INFLUENCE OF MIXELS ON LAND COVER CLASSIFICATION IN RESIDENTIAL AREAS USING AIRBORNE MSS DATA

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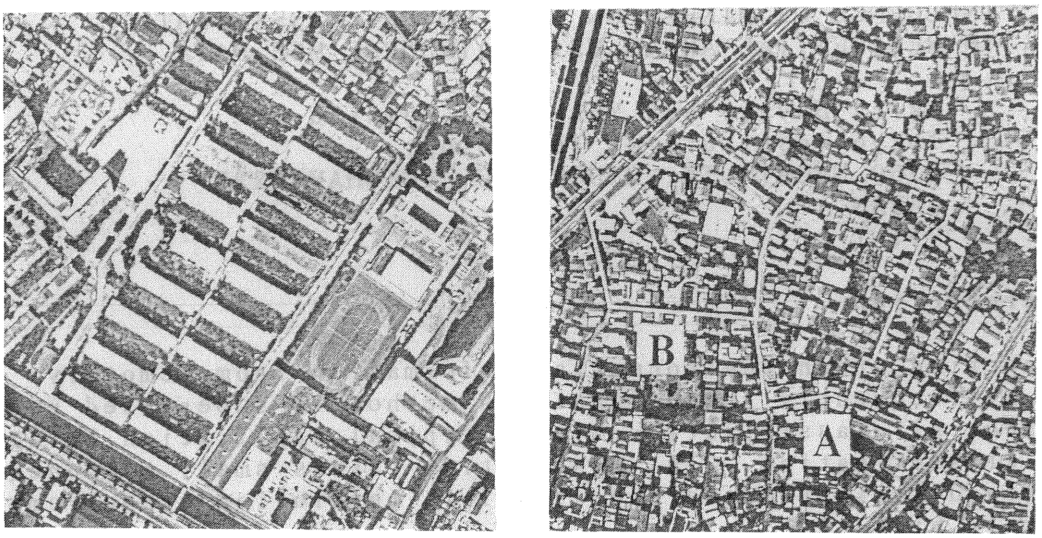
1. Introduction

In extracting urban environmental information from remotely sensed data, a frequently used analysis method is supervised per-pixel multispectral classification with a typical application being land cover classification. In residential areas small components are complexly distributed and the spatial resolution requirement is relatively high [1].
A number of studies have discussed the spatial resolution requirements for land cover classification [e.g. 2-5]. Almost all studies conducted for the land cover categories were determined assuming resolution data of several tens meters such as LANDSAT MSS or TM data. Their results are therefore not adapted to the analysis for urban residential areas, because changes in classification accuracy based on spatial resolution depends on the setting of land cover categories.
In this study we assign the components of urban residential areas, such as buildings, vegetation, streets, etc. [6], to the land cover categories. The percentage of mixels and the proportion of classes in mixels are documented as a function of spatial resolution. We assess the effect of mixels on the ability to classify the types of land cover material using a pixelwise classification method, in order to clarify the optimum spatial resolution for land cover classification of residential areas.

2. Areas and data for analysis

Urban residential areas are basically divided into two types: public housing complexes and private detached housing areas. Both of them are high dense areas. The sizes and distributions of parcels vary greatly between housing complex areas and and detached housing areas. The housing complex area chosen for the survey consists of middle-rise, steel-reinforced concrete housing blocks. Compared with detached housing areas, this area has much greenery. The detached housing areas selected for this study are divided into sections consisting of private detached houses and sections consisting of private detached houses, shops, small factories, etc., in a random mixture. We named the former 'Detached Housing Area-A' and the latter 'Detached Housing Area-B'. Most of the private detached houses are wooden structures of one or two stories. In Fig. 1, aerial photography of three objective areas is shown: these are typical residential areas in metropolitan Japan from the view point of land coverage conditions.
Airborne remote sensing and ground-truth were performed. Multispectral scanner (MSS) data and aerial color photography were obtained by airborne remote sensing. The outlines are as follows;

Date: 24 DEC. 1984, 12:45
Altitude: 500m
Resolution of MSS data: 1.25m at nadir



Housing complex area (Bunka-danchi, Sumida-ku, Tokyo) — Detached housing area-A and B (higashi-mukouzima, Sumida-ku, Tokyo)

Fig. 1 Aerial photographs of analyzed areas (scale=1:1000)

Weather: clear sky day
Objective area: Sumida-ku, Tokyo, Japan.
Along with remote sensing a survey of the land cover materials and the detail of vegetation distribution was carried out.

