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Using an object-based imagery processing to increase the accuracy of delineating spatial forest operational units from IKONOS image and DEM data integration

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Abstract: By using new high-resolution satellite imagery, 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 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 was developed which used a DTM with IKONOS imagery 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. Results indicate that object-oriented approaches have great potential for improved site-specific operational planning and monitoring system in decision-making processes for timber harvesting strategy.

1 Introduction

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). Remote sensing is more cost-effective technique than field survey to conduct long-term and broad area census.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 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). Because of the stretch of precipitous mountain forests in Japan, the analysis that combined the topography with other various forest attributes is indispensable for forest operational planning.

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).

2 Material and methods

2.1 Study area

The study area (about 1600 ha) consists mostly of artificial forests in Miyagawa of Mie prefecture located in Central Japan (Figure 1). 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).

2.2 Data sources

We used IKONOS satellite image data (Space

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Imaging™ processing level: standard geometrically projected, multi-spectral:4 m / pixel) covering the study area of about 1600 ha (Figure 2). 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 image) in the eCognition. Near infra-red and red bands were used to calculate a normalized difference vegetation index (NDVI). NDVI is expressed as

$$NDVI = \frac{NIR - red}{NIR + red} \tag{1}$$

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 ERDAS image format. DEM was delivered from Geographical Survey Institute in Japan. Spatial resolution was 50 m/grid. It 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 1-5 after having output a unit with a degree, which was location from the north. The flat assigned 0.

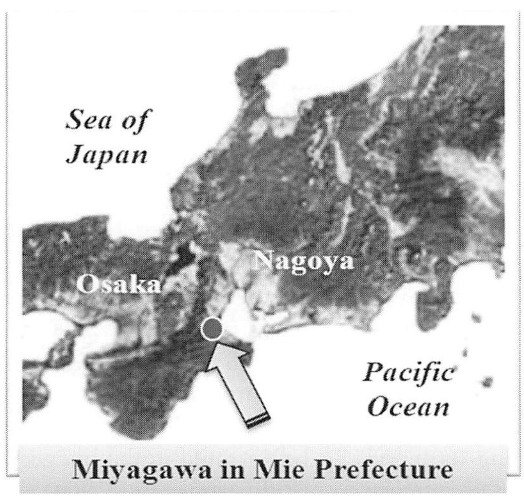


Figure 1: Location of the study area (Miyagawa, Mie Prefecture)

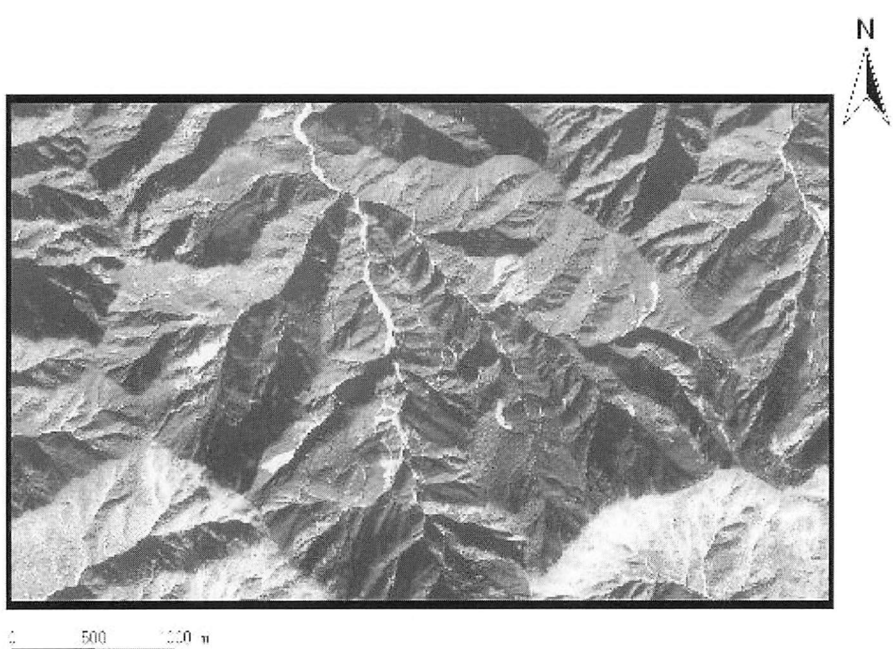


Figure 2: IKONOS satellite multi-spectral image (November 23, 2004; R, G, B, NIR; 4 m/pixel)

