FEASIBILITY STUDY ON DEMOGRAPHIC ANALYSIS BASED ON SPATIAL ANALYSIS APPLYING THE G STATISTICS

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KEY WORDS: Spatial analysis, population distributions, urban structures

ABSTRACT: In Japan, the population will keep decreasing over the next 40 years because of a declining birthrate and an aging society. The policy named "Compact Plus Network" has been promoted by the Japanese government. Under the policy that encourages maintaining sufficient population density in some core areas, the government stimulates the reproduction of community and realization of livable city. However, it is necessary to cope with “Urban spongification” which is the current and future problem with respect to lower population density of the center and fringe of a city. In this study, we discuss the spatial features of the population distribution through the application of several analysis methods.

1. BACK GROUND

In Japan, there have been a declining birthrate and an aging society since the late 1990s. The population will keep decreasing over the next 40 years. On the other hand, it is said that infrastructure maintenance costs will increase as suburbanization is still occurring. Under the initiative of the Ministry of Land, Infrastructure, Transport and Tourism, a policy named "Compact Plus Network" is promoted. In this policy, the government aims at reproduction of community and realization of livable city, while maintaining sufficient population density in some core areas. However, it is necessary to cope with “Urban spongification” which is the current and future problem with respect to lower population density of the center of a city because population inflows and outflows randomly occur around Residence Attraction Districts, defined as core areas for maintaining sufficient population density by the government. It is therefore desirable to analyze the population distribution spatially. We focused on railway stations that were generally designated as central facilities in the Residence Attraction Districts, and conducted the analysis of population distribution around them. Advanced Standard Distance (ASD) was applied to the analysis. The ASD is an improvement on Standard Distance (SD), which is an indicator of population concentration and diffusion. We used these 2 indicators to analyze population distribution fluctuations among 20 years. Nevertheless, the spatial scale and variation of the population distributions have not been analyzed yet because both indices are calculated based on the summation of the products of local populations and their distances to the center. In this study, we apply an analysis method composed of a spatial autocorrelation analysis to the population data generated through the 1995 and 2015 national census, and try to grasp population spatial dynamics. In particular, the spatial autocorrelation analysis, based on the G statistics, is performed with the increase of the distance parameter along 60-meter intervals. When positive spatial autocorrelation is determined, the determination results are stacked as virtual layers for the extraction of a range where high population points are concentrated. We compare the results between the application of the ASD and the accumulated number of layers by the spatial autocorrelation analysis around several characteristic points among 20 years.

2. DATA AND METHODOLOGY

2.1 Study Area

In this study, the whole area of Osaka prefecture was adopted as the target area. There is a second largest city in the Osaka prefecture, while a lot of satellite cities are located around the city. This area is almost designated as city planning areas. Local populations are distributed in various spatial patterns in the study area because there are completely urbanized areas, urbanized areas, and suburban areas.

2.2 Population Data

The basic unit blocks population data of the Population Census of Japan in 1995 and 2015 were applied to the analysis of demographic dynamics. The Population Census data is one of the results of the National Census. The basic unit blocks population data has the highest spatial resolution based on the management of National Census investigators.

