# OBJECT-BASED CLASSIFICATION OF IKONOS DATA FOR RURAL LAND USE MAPPING

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**ABSTRACT:**

Land uses in rural areas of Japan, which typically consist of small agricultural fields, complex vegetation covers, and sparsely distributed residential areas, have been problematic in terms of land use mapping using satellite remote sensing data due to the complexity of the spatial structure. Increasing availability of very high resolution satellite (VHRS) data and the advancement of object-based image classification techniques in recent years provide a new opportunity for mapping detailed land uses from space. To utilize VHRS data and object-based image classification for creating land use maps, the correspondence between image objects extractable from VHRS data and land use classes observable on the ground, based on the spectral, spatial, and contextual relationships among image objects, must be established, because neither pixels nor segmented image objects of VHRS data directly correspond to land use classes into which we want to classify geo-spatial features on the ground. In this study, we conducted quantitative analyses of the spectral and spatial properties of image objects extracted from an IKONOS pan-sharpen image of a rural town in southwestern Japan, and proposed a classification framework for detailed land use mapping. Firstly, we extracted image objects from the IKONOS data using a multi-scale segmentation technique. Based on the statistical analyses of image objects, a hierarchical classification scheme for object-oriented land use classification was proposed.

## 1. INTRODUCTION

Very high-resolution satellites (VHRS) including IKONOS provide a useful way for us to periodically monitor detailed land use in broad areas. Pixel sizes on the ground of VHRS sensors are small enough to capture geometrical details of common land use patches, and most geographic features on VHRS images, which we want to map on land use maps, are represented as clusters of multiple pixels. For mapping land use from VHRS images, object-oriented classification methods utilizing image segmentation and contextual rule-based labelling techniques are expected to be more suitable than traditional pixel-by-pixel classifiers (Blaschke, T., Strobl 2002).

To utilize VHRS data and object-based image classification for creating land use maps, the correspondence between image objects extractable from VHRS data and land use classes observable on the ground must be established, based on the spectral, spatial, and contextual relationships among image objects, because neither pixels nor segmented image objects of VHRS data directly correspond to land use classes into which we want to classify geo-spatial features on the ground.

In this study, we conducted quantitative analyses of the spectral and spatial properties of image objects extracted from an IKONOS pan-sharpen image of a rural town in southwestern Japan, and proposed a classification framework for detailed land use mapping. Firstly, we extracted image objects from the IKONOS data using a multi-scale segmentation technique. Based on the statistical analyses of image objects, a hierarchical classification scheme for object-oriented land use classification was proposed.

## 2. LAND USE IN RURAL PARTS OF JAPAN

Figure 1 shows a schematic view of the land use pattern often seen in the rural parts of Japan, depicted on a panchromatic image taken from the IKONOS-2 satellite. A typical land use pattern in rural parts of Japan consists of houses (usually with backyards), agricultural fields (rice, wheat, etc.), forests, and networks of roads.

In a macroscopic view, houses in a rural town in Japan tend to aggregate in certain areas of the town, and form residential areas. Residential areas are usually surrounded by agricultural fields growing rice, wheat, vegetables, etc. The boundaries between residential areas and agricultural fields are relatively clear for human interpreters. Road networks are not in a grid-like arrangement, and the shapes and sizes of parcels are not uniform.

A house in the countryside usually has a backyard or a small plot of ground for growing vegetables. That is, image objects corresponding to the houses and agricultural fields in rural towns in Japan share relatively similar constituents.

The relationship between houses and residential areas can be seen as a hierarchical structure of the land use pattern in the view of landscape ecology, and pixel-by-pixel-base image classifiers hardly produce optimal land use maps without intensive editing by human photo-interpreters.