Table 1. Land cover categories

Large class	Small class	
Vegetation	Tree Shurb Grass	
Building	Zink Tile Slate	Roof of wooden structure
	Aluminum Asphalt Concrete	Roof of reinforced concrete structure
Others	Soil Sand Asphalt pavement Concrete pavement Shadow (on vegetation) Shadow (on excluded vegetation)	

Table 2. Classes of pixels for the land cover grid image

Pure pixel	
B	: Building
V	: Vegetation
O	: Others
Mixel-A	
B-O	: Building, Others
V-O	: Vegetation, Others
B-V	: Building, Vegetation
B-V-O	: Building, Vegetation, Others
Mixel-B	
(B)	: Building
(V)	: Vegetation
(B)(V)	: Building, Vegetation

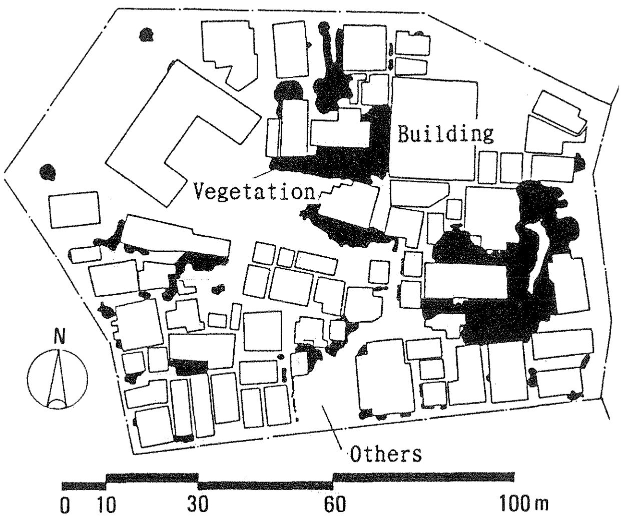


Fig. 2 Large classified land cover map (Detached housing area-B)

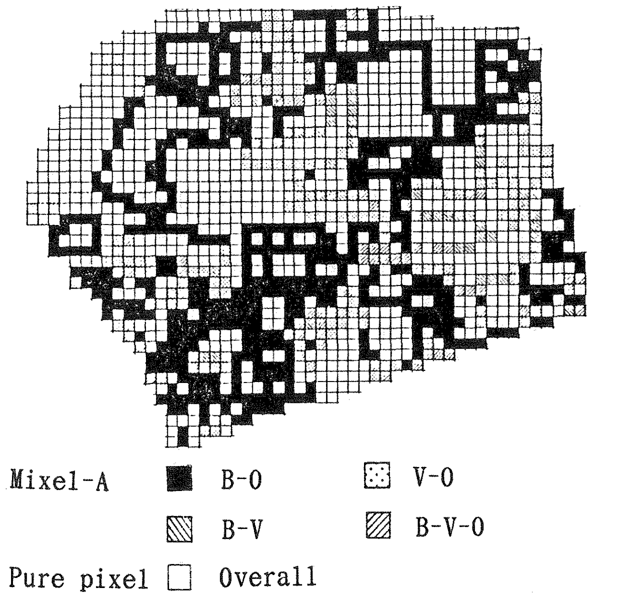


Fig. 4 Large classified land cover grid image (Resolution: 2.5m , Detached housing area-B)