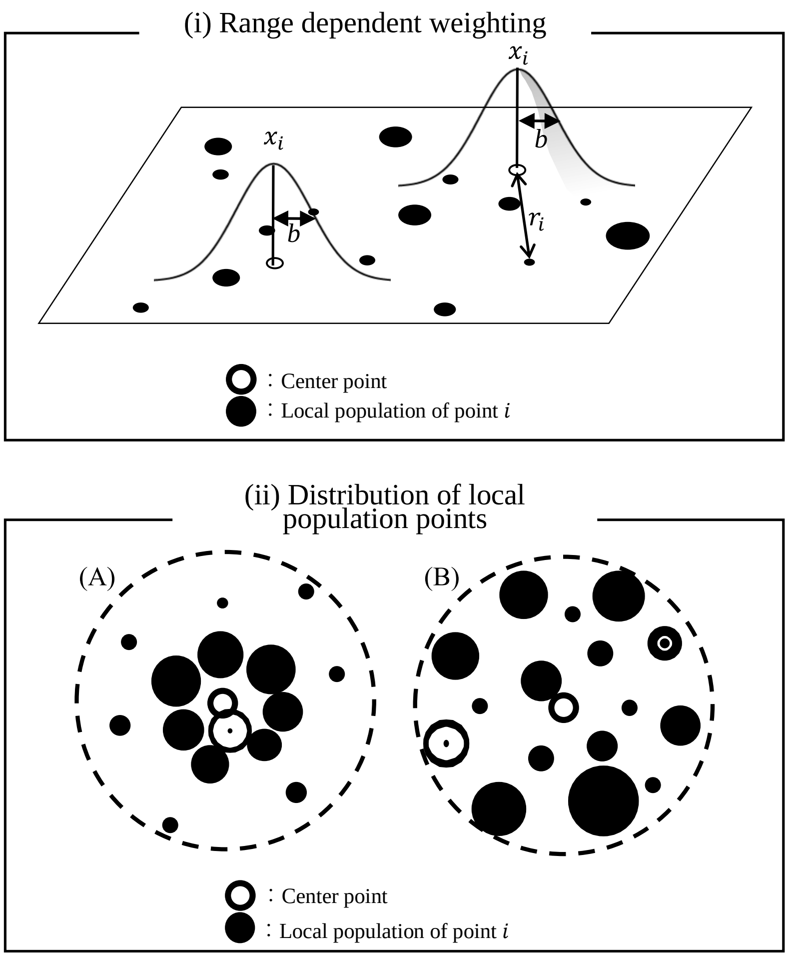
2.3 Methodology

2.3.1 Advanced Standard Distance

Advanced Standard Distance (ASD), which is an index representing the spatial distribution of local populations, is described as

$$ASD = \sqrt{\frac{\sum_{i=1}^{n} h_i x_i^2}{\sum_{i=1}^{n} h_i}} \qquad x_i = e^{-\frac{r_i}{b}}$$

where h_i is the local population at point i, n is the number of local population data, r_i is the distance from the center point to each local population point i, b is the bandwidth, and x is the range of weighting. Figure 1 shows a conceptual diagram of ASD. If there are many highly populated points near the central point, the ASD value shows a large value (e.g. (A) in Figure 1(ii)). On the other hand, if many points with large population are located far from the center point, the calculated value of ASD becomes small (e.g. (B) in Figure 1(ii)).



The size of a black circle means a population size

Figure 1 Concept of ASD

2.3.2 Spatial Scale of Clumping

Spatial Scale of Clumping (SSC) is based on G statics. The G statics is described as

$$G_i(d) = \frac{\sum_i w_{ij}(d) h_i}{\sum_i h_j} \qquad i \neq j$$

where is G_i is G statistics, h_i is the local population located in the area, w_{ij} is a symmetric binary spatial weight matrix with ones for all links defined as being within distance d of a given i; all other links are coded zero, including the link of a point i to itself. Figure 2 shows a conceptual diagram of SSC. The top layer of the SSC (e.g. (a) in Figure 2(ii)) means that a dense distribution area of high population pixels from the narrowest range to the widest range, while the outskirts of the SSC (e.g. (b) in Figure 2(ii)) denote that the dense distribution area of high population pixels solely within the widest range: highly populated pixels and low population pixels are randomly distributed closer to the point i.

3. RESULTS AND DISCUSSION

3.1 Results of ASD

Figure 3 shows the calculation results of ASD in 1995 and 2015. There are almost same patterns of the spatial distributions of ASD between the two periods. It is also shown that in the middle of the test site, the area of low ASD in 2015 colored green is smaller than that of low ASD in 1995. Figure 4 displays the difference of ASD

