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Characteristics of population and land cover changes in the Korean local depopulating cities

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Abstract

The purpose of this paper is to quantitatively explore the changes in population and the spatial extent of built-up areas in Korean local depopulating cities. Additionally, this paper intends to comparatively analyze their characteristics. This paper examines 20 out of the 77 general cities in South Korea, whose population has been declining over the 20 years from 1995 to 2015. The results revealed that the degree of population decline varies from city to city, and that the built-up areas of all cities are significantly expanding. Conversely, while certain existing built-up areas had transformed to non built-up areas because of an increase in underutilized and unused lands, a phenomena called urban sponging, positive changes to non built-up areas were also confirmed due to the development of river environments and historical parks.

Key words: population change, land cover change, local city, South Korea

1. Introduction

South Korea is experiencing a decrease in population because of declining birthrate and aging population, similar to Japan. From a global perspective, South Korea is a country where the population is highly concentrated in the Seoul Metropolitan Area, and the population and economic disparities between the metropolitan area and other local areas are widening (Lee et al., 2017). Therefore, in local cities other than the capital area and metropolitan cities as the center of each region, there are concerns about decline because of population decrease, and efforts are underway to revitalize such cities, including reorganization of the urban structure. In the context of the revitalization of local cities during a period of declining population, the idea of smart shrink, which transforms the conventional strategy of aiming for economic growth and population increase and downsizes urban spaces while realizing a qualitatively affluent society and life, is attracting attention in recent years (Oswalt et al. eds., 2006). Hino and Tsutsumi eds. (2015) also regards cities experiencing population decline as post-growth societies, and indicates the need for urban research based on different paradigms that has values other than population and economic growths (Kaneko, 2017).

Based on the above, the authors' research group is conducting investigations to elucidate the dynamism with which urban areas are changing not only quantitatively and spatially but also qualitatively amid the ongoing population decline in local cities in South Korea through detailed fieldwork in case cities. The purpose of this paper is to quantitatively explore the changes in population and the spatial extent of built-up areas in Korean local depopulating cities. Additionally, this paper intends to comparatively analyze their characteristics as a basic material for this research. This paper examines 20 out of the 77 general cities in South Korea classified as shrinking cities by Koo et al. (2016), whose population has been declining over the 20 years from 1995 to 2015 (Fig. 1).

2. Methodology

2.1. Dataset

This paper selected the images of Landsat 5 Surface Reflectance (L5sr) in 1995 and Landsat 8 Surface Reflectance (L8sr) in 2020 for land cover change analysis, and Sentinel-2 Surface Reflectance (Sentinel-2sr) in 2020 for ascertaining the detail land cover distribution in the central districts of the 20 local depopulating cities. All these images were atmospherically corrected and provided by the Google Earth Engine platform. Four popular auxiliary datasets, Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), Normalized Difference Built-up Index (NDBI), Digital Elevation Model (DEM), and one method called Tasseled Cap Transform (TCT) were calculated and used based on the L5sr, L8sr and Sentinel-2sr data to increase the accuracy of land cover classification (Fig. 2).

2.2. Training sample data

Six land cover types dominate the area of investigation such as (1) Forest(F), (2) Grassland(GL), (3) Bareland (BL), (4) Water(W), (5) Built-up(BU), and (6) Plastic greenhouse(PG). All training samples were collected based on manual visual interpretation of high-resolution base map or satellite images from Google Earth. In each

