ESTIMATION OF LANDFORM CLASSIFICATION BASED ON LAND USE AND ITS CHANGE
- Use of Object-based Classification and Altitude Data -

Shoichi NAKAI[1] and Jaegyu BAE[2]

[1] Professor, Chiba University, Chiba, Japan. Email: nakai@faculty.chiba-u.jp
[2] Graduate Student, Chiba University, Chiba, Japan. Email: baelee@graduate.chiba-u.jp

SUMMARY

This paper aims to establish a method of obtaining landform classification in a wide area based on land use and its change. A fundamental method has already been proposed in the previous study in which Chiba city and its surrounding area were considered and it was pointed out that the land use of old times and satellite image are effective to this classification. In this study, this method of classification has been extended such that a new method of image classification was applied. This image classification is based on image objects rather than individual pixels. Image objects have a various attributes in addition to spectral intensity of pixels. In addition, Digital Elevation Model (DEM) was used in order to distinguish between terrace and local relief. From this study, it was found that image objects and altitude data are effective for classification.

INTRODUCTION

In recent years, the population in urban areas and expansion of human activities have shown a rapid increase. As a consequence, it has been a situation in that buildings have to be built on a land that is developed without paying much attention to its ground condition but with placing an emphasis on economic efficiency. These areas which have suffered land alteration, however, are prone to natural disasters, such as earthquakes, due to loosened soils for example. Thus, it is essential to know the condition of the ground when considering earthquake disaster prevention and mitigation as well as planning to construct buildings and facilities. However, to collect information on the ground condition over a wide area is not an easy task. In order to solve this issue, the authors have looked at the fact that the condition of the ground is closely related to the landform. This paper aims to establish a method for obtaining landform classification in a wide area based on land use and its change.

A fundamental method of analysis has already been proposed in the previous study[1, 2, 3] in which Chiba city and its surrounding area were considered and it was pointed out that land use of old times and satellite (Landsat/TM) data are effective to this classification. In this paper, this method of classification is briefly reviewed and then an extension to the method is discussed in which a new method of image classification is applied. The new method of image classification is based on image objects rather than individual pixels. Image objects have a various attributes in addition to spectral intensity of pixels. In addition, Digital Elevation Model(DEM) is used in the method in order to distinguish better between terrace and local relief.

METHOD OF ANALYSIS

Outline of method

In this study, landform classification is carried out by the following steps:

- The first step is to extract land use data from maps in the old times.
- The second step is to obtain land use in the present time based on satellite data.
- The third step is to obtain DEM data.
- By applying inference rules to this set of land use data, and also by considering DEM data, it is possible to come up with landform classification. The procedure is illustrated in Fig. 1.

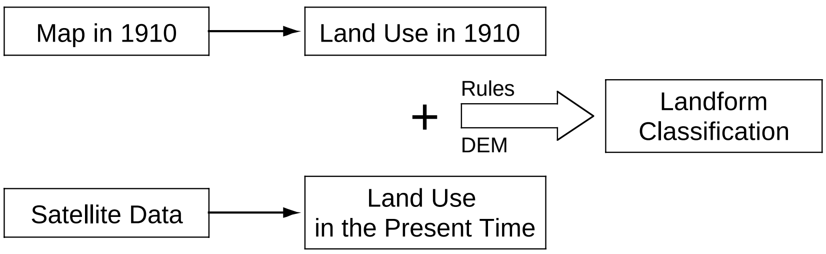

Fig. 1 Procedure for landform classification

Land use in the old times

Chiba area has been chosen for the study. From a topographic map drawn on a scale of 1 to 50,000 made in 1903. Land use and vegetation are extracted and converted to a digital form by using an electronic digitizer. Fig. 2 shows the land use and vegetation of Chiba area in 1903.