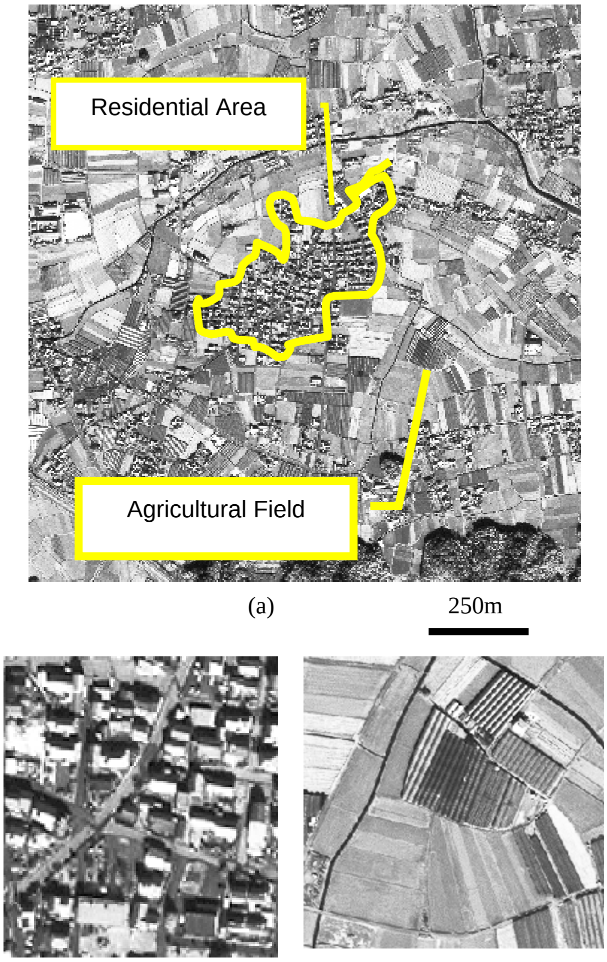



Figure 1. Land use pattern of the study area
(a) A land use pattern of a rural town in Japan depicted on an IKONOS (ⓒJSI) image. (b) Close-up of a residential area, (c) Close-up of an agricultural field.

## 3. OBJECT-ORIENTED APPROACH

Providing the complexity of the land use pattern in rural parts in Japan, traditional pixel-by-pixel-base image classifiers may hardly produce optimal land use maps from VHRS images without intensive editing by human photo-interpreters, due to the similarity in the land cover materials at the order of meters among different land use classes in those areas. To cope with the problem, contextual information such as geometrical properties of image objects including the sizes, shapes, etc. and spatial relationships among them should be incorporated in the mapping process as a set of classification rules. Object-based classifiers combining image segmentation and contextual-rule-based labelling are expected to be a useful tool for land use mapping from VHRS data.

In the past two decades, various image segmentation techniques have been developed to incorporate context in the image classification procedure (van der Sande et al. 2003). In this study, a segmentation technique developed by Baatz and Schäpe (2000), which is a type of region growing multi-scale segmentation algorithms, was used to study object-oriented land use classification.

Major research topics of this study are twofold:

- To study correspondence between image objects at different scales and geographic features. How to optimize segmentation results for mapping rural land uses.
- To select contextual information that can be used as a set of rules for contextual labelling of land use classes on the image objects produced with the image segmentation.

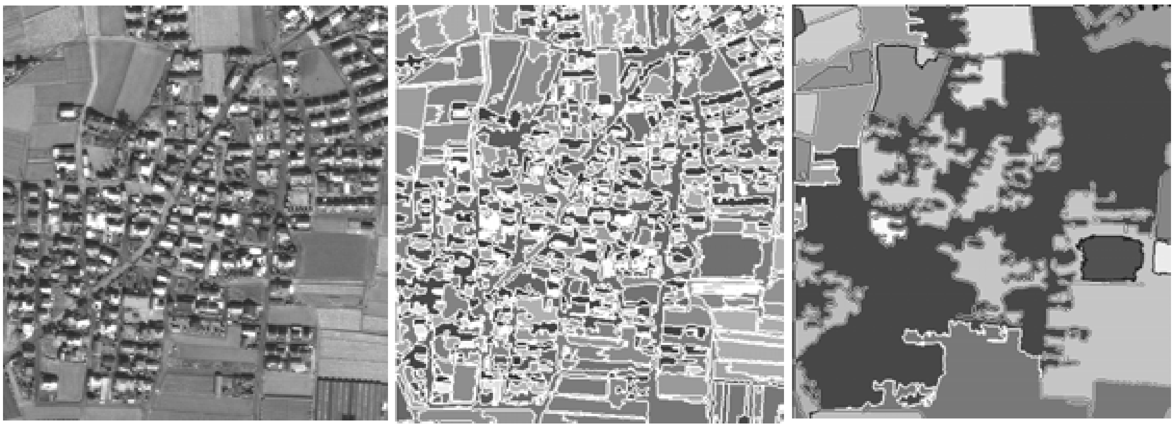
## 4. IMAGE OBJECTS AT DIFFERENT SCALES AND CORRESPONDING GEOGRAPHIC FEATURES

In this study, a set of image segmentation using the algorithm developed by Baatz and Schäpe (2000) with different scale parameters were conducted using an IKONOS pansharpen data (4 band) of a rural town in *Kouchi-ken* in south-western Japan taken on November 21, 2001 to study the correspondence between image objects at different scales and geographic features. The segmentation criterion used in this study for merging multiple image objects into a larger image object was a standard deviation of the pixel values in an image object (segment).

