Paper presented at the 22nd Asian Conference on Remote Sensing, 5 - 9 November 2001, Singapore.

ANALYSIS OF THE URBANIZATION USING THE EXTENT AND DISTRIBUTION OF LAND-COVER CHANGES

Kiichiro KUMAGAI
Lecture, Dept. of Civil Engineering
Setsunan University
17-8 Ikedanakamachi, Neyagawa, Osaka 572-8508
Phone & Fax: +81-72-839-9122
E-mail: kumagai@civ.setsunan.ac.jp
JAPAN

Genya SAITO
Head of Ecosystem Group, Dept. of Global Environments
National Institute for Agro-Environmental Sciences
3-1-1 Kannondai, Tsukuba, Ibaraki 305-8604
Phone: +81-298-38-8228 FAX: +81-298-38-8199
E-mail: genya@niaes.affrc.go.jp
JAPAN

KEY WORDS: land classification map, distributional entropy, areal ratio, urbanization

ABSTRACT: There are various forms for land-use change processes in urbanization. In the case of evaluating the land use widely with land classification maps calculated from satellite remotely sensed data, it is required to investigate not only the areal ratio of each land-cover class but also the complexity of each land-cover distribution. In the area where land-cover classes are distributed complexly each other, there is a possibility that the urban sprawl may have occurred. The objective of this study is to analyze land-cover changes with the spatial analysis, developed ourselves in 2000, using land classification maps. The spatial analysis of each land-cover class included a window process for the local calculation of areal ratio and distributional entropy. As a result, it was suggested to be able to extract the complex areas of land cover by overlaying the discriminant-analysis results of the areal ratio and distributional entropy of each land-cover class. Finally, we proposed the procedure of evaluating the extracted areas with three land-cover maps. It was indicated that the proposed procedure was useful for estimating the process of urbanization in the extracted areas.

1. INTRODUCTION

There are various forms for land-use change processes in urbanization. In the case of evaluating the land use widely with land-cover classification maps calculated from satellite remotely sensed data, it is required to investigate not only the areal ratio of each land-cover class but also the complexity of each land-cover distribution. In the area where land-cover classes are distributed complexly, there is a possibility that the urban sprawl may have occurred. The urban sprawl has a tendency to occur by boundaries between the urban area and the other land-cover class areas. It is important for the urban development and urban renewal to extract the parts with the possibility that urban sprawl may have been generated from a wide area. The objective of this study is to analyze land-cover changes with the spatial analysis, developed ourselves in 2000, using land classification maps. The spatial analysis of each land-cover class included a window process for the local calculation of areal ratio and distributional entropy. We carried out a discriminant analysis using the distributional entropy and the areal ratio every land-cover class. Through making overlapping images between the results of the discriminant analysis, we proposed a comparison procedure for the analysis of land-cover changes. In this study, the effectiveness of the proposed procedure was verified using the city planning zones of Marugame city.

2. MATERIALS AND METHODS

2.1 Study Area

Figure 1 shows the study area that is located in the western Sanuki Plains, Shikoku, the western part of Japan. The test site is a region surrounded in the dotted lines in Figure 1. It covers 12 km horizontally by 12 km vertically. There are the Seto-Ohashi bridges constructed in 1988 near the north part of the test site. It is assumed that various forms for land-use change have occurred in the test site because of the changes of a transportation mode due to the construction of the Seto-Ohashi bridges.

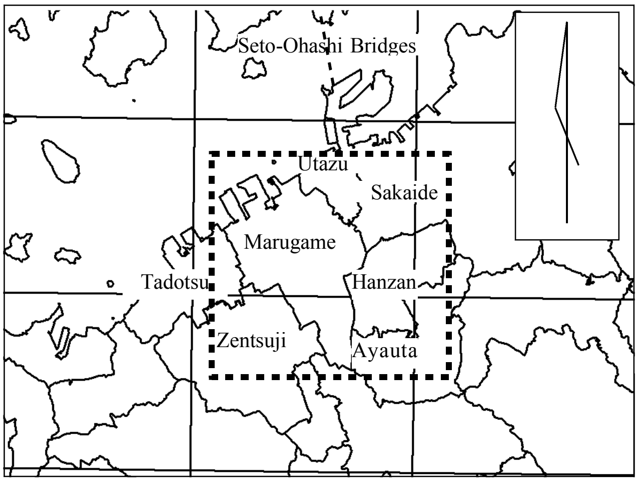


Figure 1 Test area in this study. The test site enclosed with dotted lines covers 12 km by 12 km.