3. Relation between ratio of Mixel and spatial resolutions

3.1. Land cover map

Airborne MSS data with a resolution of less than 1m is hardly obtainable. Therefore, a land cover map (scale=1/1000) --"ground-truth" for this study-- is made based on aerial color photography which has a very high spatial resolution. The land cover categories are divided into two levels: small classified (15 classes) and large classified (3 classes). Small classified land cover categories are the same as those for the land cover classification using airborne MSS data. Maps with small classified categories were used when the relationship between spatial resolution and the proportion of pure pixel classes was investigated. Large classified categories consist building, vegetation and others. Maps with these categories were utilized for a study of ratio and quality of mixels which is hardly to be done using small classified categories. Land cover categories are shown in Table 1 and an example of large classified land cover is shown in Fig. 2.

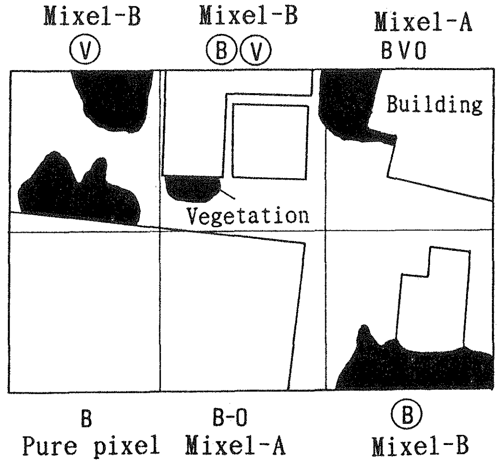


Fig. 3 Interpretaion of grid cells using the large classified land cover map

3.2. Land cover grid image

A grid system was chosen for the interpretation of mixels and pure pixels in order to match the raster format of the air borne MSS image. Each grid cell corresponded to a pixel with various resolutions, i.e. 1m, 2.5m, 5m, 10m, and 30m. A grid drawn on a transparent sheet was superimposed onto the land cover map and manual interpretation was performed. In Table 2 the classes of this image are shown.

Pixels are classified into three large groups: pure pixel, mixel-A, and mixel-B. The definition of those are as follows:

Pure pixel: pixels composing a single class category

Mixel-A: pixelscomposing plural class categories and not containing detached parcels

Mixel-B: pixelscomposing plural class categories and containing detached parcels.

Examples of interpretation using a large classified map are shown in Fig.3. An example of the large classified land cover grid image with a spatial resolution of 2.5m is shown in Fig. 4.

3.3. Results of analysis using the small classified image

The ratio between pure pixels and all pixels and the proportion of pure pixels of each class to all

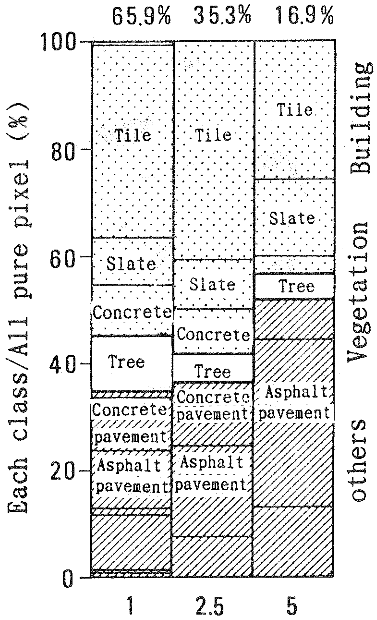


Fig. 5 Ratios of pure pixels to all pixels and proportions of pure pixels of each class to all pure pixels as a function of resolution.

