A Simple Relationship between Neighborhood and Land Use Change: An Empirical Study in Japan

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Introduction

From the 1990s onward, many articles focusing on the application of Cellular Automata (CA) to the modeling of land-use dynamics have been published. (Santé, 2010) Nevertheless, calibration of created models utilizing empirical data was not fully carried out in most cases partly because it is difficult to collect the land use data at each small land division.

Fortunately, recently another source, “National Land Numerical Information, Land Use Tertiary Mesh” (NLNI data) has been published by the Ministry of Land, Infrastructure, Transport and Tourism in Japan. It covers almost over Japan and contains 100m grid land use data. The number of categories is 11 as shown in Table 1.

Table 1: Categories of land use

Land use category	Urban or Non Urban
Paddy field	Non
Other agricultural land	Non
Forest	Non
Waste land	Non
Building land	Urban
Trunk transportation land	Urban
Other use (Under construction)	Urban
Rivers and lakes	Non
Beach	Non
Salt waters	Non
Golf course	Non

Generally, in a set of local rules for a cellular automaton, the relationship of the present states of a site and its nearest neighbors to the state to be taken by the central site on the next time step is essential. This research focuses on finding the relationship between a grid's land use change and the land uses in its neighborhood. Three regional hub cities of northern Central Japan, namely Kanazawa, Toyama and Fukui are picked out for the case study areas. (Figure 1) By analyzing the NLNI data of three areas in the year 1976, 1987, 1997 and 2006, a simple stable long term relationship has been found.

Finding a relationship

What relationship?

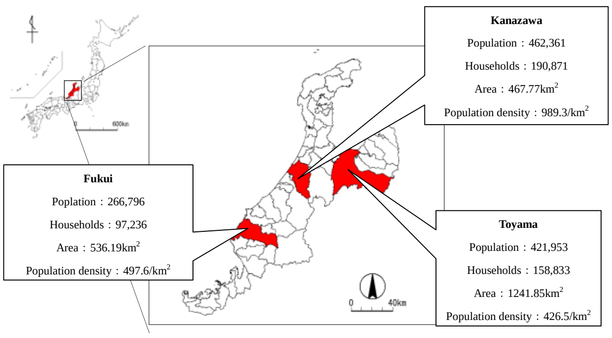

Figure 1: Three regional hub cities

In order to find a fundamental relationship, land use categories are re-categorized into two categories, namely urban and non-urban as shown in Table 1.

In the following equation, Z(t,t+dt,k) is the proportion of the number of grid cells each of which has changed its land use from non-urban to urban between time t and t+dt and which has k urban cells within its Moore neighborhood. Y(t,t+dt,k) is the number of grid cells each of which has changed its land use and has k urban cells within its neighborhood. X(t,t+dt,k) is the number of grid cells each of which is non-urban and has k urban cells within its neighborhood. Accordingly,

$$Z(t,t+dt,k)= Y(t,t+dt,k) / X(t,t+dt,k) \quad (1)$$

The relationship **F** which is the target of this study is a mapping or a mathematical function which satisfy the following equation.

$$Z(t,t+dt,k)= \mathbf{F}(k) \quad (2)$$

Results of data analysis

Since the intervals of the time which the data were taken are different, values of Z which were calculated by (1) were converted to 10 years average values (Z*). Namely,

$$Z^*(t, k)=1- (1-Z(t, t+dt, k))^{10/dt} \quad (3)$$

The following three figures show the results of calculations. They show the shapes of function F in three periods, namely for 30 years, in three case areas.

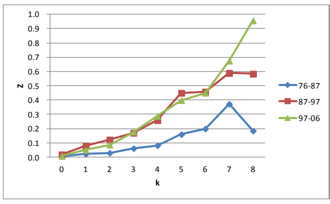

Figure 2: Fukui city

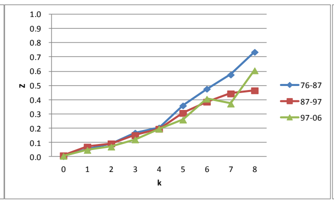

Figure 3: Toyama city

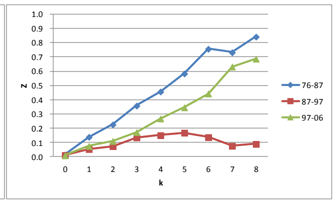

Figure 4: Kanazawa city

Except the second period, between 1987 and 1997, in the biggest city, Kanazawa, the curves are monotonically increasing. In the second largest city, Toyama, the shapes in three periods are almost the same. In the smallest city, Fukui, the shapes of the curves in the second and third periods are almost the same. The slope of the curve in the first period, which is the period of economic bubble, becomes steeper in proportion to individual city's population. In the second period, the backlash against the first bubble period appears in the largest city.

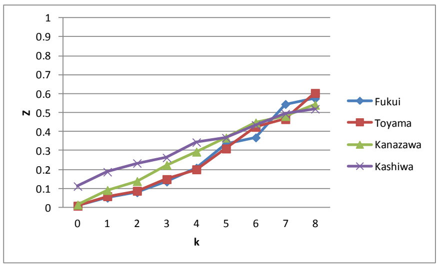

Figure 5: Relationships in three areas

However, as shown in Figure 5, the average curves for 30 years in three cities are almost the same, and the shapes of them are almost linear. Additionally, the line showing the relationship at Kashiwa area in Tokyo Metropolitan region, which was found in the separate work by the authors, is close to the three lines.

Conclusion

A simple and stable relationship between the state of the neighborhood and the land use change in the central site was found by simple calculation of published land use data in Japan. The equation of the function **F** is,

$$Z^*=\mathbf{F}(k)=0.075k \tag{4}$$

where, Z* is the change ratio of land use, from non-urban to urban, at a site, and k means the number of urban cells in the neighborhood of the site. In other words, if a non-urban use cell (100m square) is surrounded by k urban cells in its Moore neighborhood, then after 10 years its use will be changed to urban use with a probability 7.5k percent. Although the function is affected by some sudden economic change from the outside, over the long term it is stable and common in the Japanese cities.

References

Santé I., García A.M., Miranda D., Crecente R., 2010 Cellular Automata Models for the Simulation of Real-World Urban Processes: A Review and Analysis. Landscape and Urban Planning 96, 108-122.