2.2 Satellite Data

Table 1 Classification accuracy

Date	5/8/1984	5/6/1990	4/26/1997
Division accuracy(%)	99.1	99.2	98.7
Error ratio(%)	1.3	1.2	2.1

We used three satellite remotely sensed data, Landsat-5 TM data observed on May 8, 1984, May 9, 1990, and April 26, 1997, respectively. The study area was not covered with clouds in the images obtained from each satellite data. Moreover, we made three land classification maps with the maximum-likelihood method from these satellite data. Land-cover classes were adopted as follows: urban, agricultural fields, forest, glass, bare soil, and water body. Training areas for the classification were selected from each image based on our ground-truth checking. Table 1 shows the classification accuracy of each land-cover classification map. Division accuracy, D_i, is described as

$$D_i = M_i \;/\; N_i \times 100 \qquad (1)$$

where M_i is the number of pixels classified again as a class i in the training area defined originally as the class i, and N_i is the number of pixels in the training area defined originally as the class i.

An error ratio, E_i, is written as (Congalton, 1983)

$$E_i = \Sigma(M_{ij} + M_{ji}) \;/\; N_i \times 100 \qquad (2)$$

where M_{ij} is the number of pixels classified as a class j in the training area defined originally as a class i and M_{ji} is the number of pixels classified as the class i in the training area defined area originally as the class j.

The classification was carried out with the average of the division accuracy ranged from 98.7-99.2 % and error ratio ranged from 1.3-2.1 %. The land classification maps seemed to be available for the analysis of the urbanization.

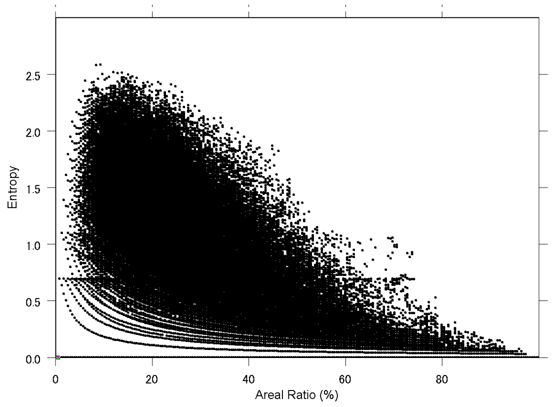


Figure 2 Relationship between the distributional entropy and the areal ratio (the urban in 1997).

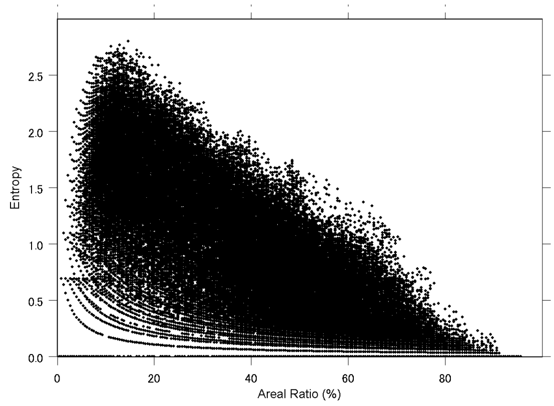


Figure 3 Relationship between the distributional entropy and the areal ratio (the agricultural fields in 1997).

2.3 Methods

2.3.1 Calculation of the Extent and Distribution of Land cover: Evaluating the complexity of land cover distribution, we calculated distributional entropy with the two-valued images of each land-cover class derived from the land classification maps (Turcotte, 1997). The calculation of distributional entropy, En_i, is described as

$$\begin{aligned} En_i &= \log \{N_i! \,/\, (N_{i1}! \cdot N_{i2}! \cdot \ldots \cdot N_{ik}!)\} \times 1 \,/\, N_i \\ &= - \sum_j f_{ij} \log f_{ij} \quad (j = 1, 2, \ldots, k) \end{aligned} \tag{3}$$

where N_{ij} is the number of pixels classified as a class i, which forms a region in isolation from each other, j the discriminated symbol of the formed region, $N_i = N_{i1}+N_{i2}+\cdots+N_{ik}$, $f_{ij} = N_{ij} / N_i$. We applied this calculation to the two-valued images derived from the land classification maps through the window process with a size of 15 pixels by 15 pixels (Kumagai, 2000).