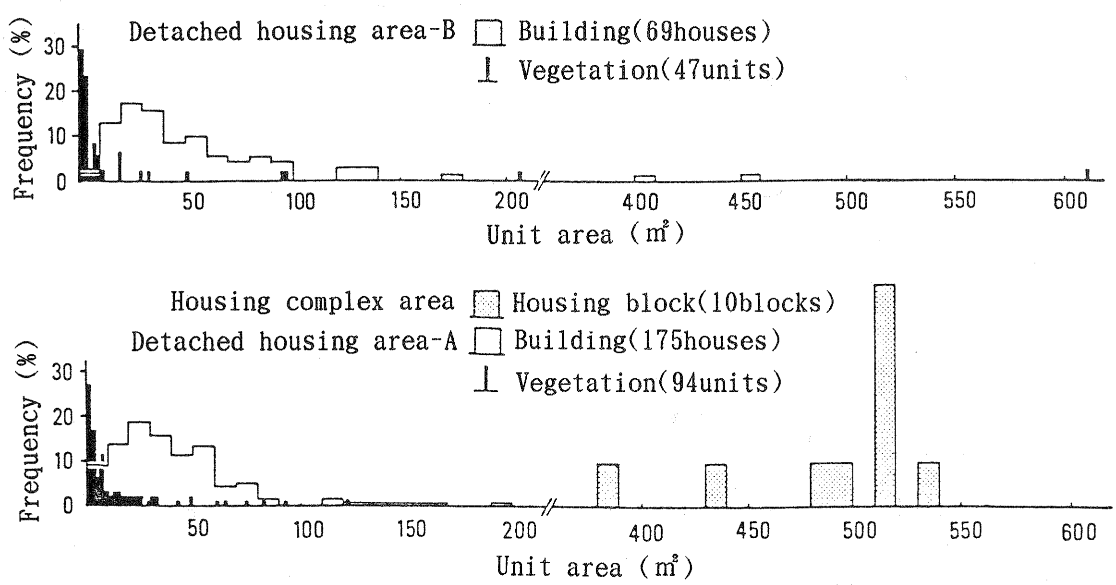


Fig. 6 Unit areas and frequency of buildings and vegetation in three analyzed areas.

pure pixels are shown in Fig. 5. At 2.5m and 5m resolutions, the ratios are reduced by 1/2 and 1/4 such as 35% and 17%.
Additionally, in regard to small class categories such as trees and tile roofs, the ratios are reduced by half at a certain spatial resolution. These are seems which relate the unit areas of each category.
The relation between the unit areas of buildings and vegetation and the frequency of those units are shown in Fig. 6. The peak frequency of buildings of Detached housing area-A is $25m^2$ and almost 90%of the units are less than $100m^2$. That of the housing complex area is $500m^2$ and 90% of the units are more than $400m^2$. Thus they are quite different from each other. Many units of vegetation in Detached housing areas are small. Over half of those areas are less than $6m^2$ and more than 70% of those are under $10m^2$.
On the other hand, in Fig. 5, the proportions of pure pixels of vegetation to all pure pixels is reduced by half at a resolution of 1m to 2.5m (10% to 6%). This was the effect that over 55% of vegetation units were under $6m^2$ which was equal to an area of pixels with a resolution of $2.5m^2$. An area of pixels with a resolution of 5m is $25m^2$ and this was the maximum frequency of buildings in Detached house areas. This was the cause for the decrease in the proportion of pure pixels of tile roof to all pure pixels (such as 42% at 2.5m to 28% at 5m).

3.4. Comparison of analysis results using small and large classified images

Correlation of the ratio of pure pixels for each analysis is assessed(Fig.7) in order to examine the propriety of making use of the large classified image for the analysis of mixel effects. At high resolutions, the percentage of pure pixels of large classified images are 2-16% higher than that of small classified images. This difference became reduced with coarsening resolution while a high correlation was obtain. Because high correlations were observable we chose an analysis procedure that used large classified image.