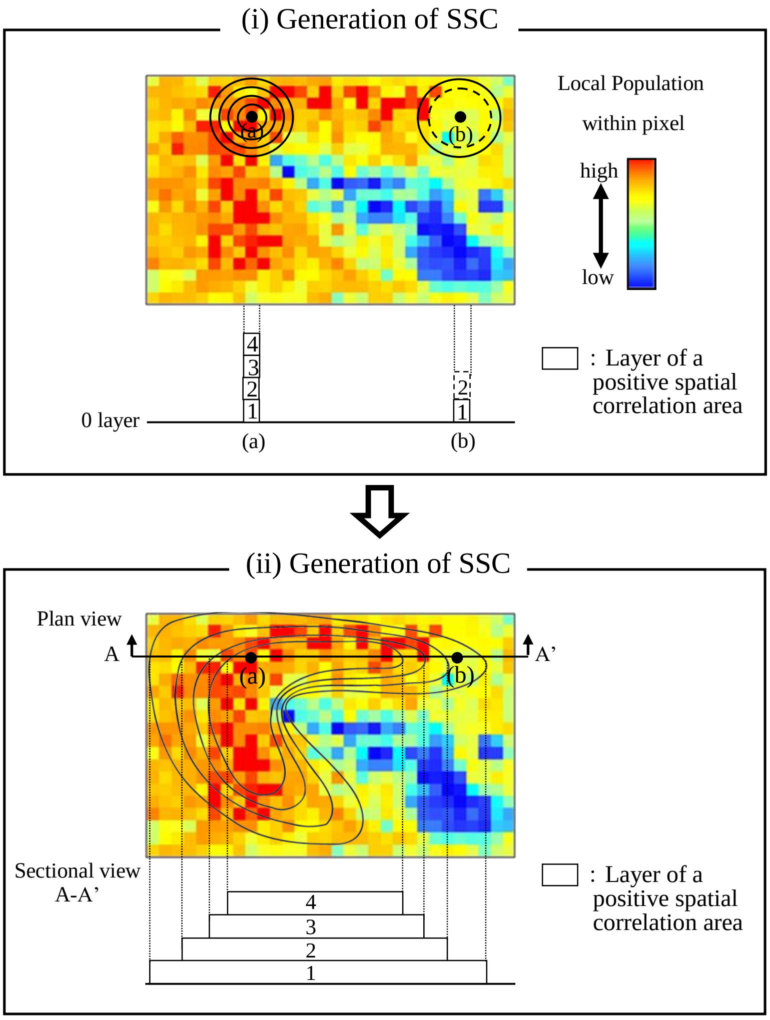


Figure 2 Procedure of the spatial analysis of population distributions
: the basic generation of the SSC derived from G statistics calculations