Land use in the present time

Latest information on land use is available in a digital format from Geographical Survey Institute, Ministry of Land, Infrastructure and Transport, Japan. However, this information is given as grid data that consist of pixels with the size of 1 kilometer or 100 meters,

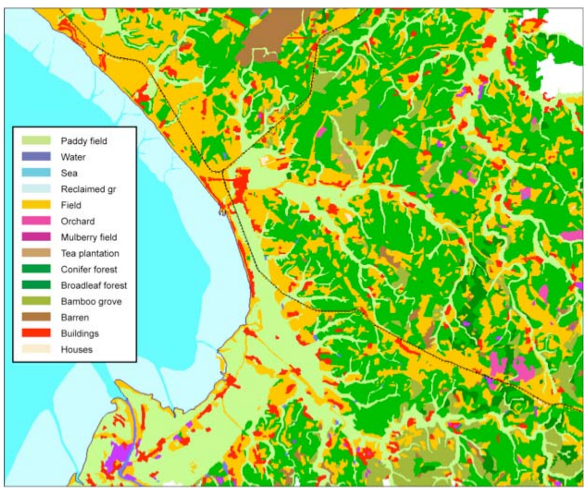

Fig. 2 Land Use of Chiba in 1903

which is a little too large when micro landform of the size of 100 meters is discussed. Therefore, we need another source of information and will look at satellite data.

The satellite data that was used in this study is Landsat Thematic Mapper (TM) data. A procedure of land use classification based on the satellite data is shown in Fig. 3. In this study, three scenes of September, 1986 (scene I), June, 1987 (scene II), and July, 1987 (scene III) were used. The procedure is summarized as follows:

1 Compute NDVI of the scene II and III. NDVI (Normalized Difference Vegetation Index) is an index which is believed to indicate vegetation activity[4]. In the case of Landsat TM, NDVI can be computed by the following expression:

$$NDVI = \frac{Badn4 - Band3}{Band4 + Band3} \quad Band3: \text{visible} \quad Band4: \text{near infrared}$$

2 Compute the difference of the two NDVI's. This seasonal difference is introduced to classify paddy fields in an efficient manner.

3 Except for band 6 which has comparatively low resolution, a total of six bands are created from the scene I. The difference of the two NDVI's is added to form a data set with a total of seven bands.

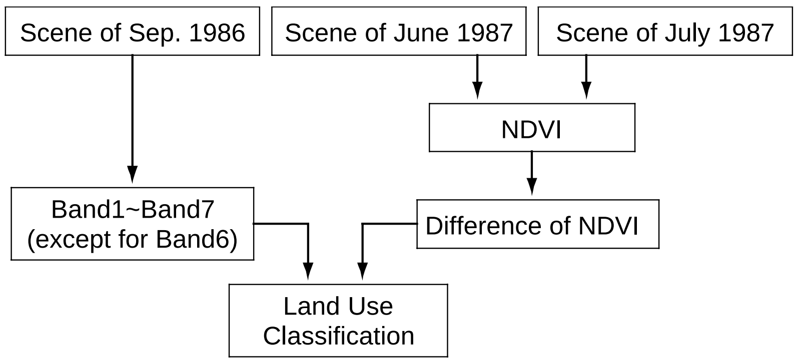

Fig. 3 Procedure for Land Use Classification

LAND USE CLASSIFICATION

Method of land use classification

The supervised classification was performed by the land use classification in the previous study. In this study, a pixel-based supervised classification (method I) and a new method of image classification (method II) are introduced. The image classification is based on image objects rather than individual pixels[5]. Method I is a classification based on individual pixels. Image objects have a set of attributes in addition to the spectral intensity of pixels. Fig. 4 shows the result of pixel-based classification. Fig. 5 shows the result of object-based classification. Fig. 6 shows 1/10 detailed digital land use information in 1989 which was issued from Geographical Survey Institute.