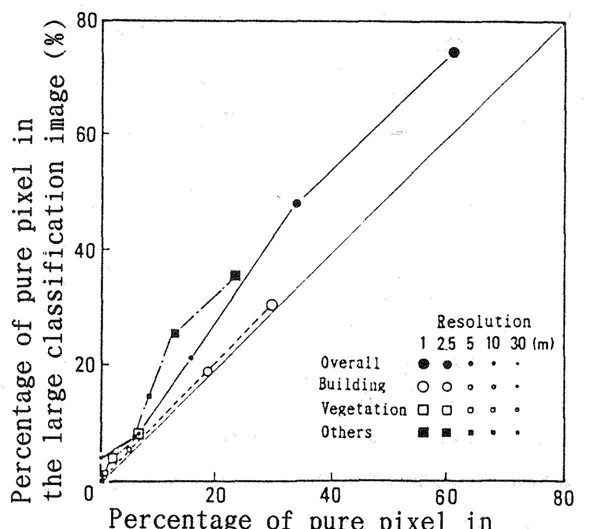


Fig. 7 Correlation of the ratios of pure pixels in small and large classification images

3.5. Results of analysis using the large classified image

3.5.1. Relation between the ratio of mixels and spatial resolution

In Fig.8, the relation between the ratio of each pixel in the large classified image and spatial resolution is shown. In addition, the proportions of pixels in the large classified image are given in Fig.9 for reference. An image with a resolution of 1m corresponds to data from airborne MSS(IFOV: 2.5mrad) surveyed at a low altitude. In this image, the ratio of mixels is 35% in the Detached housing area-A and 20%

in the Housing complex area. In an image with a resolution of 2.5m, the ratios increase nearly 65% and 50%. The ratios are inversely proportional to spatial resolution and in an image with a resolution of 5m, there is little difference between each area and the ratios are about 80%. In those for 10m ,corresponding to the P mode data of SPOT, there are few pure pixels, most are mixels.

3.5.2. Mixels quality

We divided mixels qualitively into mixel-A and mixel-B groups, the relation between each ratio and spatial resolution was also discussed. At less than 2.5m, most mixels are mixel-A which did not contain a detached parcel. At 5m some amount of mixel-A changed into mixel-B which contained detached parcels. The ratios of mixels for all areas show little alteration between 10m and 30m resolution, but mixel-B became predominant at 10m in the Detached housing area-A. The ratio of mixel-B is 90% at 30m and, in the Housing complex area, mixel-A is still predominant at 10m. From this point of view, the quality of data varies between SPOT data with a 10m resolution and LANDSAT TM data with a 30m resolution, although the ratios of mixels are equal in each data set.

4. Land cover classification studies

4.1. Analytical method

MSS images with various resolutions were made from smoothing an airborne MSS image with the original 1.25m resolution. Land cover classification was executed using those images in a maximum likelihood procedure. The ratio of pixels classified in the

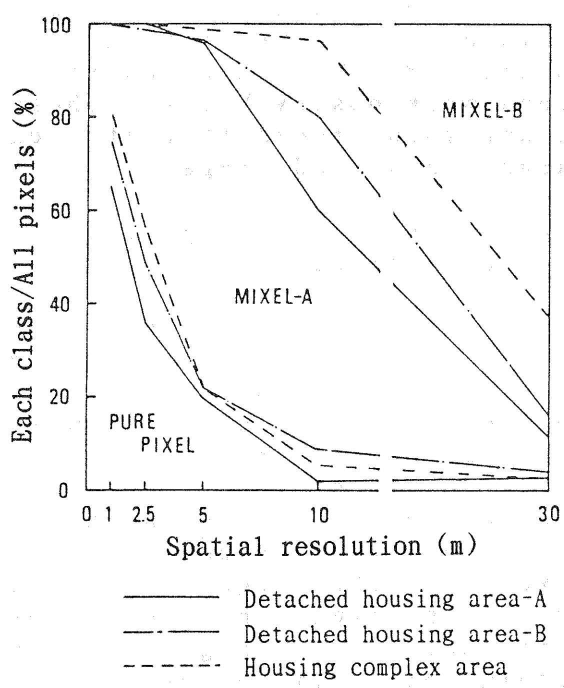


Fig. 8 Relation between the ratios of pure pixels or mixels to all pixels and spatial resolutions. (In land cover grid images)