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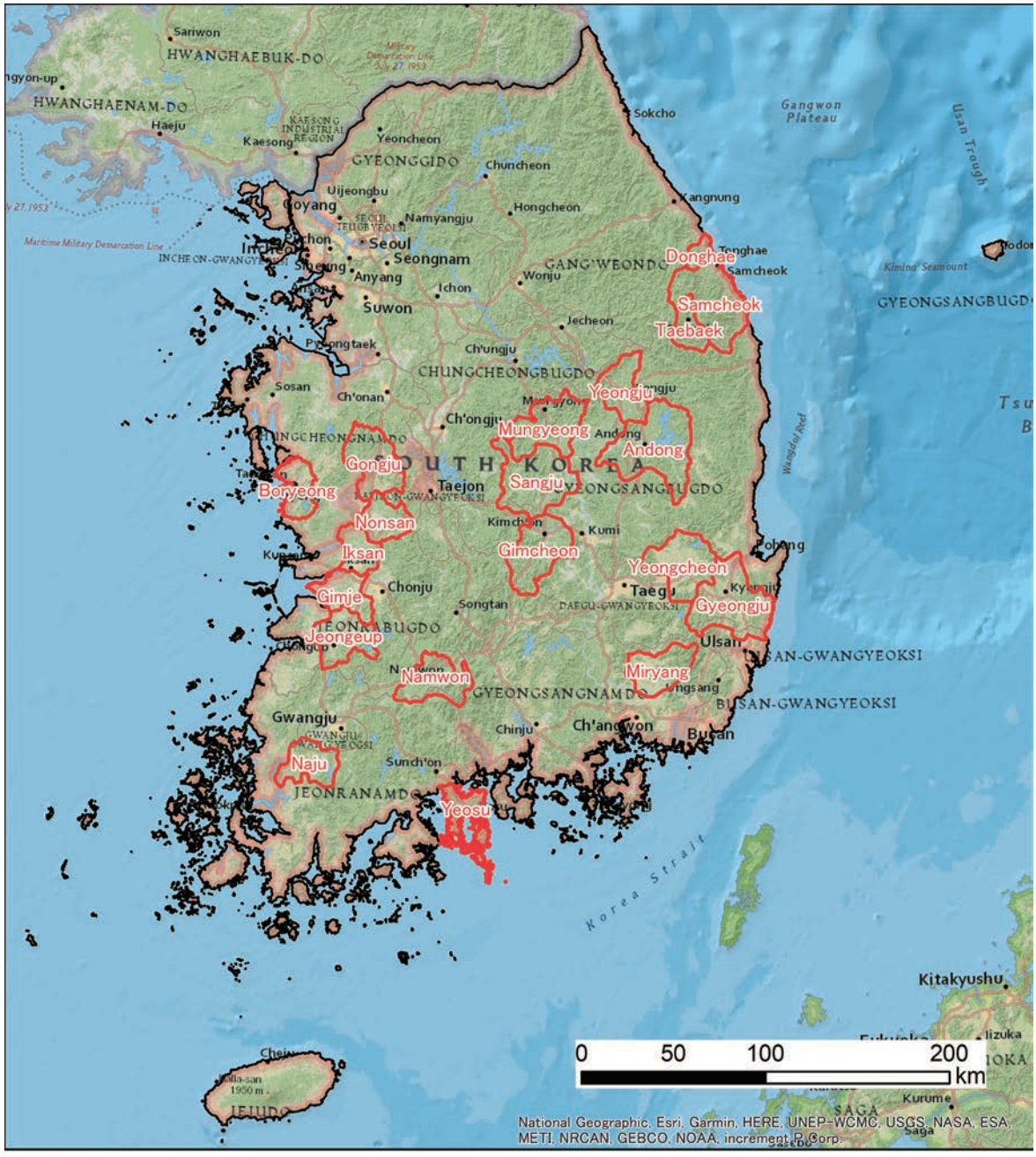

Fig. 1 Location of the 20 local cities targeted by this study. sources: National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

small field in our study area, about 100-200 points of each land cover type were selected as training samples for analysis.

2.3. Random forest classifier

Random forest classifier is a supervised classification method that requires a reference dataset containing numerical data for classifier training and internal accuracy calculations. It is a widely used algorithm for land cover classification using remote sensing data. Owing to its: (1) good performance with multi-source datasets, (2) higher classification accuracy, and (3) faster processing speed, it is widely used in satellite images classification. Based on the recommendations of pretests from our data, we selected 125 trees (ntree = 125), while mtry was set to the default value. And the accuracy for all of our land cover classification results is around 80% (Fig. 2).

3. Population change

Table 1 shows the population change of the 20 cities.