3 Analysis procedures

We used eCognition software (Definiens, 2000) to produce the image segments. The eCognition creates segments based on three criteria: scale, color (values which the grid has) 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. 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 segmented areas, although there is not a direct relation between the input scale and the number of pixels per the segmented area (Definiens, 2000). Table 1 shows segmentation parameters used in this study. The study area was segmented by two steps. After it segmented by level1, they integrated by level 2. 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 objects. This process stops when the smallest growth exceeds the threshold defined by scale parameter. A large-scale parameter results in large image objects (Benz *et al.*, 2004).

Table 1: Segmentation parameter set derived from test run results

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

4 Results

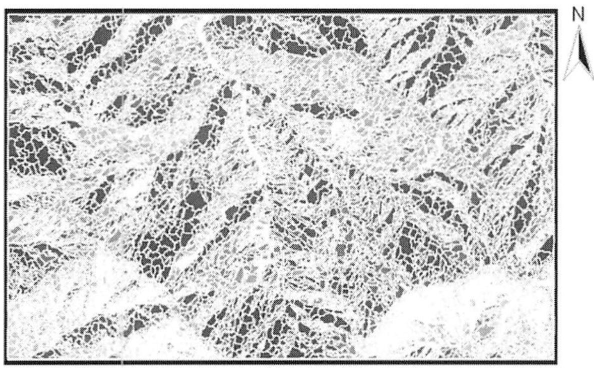
The land cover of the study area was segmented by using a false-color composite and NDVI images at a lower level (Figure 3) and at a higher level (Figure 4) based on the image object hierarchy. The number of the objects that was obtained was 11898 (the mean area was 1289.73 m^2) in the lower level. In the higher level, it was merged to 732 (the mean area was 20963.45 m^2 in Table 2).

Table 2: Results of segmentation of unit areas

Segmentation level	Unit area	Attribute used for segmentation		
		R, G, B, NDVI	Slope, Aspect	All
Level 1	No. of segmentation	**11898**	**6120**	NA
	Mean Area ± SD (m^2)	1289.73 ± 1501.47	2537.98 ± 1599.68	NA
Level 2	No. of segmentation	732	383	585
	Mean Area ± SD (m^2)	20963.45 ± 20833.32	40554.61 ± 25896.17	26030.41± 23442.12

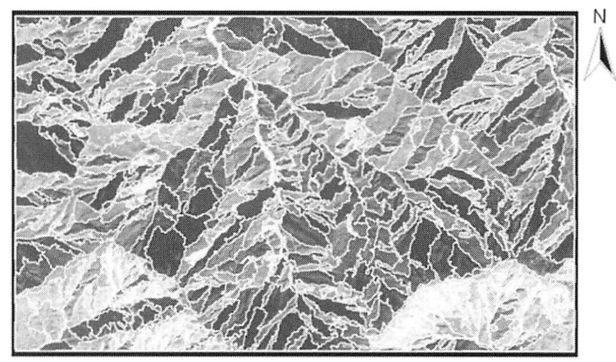
Remarks: SD (Standard Deviation)

Landform characteristic of the study area was segmented by using topographic data at a lower level (Figure 5) and at a higher level (Figure 6) as well as above IKONOS image data. The number of the objects obtained was 6120 (the mean area was 2537.98 m^2) in the lower level. In the higher level, it was merged to 383 (the mean area was 40554.61 m^2 in Table2). The segmentation which used the parameter of level 2 was more suitable for forest operations than level1 as a result of this analysis. 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 (Figure 7) based on the object hierarchy. The number of the objects that was obtained was 585 (the mean area was 26030.41 m^2) in the higher level.