Figure 2 shows two examples of the subset of the segmentation results with an original IKONOS data; these are at the intermediate steps corresponding to certain scale parameters of a region growing process started from individual pixels. Although they do not perfectly match the shapes of geographic features on the ground, image objects produced with certain scale parameters shows relatively good correspondence with some geographic features. Figure 2 (b) shows the segmentation result with scale parameter 75, and the image objects depicted with white lines correspond to the rooftops of individual houses and parcels of agricultural fields relatively well. On the other hand, image objects in Figure 2 (c) appeared at scale parameter 350 correspond to larger geographic features such as the boundary between residential areas and agricultural fields.

Figure 3 and Figure 4 show examples of the growth curves of the areas of image objects to exemplify how an image object, starting from an individual pixel corresponding to a rooftop of a house, a tree crown, a agricultural field, etc. increases its area in accordance with the increase of the scale parameter. Studying the optimization of image segmentation, Usuda et al. (2003) focused on the stable periods observable in growth curves of the areas of image objects as a key to decide optimal scale parameters for specific applications of image segmentation techniques. Stable periods are thought to be the period when standard deviations of pixel values of neighbouring image objects are apparently different, and the merge process of the image objects becomes relatively slow. Stable periods of the growth of image object sizes are also observed in the image segmentation experiments in this study. In this study, every growth curve of an image object corresponding to a certain geographic feature has multiple stable periods. In addition, the change from one stable period to the next stable period on a growth curve is usually abrupt. These results suggest there is a hierarchical spatial structure in the land use of the study area.

Based on the analysis of the growth curves of the image objects produced with the multi-scale image segmentation, each land use class appears to have a class-specific growth pattern (see Figure 3 and Figure 4). Considering the correspondence between the stable periods appearing in the growth curves and



(a) IKONOS imagery
(ⓒJSI)

(b) Segmentation Result
(Scale parameter 75)

(c) Segmentation Resul
(Scale parameter 350)

Figure. 2 Image Segmentation results

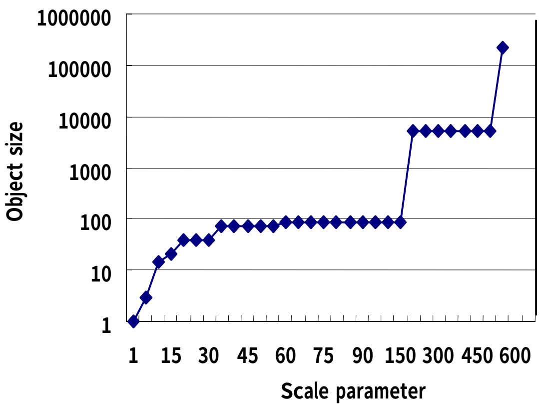



Figure. 3 A growth curve of the area of an image object starting from a pixel belonging to a house

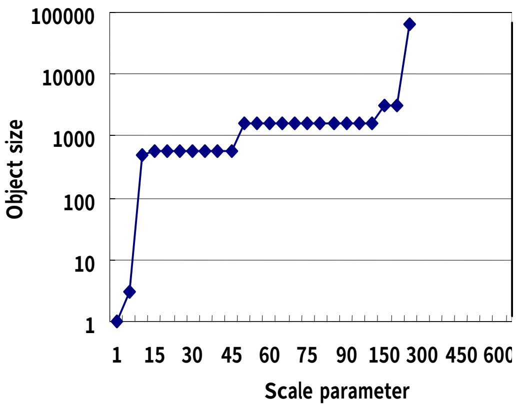



Figure 4 A growth curve of the area of an image object starting from a pixel belonging to an agricultural plot

corresponding image objects (segments), the segmentation results at the stable periods seem to reflect the hierarchical spatial structure of the study area. For instance, a small-scale pattern in the hierarchical spatial structure corresponds to the rooftops of houses. Parcels of houses appear to match the image objects at the next level of the spatial structure. Further, the polygons corresponding to the boundary between residential areas and agricultural fields seem to match the larger spatial pattern. However, the larger the image objects become, the weaker the correspondence between the stable periods and land use classes becomes. Moreover, the length of stable periods does not appear to be an appropriate index for obtaining optimal segmentation results, based on the observation of the correspondence between the lengths of the stable periods and segmentation results; the length of the stable periods does not correspond to meaningful land use classes such as the apparent boundary between residential areas and surrounding agricultural fields. Instead, stable periods appear in the early stages of the growth curves, i.e. small-scale image objects, show relatively good geometrical correspondence with basic land cover patches such as rooftops of houses, patches of grasses, plots of farmland, etc.