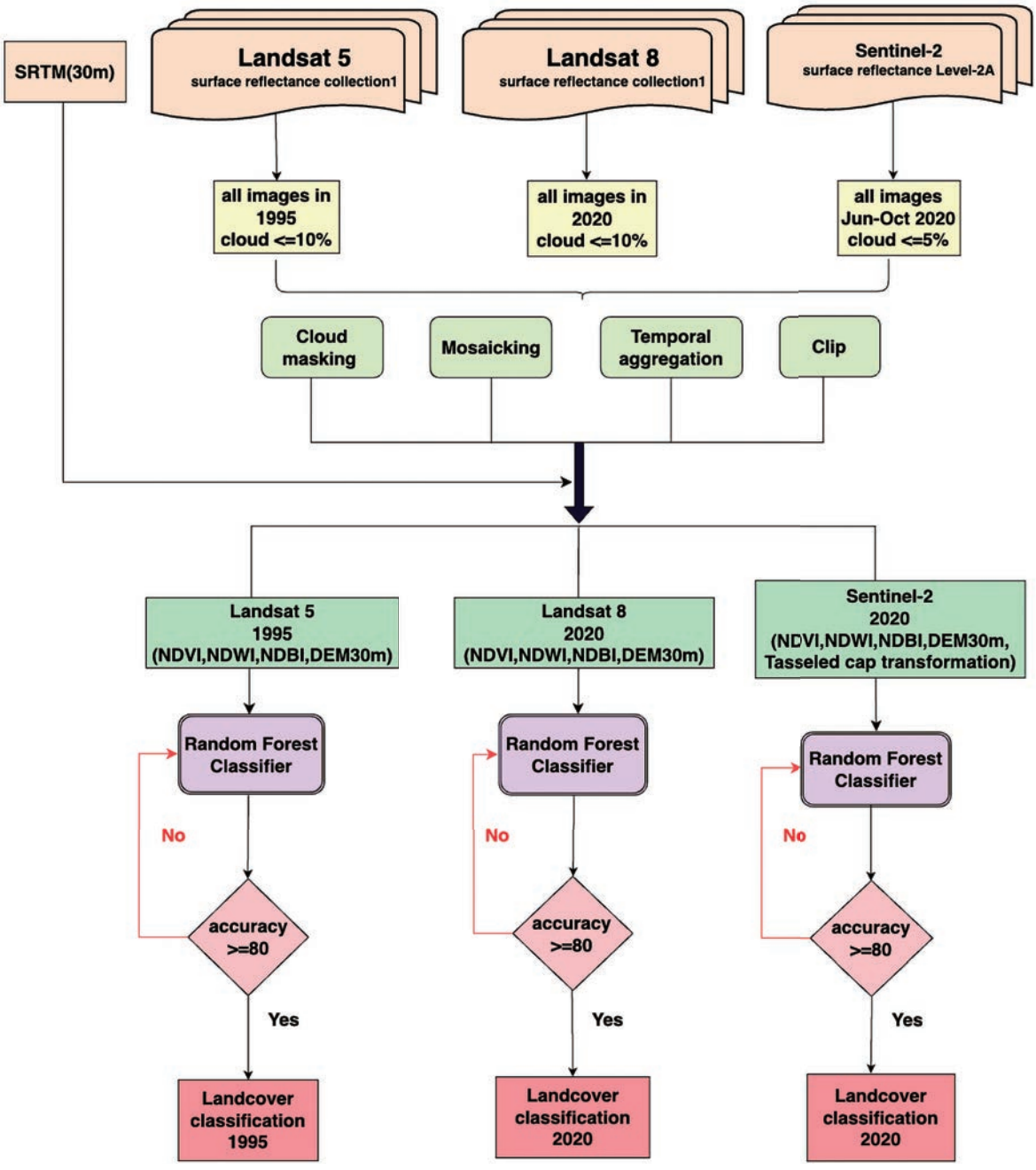

Fig. 2 Methodology of land cover analysis

Although the population of all 20 cities has declined over the 20-year period from 1995 to 2015, there are significant differences between cities in terms of population size and rate of decrease. In 1995, Taebaek had the smallest population (64,850); Samcheok had less than 100,000; and Iksan and Yeosu exceeded 300,000 each. Regarding the rate of population decrease, Gimje had the highest rate at -30.9%, followed by seven cities with rates ranging from -30% to -20%, eight cities with rates ranging from -20% to -10%, and four cities with rates less than -10%. Over the 25-year period from 1995 to 2020, Taebaek, the city with the smallest population size, experienced a population decline rate exceeding -30%, and the number of cities with rates of decline from -30% to -20% increased to nine. These cities are widely distributed throughout the country, so it is thought that the population is flowing out to the capital area or to their neighboring metropolitan cities. Conversely, the populations of Gimcheon, Yeongcheon, and Naju have turned to increase over the five years from 2015 to 2020. In particular, Naju has a high