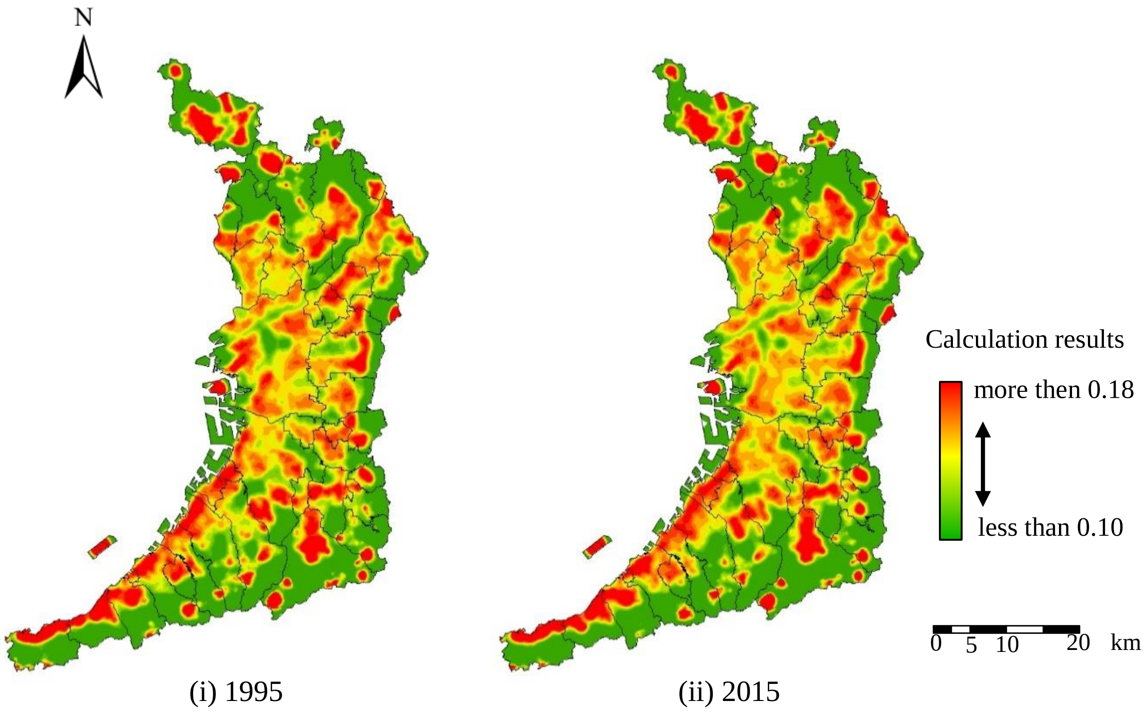


Figure 3 Results of the ASD calculation

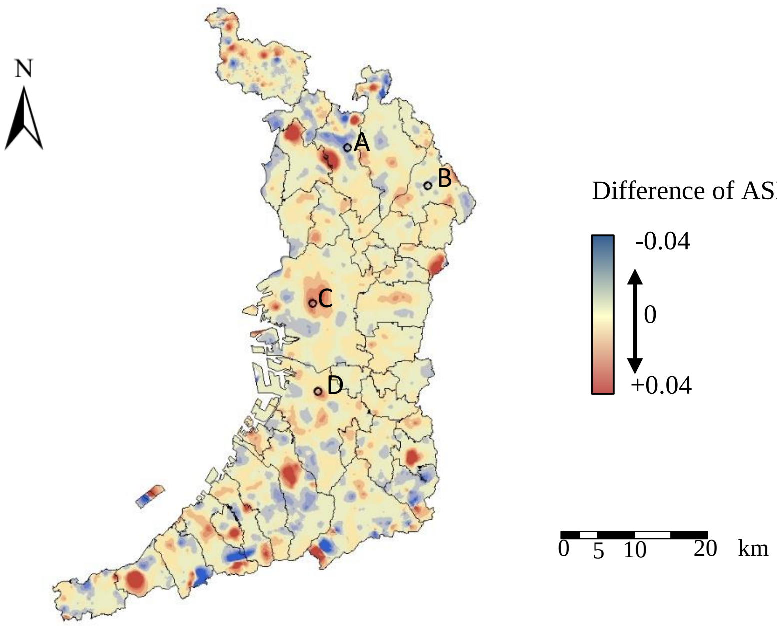


Figure 4 Difference of ASD between 1995 and 2015

between 1995 and 2015. The positive value of the difference of ASD means relatively larger local populations are generated closer to the center point, while the negative of difference of ASD means relatively smaller local populations are located near the center point. Red colored areas do not seem to be large, but spread out in Figure 4.

3.2 Results of SSC

Figure 5 indicates the results of SSC in 1995 and 2015. The number of layers is obtained by the summation of the discriminant results of positive spatial autocorrelation along with the fluctuation of the beginning of the local range. Thus, the difference of the number of layers in SSC between 1995 and 2015 denotes the difference of the beginning of the local range, statistically defined as the size of area including high local populations more. Figure 6 shows the difference of the beginning of the range between 1995 and 2015 on the basis of the comparison of the SSCs. Red