Likewise, the areal ratio, A_i, of each land-cover class was calculated with the window process using the following equation.

$$A_i = (N_i \,/\, N) \times 100 \tag{4}$$

where N is all the number of pixels included in the window.

In this study, we selected two land-cover classes, the urban and the agricultural fields because the urban sprawl had a tendency to occur by boundaries between them in the test site. Figures 2 and 3 show the scatter diagrams between the distributional entropy and the areal ratio on the urban and agricultural fields of the land classification map in 1997, respectively. Plotted points are distributed like a triangle on the scatter diagrams. It indicates that there are more various states of land-cover distributions as the areal ratio is lower.

2.3.2 Discriminant Analysis: For the distributional entropy and the areal ratio, discriminant analysis was executed with data as standard. According to our ground-truth checking, the standard data of the urban were defined 4 items such as the center of a city (CC), the suburb of a city (SC), the rural area (RA), and the scattered area of the urban (SAU). On the other hands, the standard data of the agricultural fields were defined 4 items such as the large agricultural fields (LA), the middle-size agricultural fields (MA), the narrow agricultural fields (NA), and the scattered area of the agricultural fields (SAA).

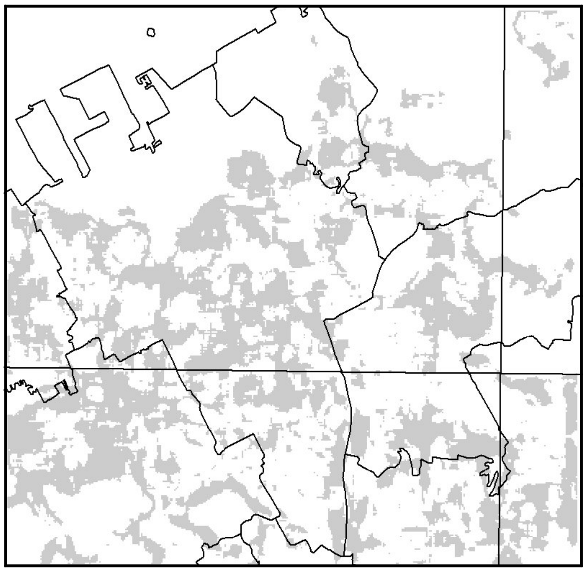


Figure 4 Overlapping image between SAU and MA.

2.3.3 Making Overlapping Images: SAU is the important part for evaluating urban sprawling. Two or more items, however, exist together complexly in the sprawl zone. Therefore, we extracted the parts where SAU and MA overlapped one another from the discriminant results so that the relationship between the two areas might be verified. Figures 4 shows a overlapping image between SAU and MA in 1997. It is shown that the overlapped areas are widespread in the test site.

2.3.4 Consideration of Land-cover Changes: For considering land-cover change, we had two viewpoints of the comparisons between the overlapping images in 1984, 1990, and 1997. One of the viewpoints means an analysis on the important parts where SAU and MA overlapped one another in 1997 (see Figure 5). The other means an analysis on the other overlapping parts in 1997 although there were covered with both SAU and MA in 1984 or 1990 (see Figure 6). The former is defined as the current analysis because the areas where the important parts are overlapping under current states are investigated through the past. The latter is defined as the past analysis since the areas covered with important results in the past urbanization process are examined. For example, Case 1 implies that there may have been the complex states of the urban and agricultural fields from 1984 until 1997. Case 4 suggests that urban development may be currently in progress. Case 3 contains land-cover changes other than the change between the urban and the agricultural fields. Cases 6 and 7 indicate the possibility of urban development process from 1984 until 1997.