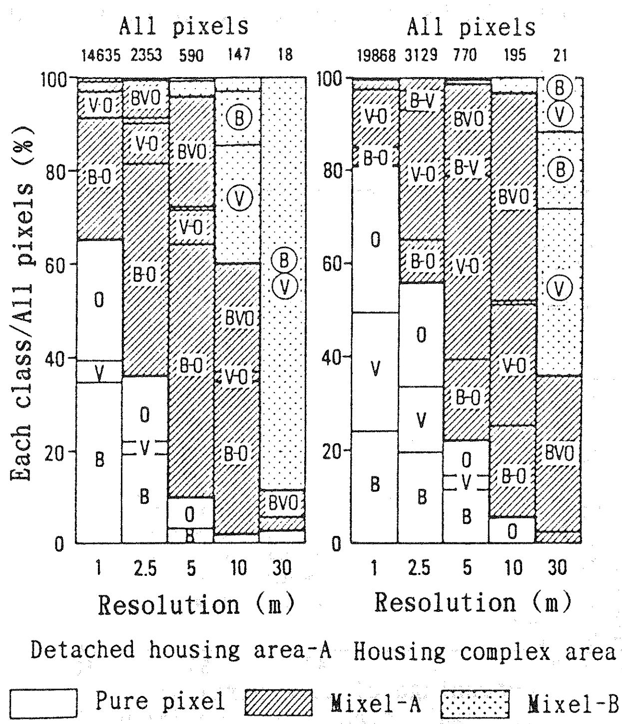
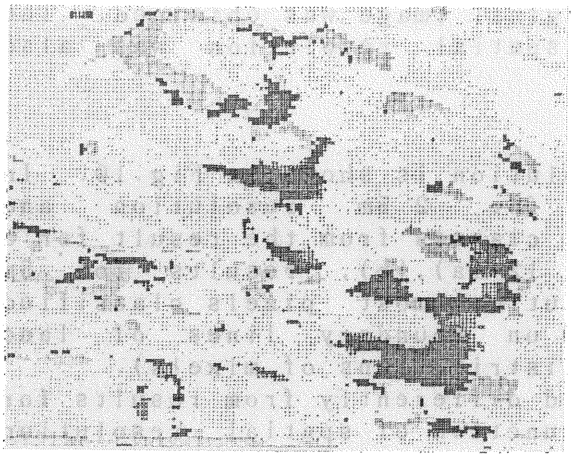


Fig. 9 Proportions of each class of pixels in the land cover grid images at various resolutions



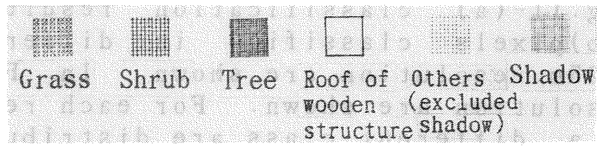


Fig. 10 Results of classification using airborn MSS data with a 1.25m resolution. (Detached housing area-B)

Fig. 11-(a) Results of classification using simulation data with a 2.5m resolution. (Detached housing area-B)

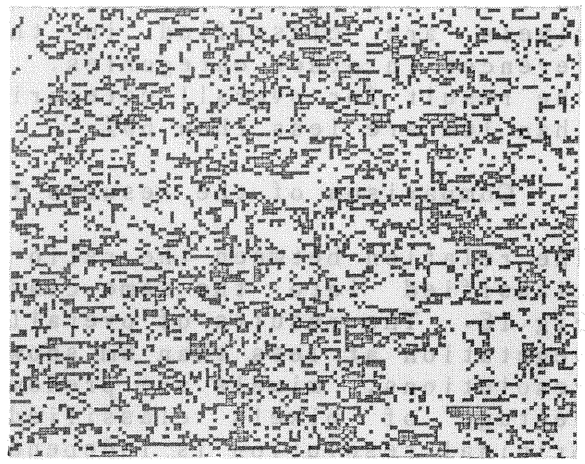


Fig. 11-(b) Comparison of classification results for original data and simulation data with a 2.5m resolution. (Blackened pixel: classified in a different class from the original)