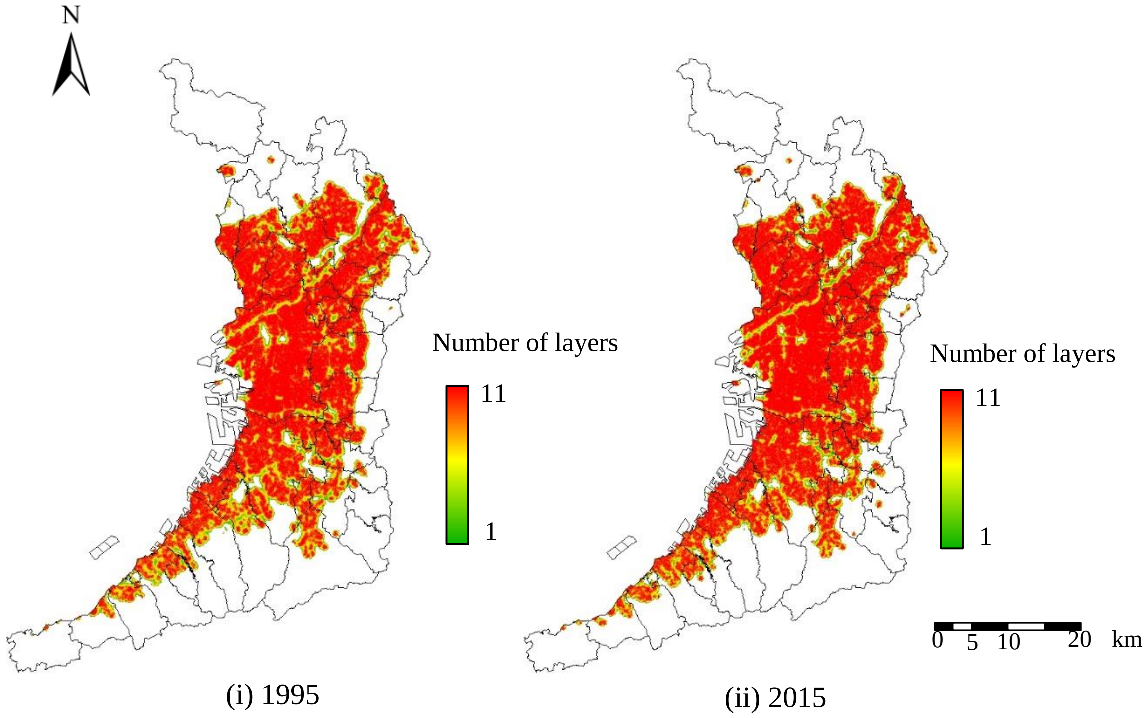


Figure 5 Results of the SSC calculation

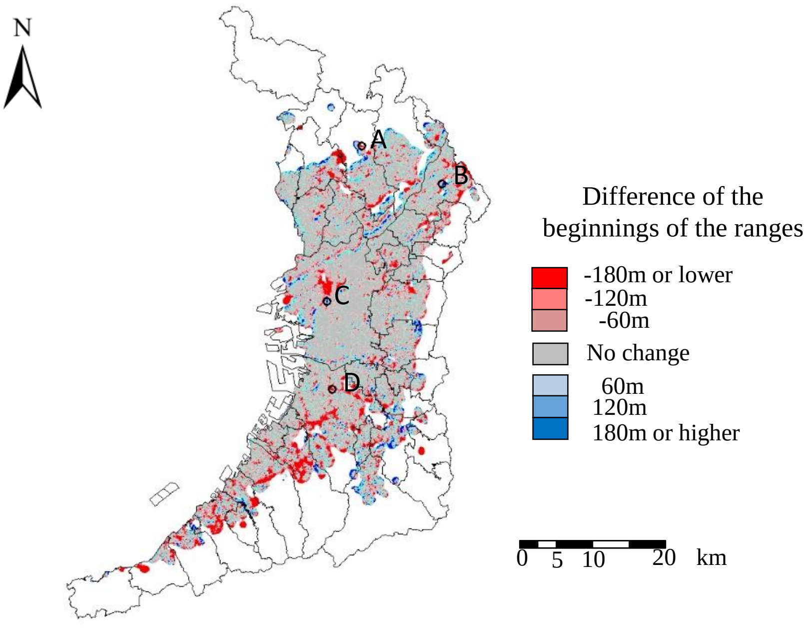
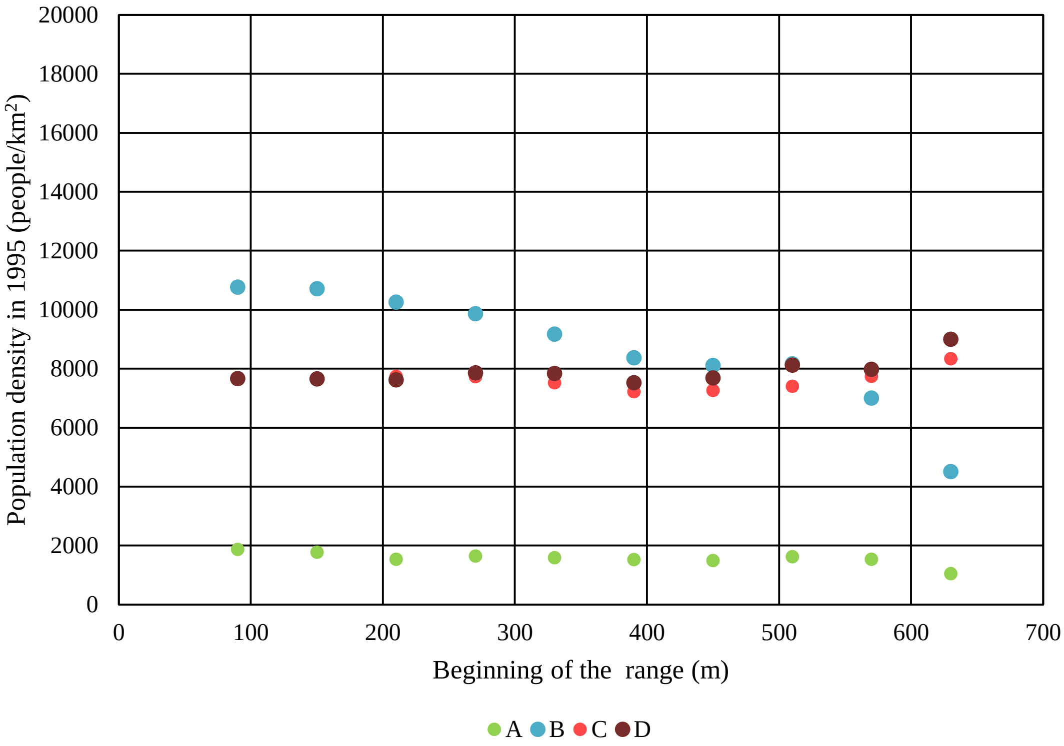