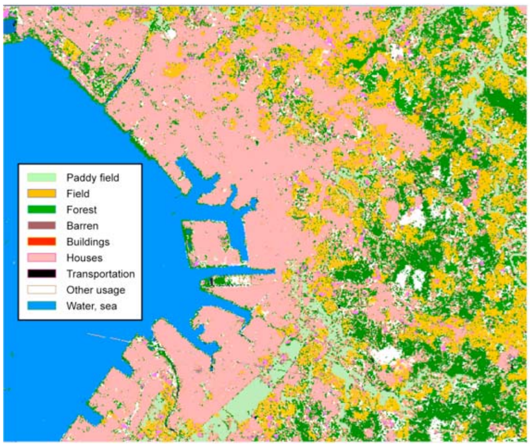

Fig. 4 Result of pixel-based classification (method I)

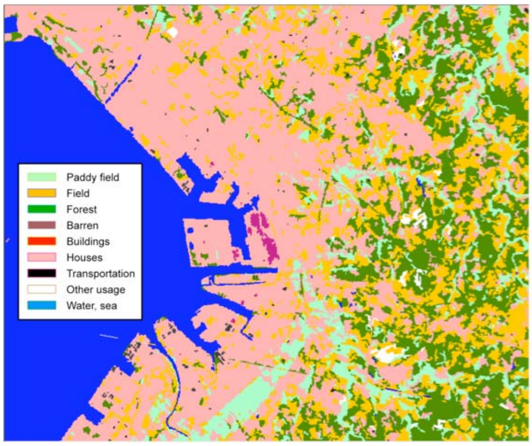

Fig. 5 Result of object-based classification (method II)

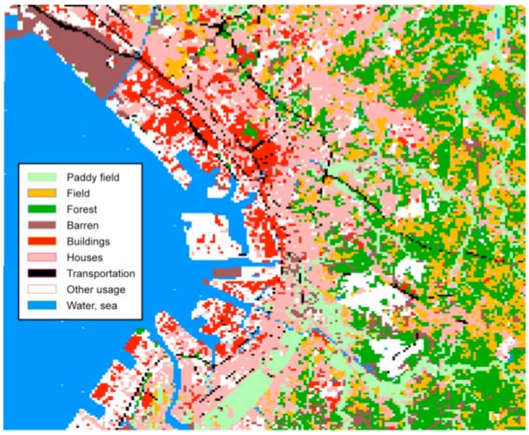

Fig. 6 1/10 detailed digital land use information

Discussion

Pixel-based classification usually gives a result that looks like a mosaic picture, as shown in Fig. 4. The reason for this is that the resulted land use classification is an assembly of pixels. Compared with this, the object-based method can give a better result that consists of a number of polygons, as shown in Fig. 5. By comparing these two results with Fig. 6, it is possible to say that overall the method II can give more accurate classification than the method I. Especially, classification of buildings, fields and paddy fields can be done well by the method II.

LANDFORM CLASSIFICATION

Method of landform classification

Landform classification is obtained by applying inference rules to the land use data of old times and the present time. Table 1 summarizes the rules that are used to infer micro topography from the change of land use. The inference rules listed in Table 1

Table 1 Inference rules

Land use in 1910	Land use in 1986	Possible landform
Paddy field	Paddy field	Lowland
Paddy field, water	Building, road	Fill
Forest	Building, road	Leveled ground
Forest	Field, orchard	Terrace, local relief
Forest	Other than above	Other than lowland
Building	-	Terrace, local relief
Field, etc.	-	Terrace, local relief

are not sufficient for the distinction between terrace and local relief. In order to address this, altitude and gradient are considered in addition to land use. In the previous study, the average altitude of pixels that form a line in a selected scene of satellite data, either in an east-west direction or a north-south direction, was adopted as a means of distinguishing between terrace and local relief.

In this study, the following rules are used instead:

1 An average terrain surface for the whole area under investigation is calculated by a multiple regression analysis and is used to distinguish between terrace and local relief by comparing the altitude of each pixel with the average surface.

It was found from the analysis that the method described above gives a good result for terrace, but a poor result for local relief. In order to obtain better results for both, additional classification is further carried out for the areas that are identified as terrace and local relief:

2 A new category of landform "slope" is introduced. Classification for this category is done such that the ground with the angle of gradient greater than 20 degrees is categorized as slope. Here, the angle of gradient is computed from the altitude data (DEM).