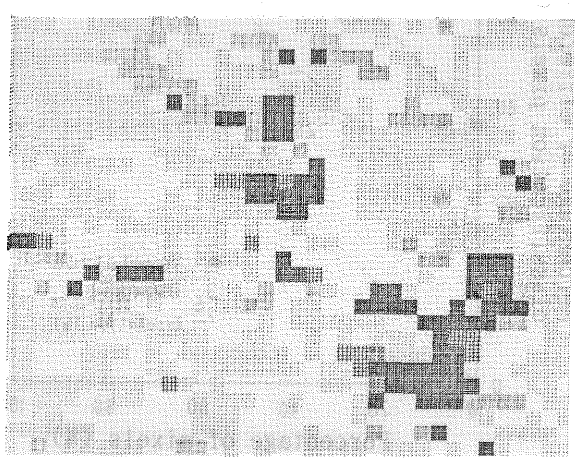


Fig. 12-(a) Results of classification using simulation data with a 5m resolution. (Detached housing area-B)

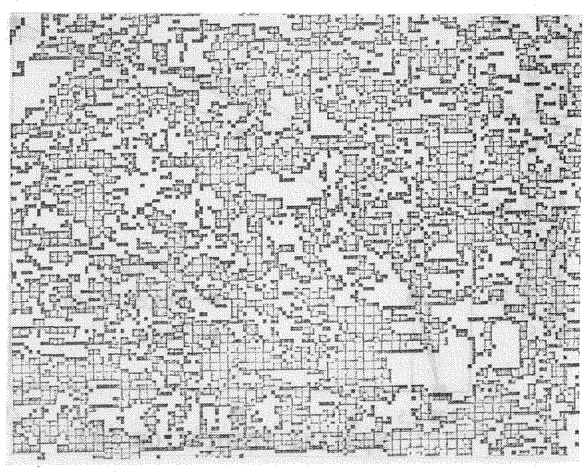


Fig. 12-(b) Comparison of classification results for original data and simulation data with a 5m resolution. (Blackened pixel: classified in a different class from the original)

different class category from the original image was obtained. The relation between that ratio and spatial resolution was also discussed.

4.2. Results

Classification result for 1.25m resolution is shown in Fig.10. In Fig.11-(a) classification results for 2.5m resolution and -(b)pixels classified in different classes from the result for a 1.25m resolution are shown. In Fig, 12-(a),(b), results for 5m resolution are shown. For each resolution, most pixels classified in a different class are distributed on boundary lines of land cover class categories (the same as distributions of mixels).

The percentages of pixels classified differently from results for the 1.25m resolution are shown as a function of spatial resolution in Fig.13. For overall categories the percentages are reduced by half for a 2.5m resolution, but for a 10m resolution only 35% of pixels are classified in the same class. There are little differences in other categories, although they are 10-15% higher than the result for overall categories. Results for resolutions greater than 10m are less than 50%.

5. Comparison of the results for Mixel/Classification studies

The relation between the ratio of mixel and pixels which were classified into the same class for a 1.25m resolution is shown in Fig.15. The results of overall categories at less than 10m and for vegetation at less than 5m show linear correlation. But at greater resolutions, mixels are predominant and the reduction of the percentage of pixels classified into the same classes for the original resolution is independent from the ratio of mixels. This is believed to be because at the resolutions above the point of