Table 1 Population change

city	population (1995)	population (2015)	population (2020)	population change rate (%) (1995-2015)	population change rate (%) (1995-2020)	population change rate (%) (2015-2020)
Gangwon-do						
Donghae	100,277	93,895	90,593	-6.4	-9.7	-3.5
Samcheok	90,005	70,839	65,243	-21.3	-27.5	-7.9
Taebaek	64,850	47,501	42,719	-26.8	-34.1	-10.1
Gyeongsangbuk-do						
Yeongju	138,654	109,735	103,119	-20.9	-25.6	-6.0
Andong	192,522	169,221	158,907	-12.1	-17.5	-6.1
Mungyeong	95,778	75,784	71,406	-20.9	-25.4	-5.8
Sangju	133,895	102,374	97,228	-23.5	-27.4	-5.0
Gimcheon	151,641	140,132	140,548	-7.6	-7.3	0.3
Yeongcheon	123,069	100,648	102,015	-18.2	-17.1	1.4
Gyeongju	283,766	259,773	253,502	-8.5	-10.7	-2.4
Gyeongsangnam-do						
Miryang	131,187	107,896	104,831	-17.8	-20.1	-2.8
Chungcheongnam-do						
Boryeong	122,895	104,754	100,229	-14.8	-18.4	-4.3
Gongju	138,069	111,261	104,545	-19.4	-24.3	-6.0
Nonsan	150,190	124,232	116,675	-17.3	-22.3	-6.1
Jeollabuk-do						
Iksan	328,152	302,061	282,276	-8.0	-14.0	-6.6
Gimje	128,415	88,721	82,450	-30.9	-35.8	-7.1
Jeongeup	151,039	115,977	108,508	-23.2	-28.2	-6.4
Namwon	109,185	84,856	80,662	-22.3	-26.1	-4.9
Jeollanam-do						
Naju	116,179	98,182	115,613	-15.5	-0.5	17.8
Yeosu	329,139	290,168	280,242	-11.8	-14.9	-3.4

source: data from KOSIS

growth rate of 17.8%, and its population has recovered to the 1995 level.

4. Land cover change between built-up and non built-up areas

In this chapter, among the land cover items classified into six categories using Landsat data in 1995 and 2020, the five items other than Built-up(BU) are considered non built-up area (NBU), and changes between BU and NBU are quantitatively analyzed (Table 2).

As of 1995, there were differences between cities in terms of size and rate of built-up area. Boryeong has the largest built-up area, which is located on the coast near the Seoul Metropolitan Area. Andong, Gyeongju, Gongju, Nonsan, Iksan, Jeongeup, and Yeosu also have substantial built-up areas. Conversely, Taebaek has the smallest built-up area, approximately nine-times smaller than that of Boryeong.

Looking at the change rate of built-up area from 1995 to 2020 ((A) in Table 2), the change rate is over 100% in 19 cities, excluding Boryeong. This implies that the built-up area has more than doubled. Among them, the built-up area has expanded by more than 200% in three cities, by more than 300% in five cities, and by more than 400% in two cities, with Namwon having the largest change rate at 558%. Based on the above, it can be said that although the populations of all cities are decreasing, built-up areas of most cities are significantly expanding.

It is noteworthy that the expansion of built-up areas is not merely the result of new urban development with maintaining existing built-up areas. Actually, this expansion of built-up areas is the consequence of new urbanization elsewhere on a larger scale, whereas existing built-up areas change into non built-up areas. Looking at the ratio of the area converted to non built-up areas in 2020 to the area of built-up areas in 1995 ((B) in Table 2), even

Table 2 Land cover change between built-up area (BU) and non built-up area (NBU) from 1995 to 2020