3 Distinction between terrace and local relief is judged by introducing a new threshold for altitude, which corresponds to the average altitude of lowland that is found in the neighboring limited area (a "windowed" area).

Fig. 7 shows the distribution of thus obtained angle of gradient. Fig. 8 represents a landform classification map computed without considering slopes, while Fig. 9 shows the result obtained by the introduction of slopes. Fig. 10 shows a 1/25,000 land condition map issued by Geographical Survey Institute.

Discussion

A comparison among Figs. 7 through 10 shows that by considering slopes it is possible to get a better classification result. Especially, the new method of distinction between terrace and local relief does a very good job.

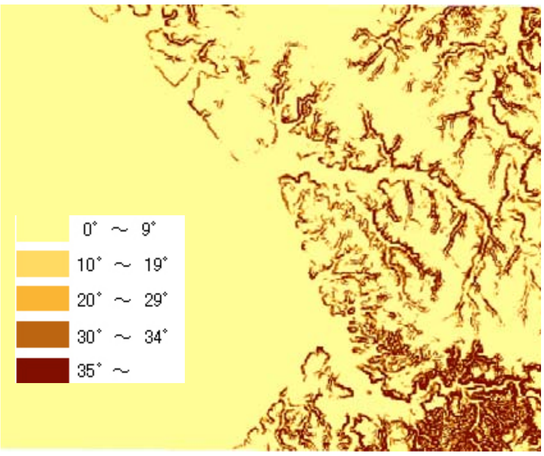

Fig. 7 Distribution of angle of gradient

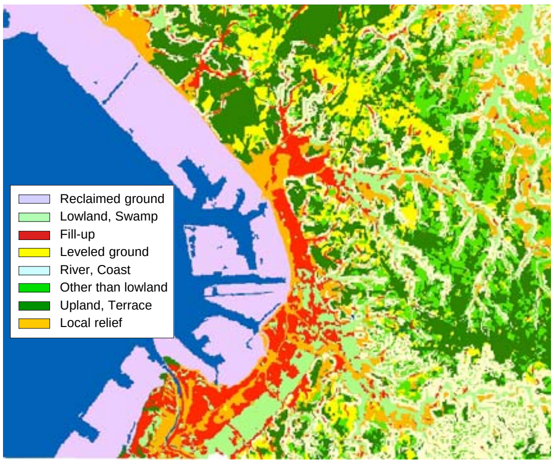

Fig. 8 Landform classification without considering slopes

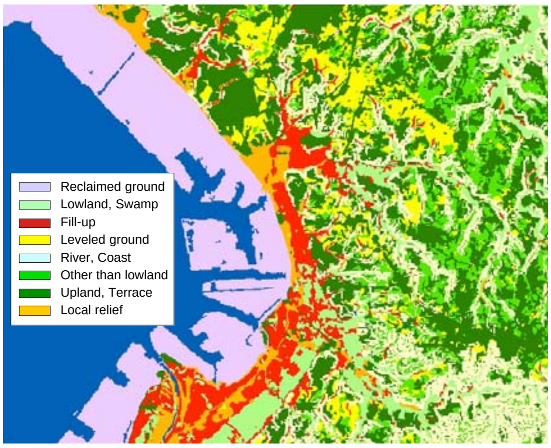

Fig. 9 Landform classification by considering slopes

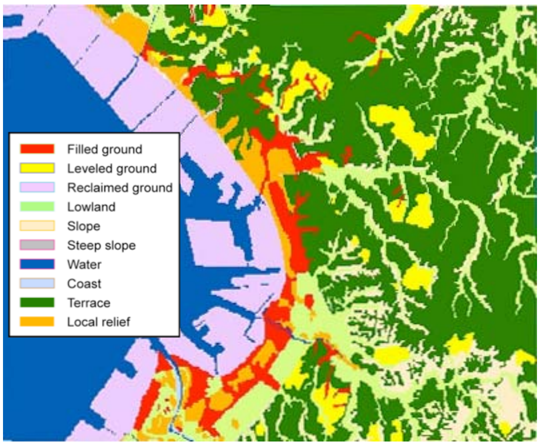

Fig. 10 Land condition map of 1/25,000

ANALYSIS OF CHIBA AREA

Landform classification in Chiba area

Based on the method described above, landform classification was performed for Chiba area that is located about 50 kilometers east of Tokyo. Fig. 13 shows the results. It is pointed out from this figure that:

- The landform of these areas consists of a coastal alluvial lowland and an inland diluvial upland.
- A wide band of reclaimed ground is strung out along the coast of Chiba area. Inside this reclaimed ground is a narrower band of filled ground that used to be paddy fields.