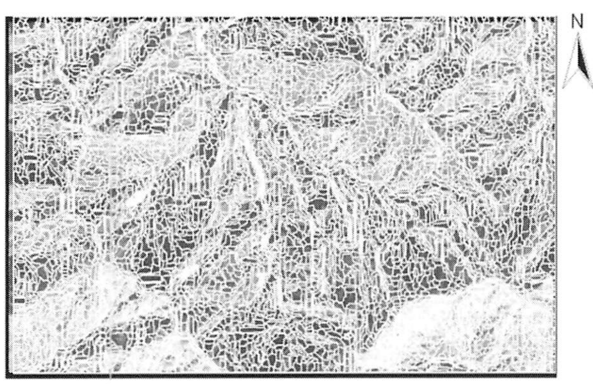
Objects: 11898
Mean area: 1289.73 m^2

Figure 3: Level 1 (R, G, B, and NDVI image)



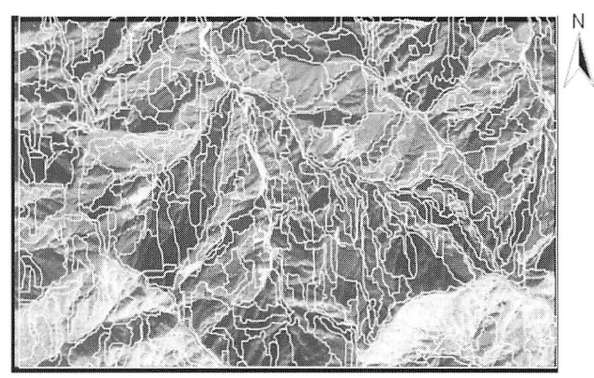
Objects: 732
Mean area: 20963.45 m^2

Figure 4: Level 2 (R, G, B, and NDVI image)



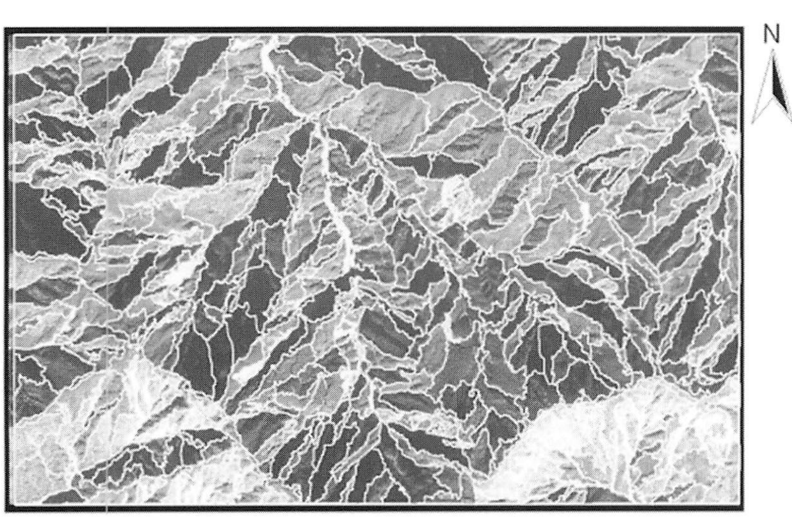
Objects: 6120
Mean area: 2537.98 m^2

Figure 5: Level 1 (Slope, aspect)



Objects: 383
Mean area: 40554.61 m^2

Figure 6: Level 2 (Slope, aspect)



Objects: 585
Mean Area: 26030.41 m^2

Figure 7: Level 2 (R, G, B, NDVI image, slope and aspect)

5 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 (Figure 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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