city	BU area (1995) (pixcels)	BU rate (1995) (%)	NBU to NBU (pixcels)	NBU to BU (pixcels)	BU to NBU (pixcels)	BU to BU (pixcels)	BU area (2020) (pixcels)	BU rate (2020) (%)	change rate of BU (%) (A)	rate of BU to NBU (%) (B)
Gangwon-do										
Donghae	6,516	2.6	232,357	9,784	2,958	3,558	13,342	5.4	104.8	45.4
Samcheok	6,047	0.4	1,704,403	14,001	3,803	2,244	16,245	0.9	168.6	62.9
Taebaek	3,266	0.6	505,576	5,748	1,792	1,474	7,222	1.4	121.1	54.9
Gyeongsangbuk-do										
Yeongju	5,905	0.6	898,545	23,815	1,540	4,365	28,180	3.0	377.2	26.1
Andong	13,301	0.6	2,104,056	26,484	7,172	6,129	32,613	1.5	145.2	53.9
Mungyeong	8,106	0.6	1,288,843	21,557	4,152	3,954	25,511	1.9	214.7	51.2
Sangju	5,791	0.3	1,699,072	30,677	3,108	2,683	33,360	1.9	476.1	53.7
Gimcheon	6,590	0.5	1,291,682	29,350	2,254	4,336	33,686	2.5	411.2	34.2
Yeongcheon	8,383	0.6	1,282,698	34,955	3,732	4,651	39,606	3.0	372.5	44.5
Gyeongju	16,933	0.9	1,783,453	57,250	6,228	10,705	67,955	3.7	301.3	36.8
Gyeongsangnam-do										
Miryang	4,756	0.5	947,713	19,758	2,263	2,493	22,251	2.3	367.9	47.6
Chungcheongnam-do										
Boryeong	29,465	4.2	645,468	34,117	21,878	7,587	41,704	5.9	41.5	74.3
Gongju	15,151	1.3	1,144,890	31,124	10,176	4,975	36,099	3.0	138.3	67.2
Nonsan	13,098	1.8	654,362	42,307	8,057	5,041	47,348	6.7	261.5	61.5
Jeollabuk-do										
Iksan	21,083	3.5	539,339	39,926	7,220	13,863	53,789	9.0	155.1	34.2
Gimje	8,810	1.1	740,931	32,157	5,323	3,487	35,644	4.6	304.6	60.4
Jeongeup	14,538	1.4	986,175	27,761	9,085	5,453	33,214	3.2	128.5	62.5
Namwon	4,436	0.5	938,546	26,490	1,726	2,710	29,200	3.0	558.3	38.9
Jeollanam-do										
Naju	7,242	0.9	774,310	26,058	3,851	3,391	29,449	3.6	306.6	53.2
Yeosu	15,454	2.3	624,608	38,829	4,749	10,705	49,534	7.3	220.5	30.7

in Yeongju, which has the lowest ratio, it is 26.1%. This implies that a quarter of the built-up area in 1995 has changed to non built-up area by 2020. Among other cities, a majority of 11 cities had a ratio of 50% or more, and six of them had a ratio of 60% or more. There is a common trend among these cities. While the change from built-up to non built-up areas occurred in the mountainous outer areas of the city, such as the northwest of Gongju (Fig. 3) and the southeast of Nonsan (Fig. 4), there has not only been the expansion of the existing built-up area into surrounding areas but also the formation of new built-up area in entirely different areas through new road construction and urban development.

Next, we categorized these 20 cities based on two indicators: built-up area expansion rate and population decrease rate, as shown in the previous chapter (Table 3). The built-up area expansion rate for all 20 cities from 1995 to 2020 is 218.9%. The rates of 11 cities are higher than this value, whereas those of nine cities are lower. On the other hand, the population decrease rate for all 20 cities from 1995 to 2020 is -18.8%. The rates of 11 cities are higher than this value, whereas those of nine cities are lower. Based on these two indicators, it can be said that the five cities of Samcheok, Taebaek, Mungyeong, Gongju, and Jeongeup, which have a relatively high population decrease rate and a relatively low built-up area expansion rate, show a relatively remarkable decline compared to other cities. Conversely, it can be said that the five cities of Gimcheon, Yeongcheon, Gyeongju, Naju, and Yeosu, which have a relatively low population decrease rate and a relatively high built-up area expansion rate, show a relatively weak tendency to decline compared to other cities.