Figure 6 Difference of the beginnings of ranges between 1995 and 2015

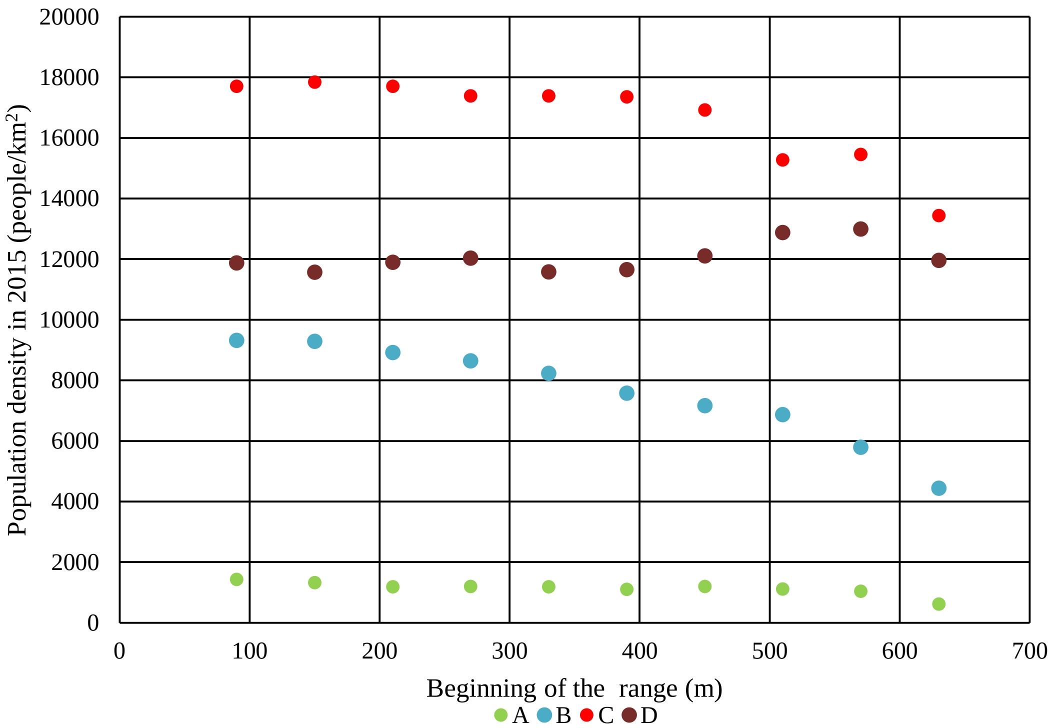
colored area means the beginning of the range of positive spatial autocorrelation in 2015 is smaller than that in 1995. In other words, the beginning of the range is closer to the center point in 2015. Then, the area of the random spatial distributions of local populations seems to be smaller around the center point. On the other hand, blue colored area in Figure 6 denotes the beginning of the range in 2015 is larger than in 1995. That means high and low local populations are randomly distributed in the larger area being around the center in 2015.