## 5. LAND USE CLASSIFICATION FRAMEWORK

Figure 5 shows a schematic of the land use classification process applying contextual rule-based labelling techniques to the segmentation results.

According to the analysis in the previous chapter, segmentation results at a stable period in the early stage of the region growing match basic land cover patches relatively well. These basic land cover units include small patches of bare land, grass, parts of manmade structures such as rooftops, trees, open water, etc. These basic land cover patches are common constituents of most land use instances. For example, small patches of bare land may be a part of a backyard of a house, or a part of a fallow. In the proposed classification framework, labelling of land use classes start from small image objects produced at an early stable period which correspond to the basic land cover classes at small scale.

Sizes and spatial relationships of the image objects would be the next criteria to determine labels of image objects. Relatively isolated small patches of bare soil may be part of backyards of

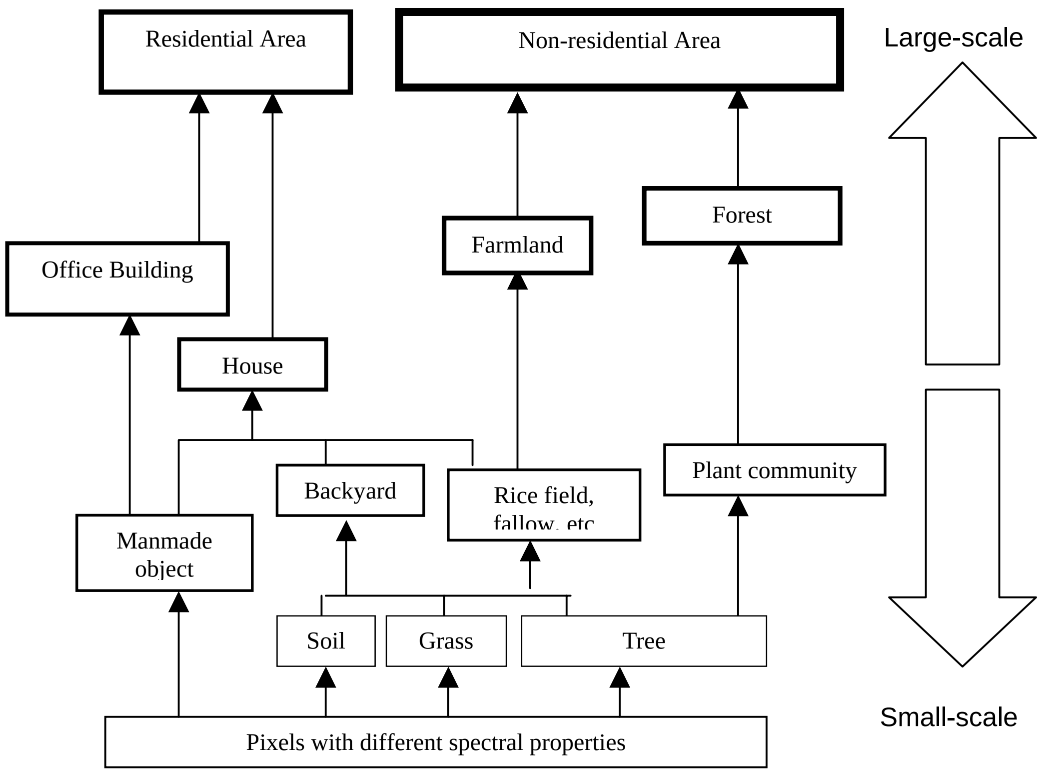



Figure 5. Schematic of the object relationships among the image and geographic features

houses. On the other hand, relatively large patches of bare soil may be part of fallow plots.

Spectral and textural information would be also utilized for detailed land use mapping in the framework of the object-based classification. Labelling plant community types such as deciduous forests, bamboo forests, etc. needs spectral and texture analyses of image objects.

A land use mapping of the study area was demonstrated using the above classification strategy, and the result was compared to an existing land use map which was compiled from the results of aerial photo-interpretation and ground truth data. The land use map created through the object-oriented approach showed a good correspondence with the existing map.

## 6. CONCLUDING REMARKS

This study discussed the correspondence between image objects produced with a multi-scale segmentation technique and land use classes commonly observable in rural land uses in Japan, through an actual image analysis using IKONOS data, and suggested a land use classification framework employing the object-oriented approach. Regarding the future work, the proposed classification framework would be tested in the land use mapping projects in the different areas for the validation and generalization of the classification strategy.

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