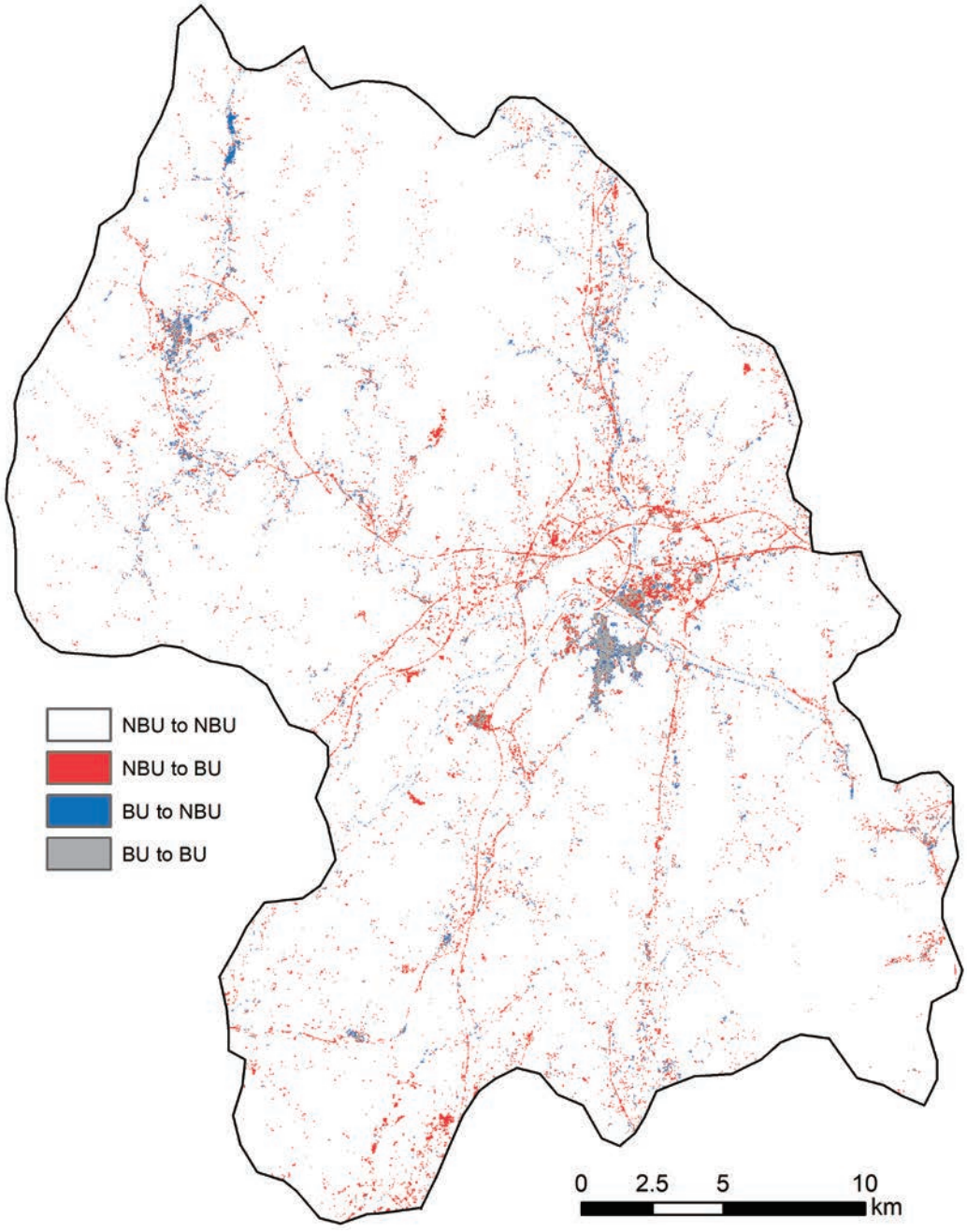

Fig. 3 Land cover change in Gongju (1995 - 2020)

5. Characteristics of non built-up areas in the central districts

As the built-up area is expanding in all 20 cities, it can be said that there is no urban downsizing in response to population decrease. On the other hand, in a few existing built-up areas of the city center, the land cover is changing to non built-up area. This suggests the occurrence of "sponging", which symbolizes urban decline due to population decline. This chapter explores two cities, Gongju and Naju. Gongju is an example of the city with the highest change rate from built-up area to non built-up area ((B) in Table 2) among the five cities with relatively high population decrease and relatively low built-up area expansion (Table 3). And Naju is an example of the city with the highest change rate from built-up area to non built-up area ((B) in Table 2) among the five cities with relatively low population decrease and relatively high built-up area expansion (Table 3). In this chapter, we confirm the land cover distributions within the existing built-up areas in the respective centers of the two cities by using the Senti-