3.3 Comparison of difference between the ASD and SSC

Figures 7 and 8 show the population density and standard deviation of local populations calculated within the range around the 4 points (from the point A to the point D) in Figures 4 and 5. The fluctuation of them are indicated in accordance with the increase of the beginning of the range, while the end of the range is fixed as 690 m. Figures 7



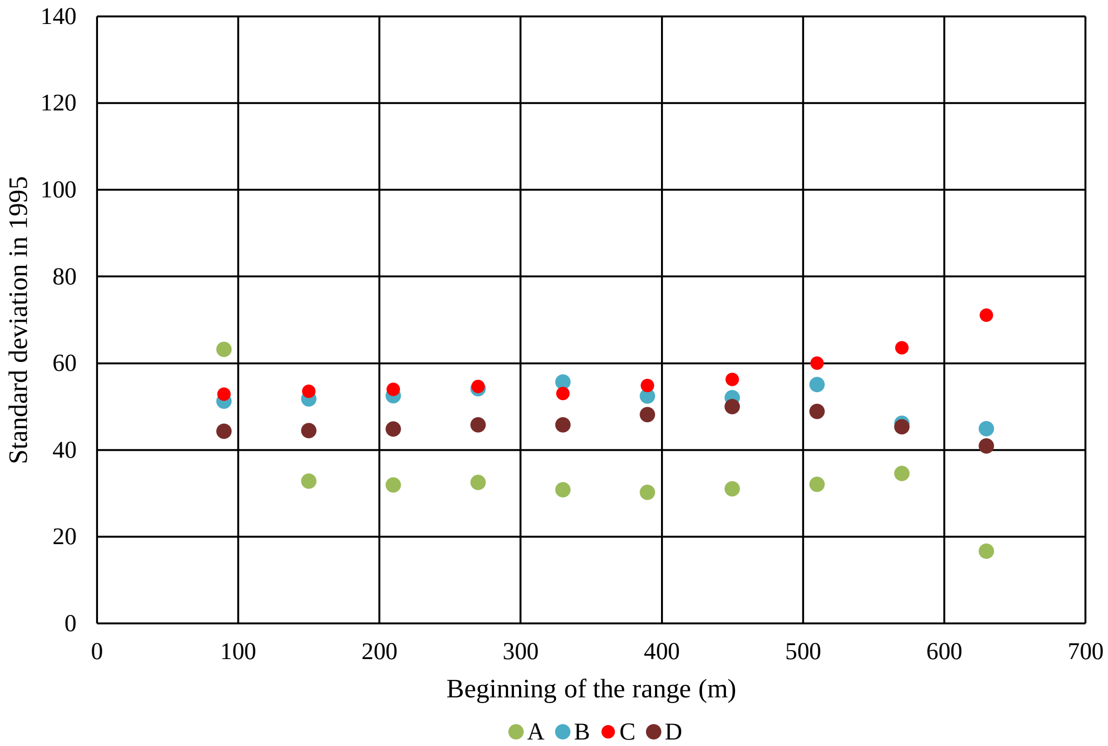
(i) Results in 1995



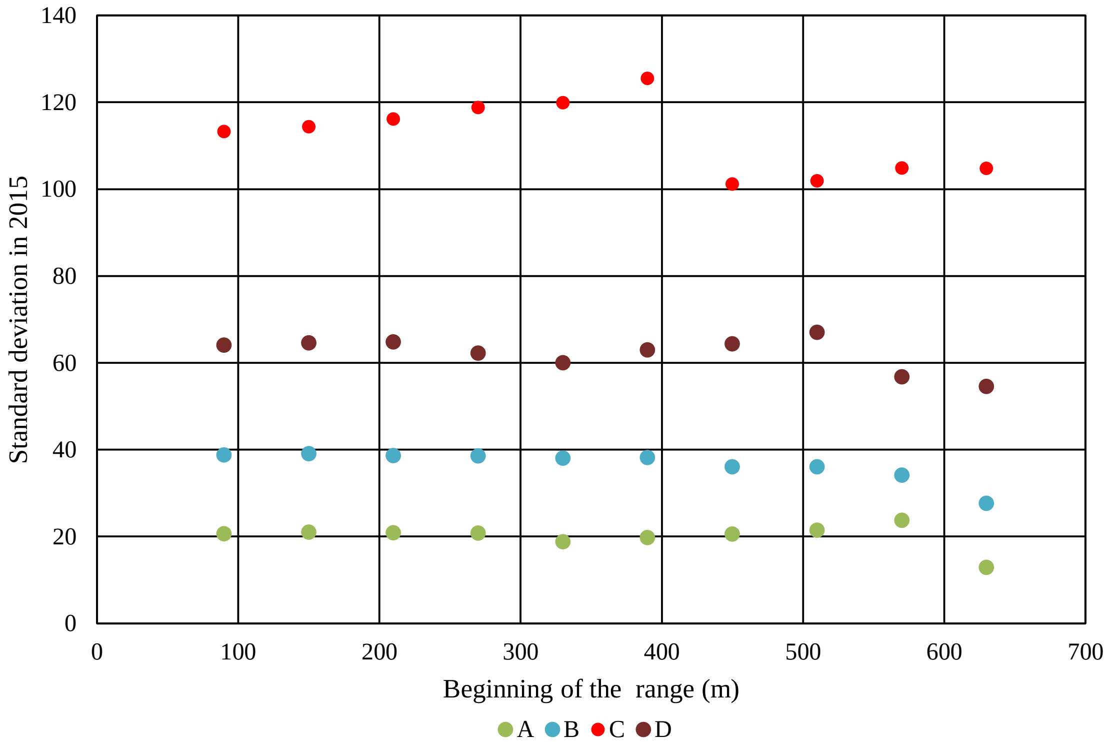
(ii) Results in 2015

Figure 7 Population density along the beginning of the range

and 8 therefore display the statistics of local populations in the fringe regions of the points. Around the point A, the population density slightly decreases from 1995 to 2015 in each of the ranges, while the standard deviation in 1995 decreases most at the smallest beginning of the range in Figure 8(i). Likewise, the population density decreases from 1995 to 2015 at all ranges around the point B: the differences of ASD show negative values at both the points A and B in Figure 4. The standard deviation around the point B, however, declines at the largest beginning of the range in 2015 though it drops at the second largest beginning of the range in 1995. It appears that the difference of



(i) Results in 1995



(ii) Results in 2015

Figure 8 Standard deviation of local populations along the beginning of the range

the beginnings of the ranges includes the fluctuation of their spatial scale: a negative value at the point A and a positive value at the point B are shown in Figure 6. At the points C and D, the differences of ASD indicate positive values in Figure 4. Nevertheless, the standard deviation around the point C in 2015 drops at the 450 m in Figure 8(ii). From the viewpoint of the difference of the beginnings of the ranges (in Figure 6), in 2015, relatively high local populations and low local populations seem to be randomly distributed in the closer area of the point C, while in the range from 450 m to 690 m, high local populations may be principally located.

4. CONCLUSIONS

We applied ASD and SSC to the local populations derived from the basic unit blocks population data of the Population Census of Japan in 1995 and 2015. Through the comparison between the results of ASD and SSC, we could see the feature of SSC with respect to spatial scale: the range where high local populations were densely distributed seemed to vary even though there were the same tendency of ASD among 20 years. Meanwhile, it is difficult to extract the changes of local population density through the application of ASD and SSC: the local population density seems to have no relevance to the two indices (see Figure 7). For the monitoring of urban shrinkage, the analysis method including the spatial analysis of both local population density and spatial scale should be developed in the near future.

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