3. RESULTS AND DISCUSSION

3.1 Results

Figures 7 and 8 show the results based on the current analysis and the past analysis, respectively. In Figure 7,

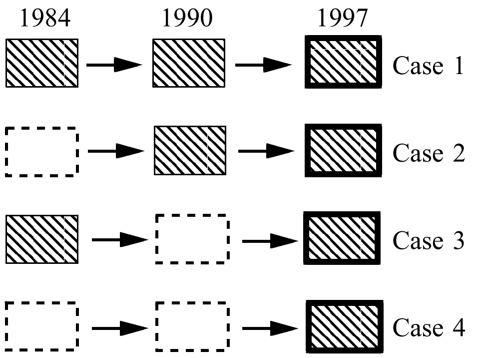


Figure 5 Concept of the current analysis. [hatched box] means that SAU and MA overlap one another, while [dashed box] means the other overlapped area.

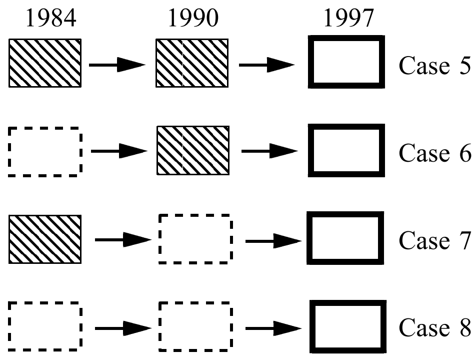
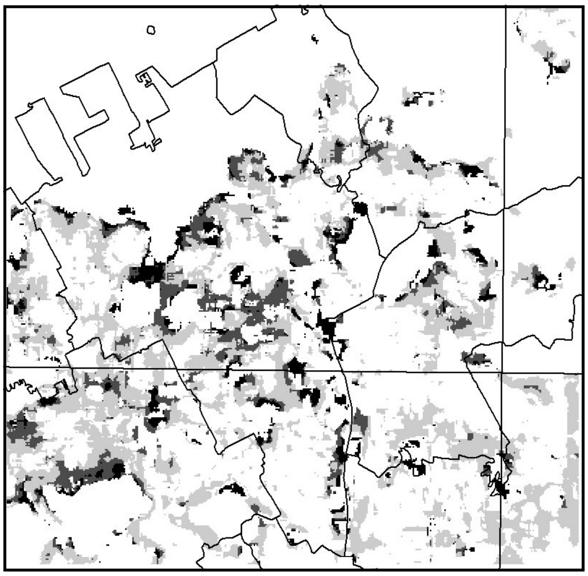


Figure 6 Concept of the pass analysis. In this study, [open box] means CC and NA overlap each other.



:Case 1, :Case 2, :Case 4

Figure 7 Results of the current analysis.

:Case 5, Case 6, :Case 7, :Case 8

Figure 8 Results of the past analysis.

the result cases of the current analysis except Case 3 are indicated since the objective of this study is to evaluate the relationship between the urban and the agricultural fields. It appears that Case 4 covers across a wide area in the test site. Therefore, it is suggested that urbanization in the agricultural fields from 1990 until 1997 was remarkable.

For example, we adopted the parts where CC and NA overlapped each other in 1997 as the current state at the past analysis in Figure 8. It is shown that Cases 5, 6, and 7 are distributed in surroundings of Case 8. It seems that the urbanization with complex distributions of the urban and agricultural fields might have been occurred around the center cities.

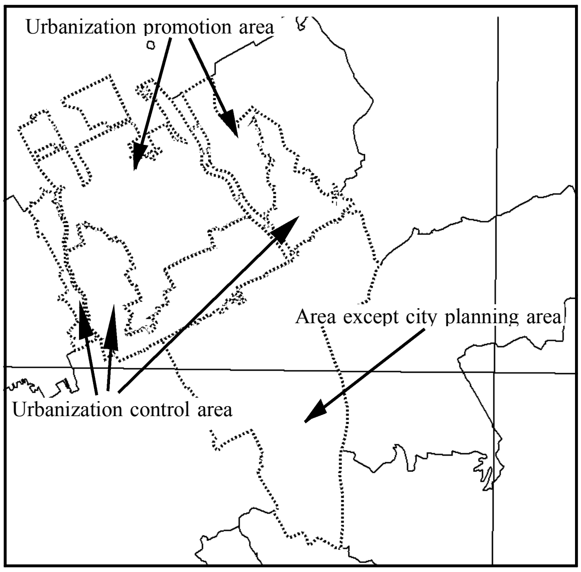


Figure 9 City planning zones in Marugame city.

