pixels sharing similar characteristics in terms of land cover and topography (Fig 7). Forest management planning strives after a desirable course of action for the management of a forest estate (Holmgren *et al.*, 1997). Forest management practices imposed at one spatial scale may affect the patterns and processes of ecosystems at other scales (Tang & Gustafson, 1997). By using the method of this study, operation units which reflect the current condition of the forest was segmented and the management which is based on these units can be practiced. The accuracy of the results using this approach is promising compared to pixel-based classification. Results indicate that object-oriented approaches have great potential for improved forest management information and monitoring system in decision-making processes for precision forestry purposes.

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