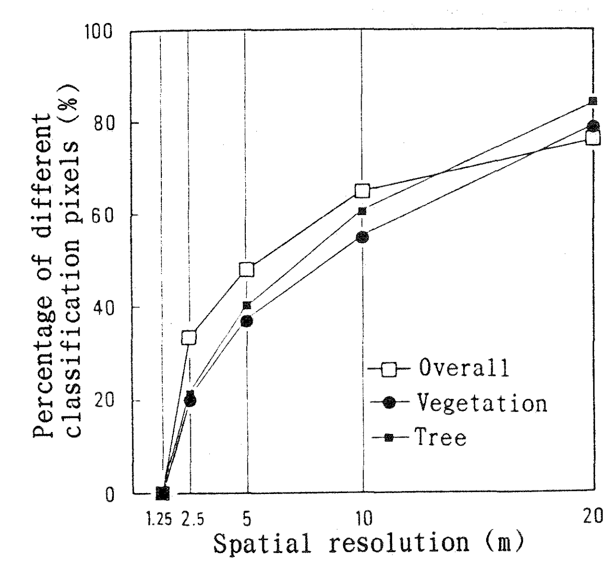


Fig. 13 Relation between the ratio of pixels classified in the different class from the original and spatial resolution.

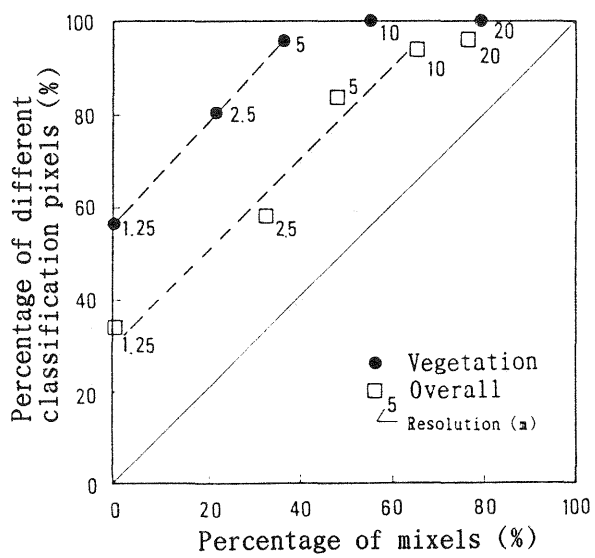


Fig. 14 Correlation between classification results using airborn MSS data or simulation data and the ratio of mixel in land cover grid images

change the areas of parcels of each category became less than those of a pixel. Therefore mixel-B became predominant.
The changing points were examined using histogram of parcels(Fig.6). At more than $25m^2$, corresponding for an area of pixels at 5m resolution (which is the changing point resolution of vegetation) there are less than 15% parcels of vegetation. At more than $100m^2$, corresponding an area of pixel at 10m (which is changing point resolution of overall categories) there are only 2% units. Also less than 10% of building areas are more than $100m^2$.
The effect of mixel on land cover classification results was assessed. As a consequence the increase in the ratio of mixels caused a decrease in the land cover classification accuracy.

6. Conclusions

We discussed the actual conditions of mixels and the effect on classification accuracy, selecting two types of residential areas. This paper first, obtains the relation between the ratios of mixels and pure pixels and spatial resolution using a land cover grid map. The results of this analysis are as follows;
(1)The ratio of pure pixels are 80-60% at spatial resolution of 1m. This distribution follows a decrease according with the decline in spatial resolution. At a spatial resolution of 5m the ratios of pure pixels decrease by about 20%.
(2)In an image with less than 5m of spatial resolution, there is little pure pixel and almost all mixel.
(3)We divided mixels into two groups: mixel-A which are pixels composing plural categories and not containing detached parcels, mixel-B which are pixels composing plural categories containing detached parcels. At less than 2.5m, most mixels are mixel-A. At 5m some amount of mixel-A changed into mixel-B. The ratios of mixels for all areas show little alteration between 10m and 30m resolution, but mixel-B became predominant at 10m in the Detached housing area-A. The ratio of mixel-B is 90% at 30m and, in the Housing complex area, mixel-A is still predominant at 10m.
Second, using simulation images with various resolutions the ratio of pixels classified in the different class category from the original image was obtained. The relation between that ratio and spatial resolution was also discussed. For overall categories the percentages are reduced by half for a 2.5m resolution, but for a 10m resolution only 35% of pixels are classified in the same class. Finery, the effect of mixel on land cover classification results was assessed. As a consequence the increase in the ratio of mixels caused a decrease in the land cover classification accuracy.

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