・ A fairly wide and intermittent range of local relief is strung out in the alluvial lowland along the coast of Togane area. The elevation of this local relief relative to the surrounding marsh is very small.

・ The diluvial upland in both areas is a dissected plain with a dendritic pattern of alluvial valleys.

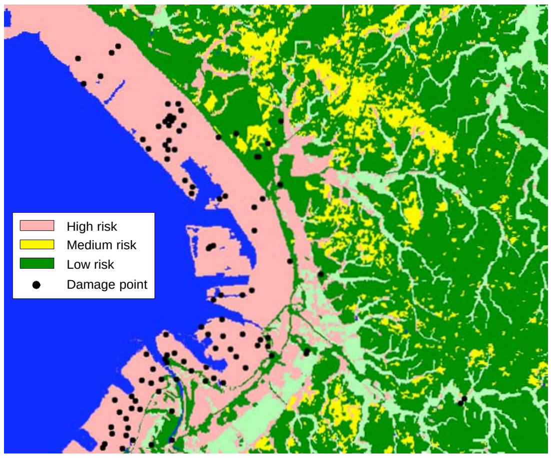

Fig. 14 Ground condition and natural hazard risk

Estimation of ground conditions and natural hazard risk

As has been pointed out by a number of researchers, there is a close relationship between landform and soils. Table 2 summarizes such relationships. Estimating the outline of the ground condition of a site is thus straightforward. Once the ground condition is obtained, then it is possible to evaluate natural disaster risk of a site. Fig. 14 shows a map of disaster risk in which the area is classified based on the intensity of seismic risk due to the ground condition. Locations of damage points during Chiba-ken Toho-oki earthquake in 1964 are also plotted in the figure. It is clearly seen from the figure that most of damage points are situated either on the area designated as high risk area or on the boundary between two landforms.

Table 2 Relationship between landform and soil condition

Landform	Possible soil condition
Backmarsh	Soft alluvial silt/clay
Fill	Fill underlain by alluvium
Reclaimed ground	Fill underlain by alluvium
Leveled ground	Cut and fill of diluvium
Plateau, terrace	Diluvium
Local relief	Alluvial sand/gravel

CONCLUSIONS

In this study, landform classification based on land use and its change was examined. Altitude data were also used for classification. As a result, the following points are made:

1 The proposed method is applicable to southern Kanto Plain.

2 An improvement in the accuracy of land use classification based on satellite data can be made by taking into consideration a set of attributes in addition to spectral intensity.

3 The use of altitude data is effective for the distinction between terrace and local relief.

4 Natural disaster risk is high in those areas where the ground condition is poor.

REFERENCES

1. Nakai S., Tanaka K., and Kondoh A. "A study on the Estimation of Soil Condition Based on the Change of Land Use." Proc. 10th Japan Earthquake Engineering Symposium; 3; 1998: 3401-3406.
2. Nakai S., Yamaguchi S. and Ishida R. "Estimation of Soil Conditions Based on Land Use in the Old Times and Satellite Data." J. Struct. Constr. Eng., Architectural Institute of Japan; 552; 2002: 69-75. (in Japanese)
3. Bae J., Nakai S. and Ishida R., 2004. A Study on the Landform Classification Based on the Change of Land Use, Proc. Annual meeting of Japanese Geotechnical Society 2004: 63-64. (in Japanese)
4. Nagatani K. "The foundation of remote sensing data analysis." 2001 (in Japanise)
5. Definiens “eCognition Functional Guide.” 2003.