3.2 Discussion

Assuming the actual use of the supposed procedure for urban planning, it is required to compare the current and past analysis results with the city planning zones. We took Marugame city as a example to investigate the extent and distribution of land-cover changes in each city planning zone. Figure 9 shows urban planning zones in Marugame city, while Figures 10 and 11 indicate the area of each case every urban planning zone at the current analysis and the past analysis, respectively. Under city planning system in Japan, the active development is recommended in the urbanization promotion area, while the control of development and the environmental conservation are executed in the urbanization control area.

3.2.1 Current Analysis: In Figure 10, there seems to be larger area of Case 1 in the urbanization promotion area than in the urbanization control area. The difference of Case 1 areas between the urbanization promotion area and the urbanization control area shows about 30 ha. On the other hands, the area of Case 4 in urbanization promotion area indicates smaller than in urbanization control area. The difference of Case 4 areas between them shows about 130 ha. Thus, it is suggested that the application of the city planning methods such as a settlement

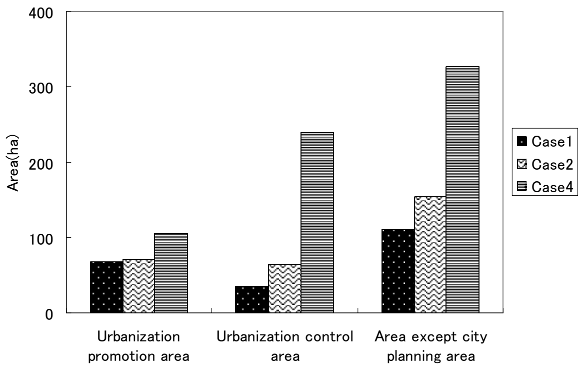


Figure 10 Results of the current analysis every city planning zone.

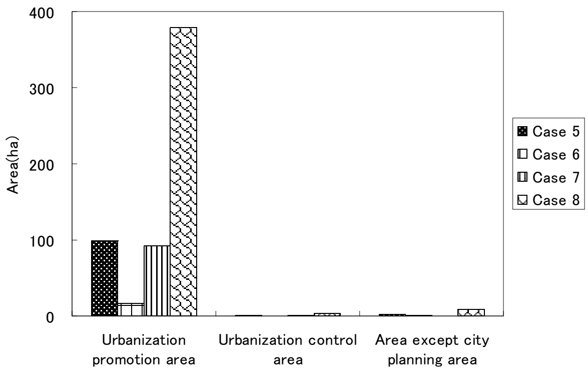


Figure 11 Results of the past analysis every city planning zone.

district plan may be necessary for the urbanization control area so that the complex areas between the urban and the agricultural fields seem to increase from 1990 till 1997. In the area except city planning area, the area of Cases 1, 2, and 4 seems widespread. This result indicates that it may be necessary to examine the designation of these areas as the quasi-city-planning area where only land-use control is applied.

3.2.2 Past Analysis: It appears that the area of Case 5 and the area of Case 7 are approximately equal. However, most of Case 5 areas locate in surroundings of Case 8 areas (see Figure 8). Therefore, it is shown that in the parts around CC, there is a possibility that the urban and the agricultural fields might have been scattered each other.

4. CONCLUSIONS

Land classification maps made from Landsat TM data observed three times from 1984 until 1997 were used for the calculation of the areal ratio and the distributional entropy with the window process. Through the discriminant analysis with the areal ratio and the distributional entropy, it was suggested to be able to extract the complex areas of land cover by overlaying the discriminant-analysis results of each land-cover class. Finally, we proposed the procedure of evaluating the extracted areas with three land-cover maps. It was indicated that the proposed procedure was useful for estimating the process of urbanization in the extracted areas through the comparison with the city planning zones.

REFERENCES

Congalton, R. G., Oderwald, R. G. and Mead, R. A., 1983. Assessing Landsat classification accuracy using discrete multivariate analysis statistical techniques. Photogrammetric Engineering and Remote Sensing, 49 (12), pp.1671-1678.

Kumagai, K., Saito, G., and Urabe, H., 2000. Development of a spatial analysis method for land cover taking into account the complexity of local distributions. Papers on Environmental Information Science, 14, pp.1-6.

Turcotte, D. L., 1997. Fractals and Chaos in Geology and Geophysics. Cambridge University Press, United Kingdom, pp.113-131.