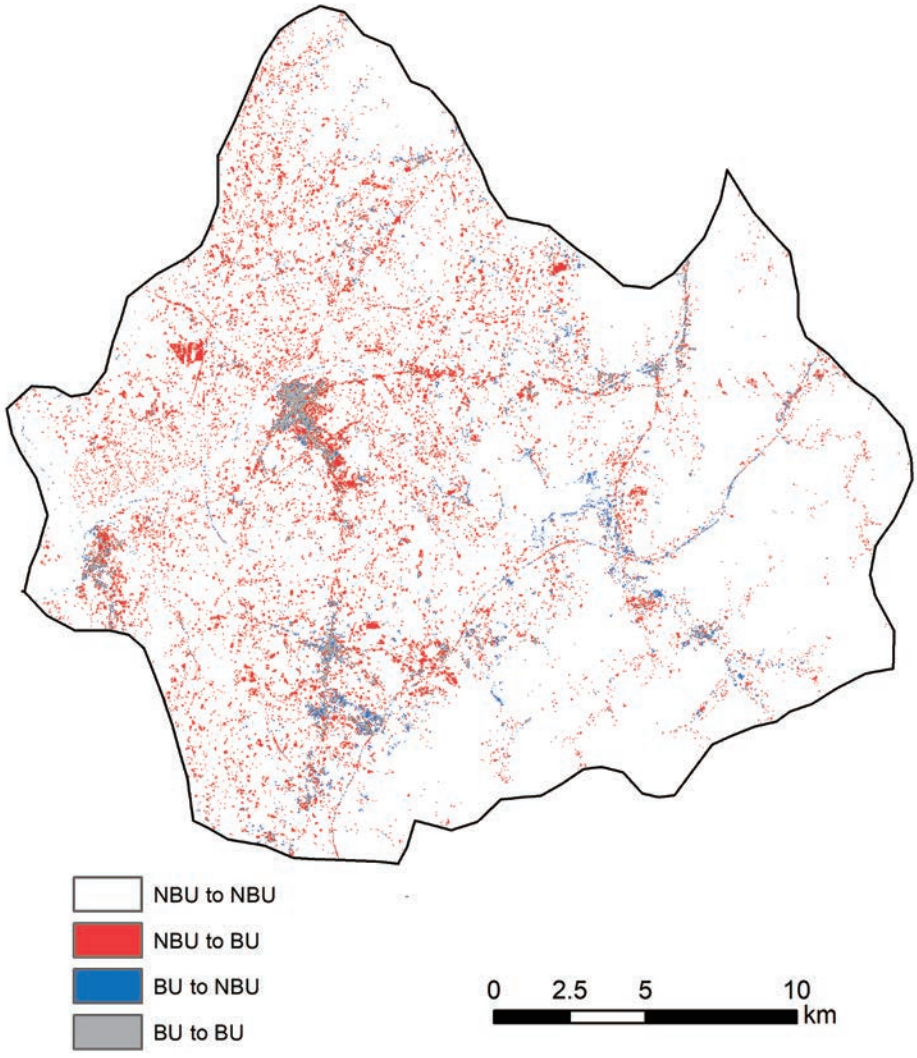

Fig. 4 Land cover change in Nonsan (1995 - 2020)

nel-2 data, which has a higher resolution than the Landsat data.

In the existing urban area of Gongju, areas transformed into non built-up are more prominent than areas that have been newly urbanized (Fig. 5a). Although this change to non built-up is often observed at the edge of existing built-up areas, it is also distributed within the existing built-up area. Many of them have changed to grasslands, and some have changed to forests and barelands (Fig. 5b). These changes could imply the shrinkage and decline of the existing urban area, but on the other hand, the grassland that runs north to south through the center of the existing built-up area (Fig. 5b) is an ecological river area where a landscape improvement project was implemented between 2011 and 2014 (Yamashita, 2017). Thus, there are instances where land cover change to non built-up area represents qualitative improvement in the urban

Table 3 Classification based on population and built-up area changes

		built-up area expansion	
		relatively high	relatively low
population decrease	relatively low	Gimcheon Yeongcheon Gyeongju Naju Yeosu	Donghae Andong Boryeong Iksan
	relatively high	Yeongju Sangju Miryang Nonsan Gimje Namwon	Samcheok Taebaek Mungyeong Gongju Jeongeup

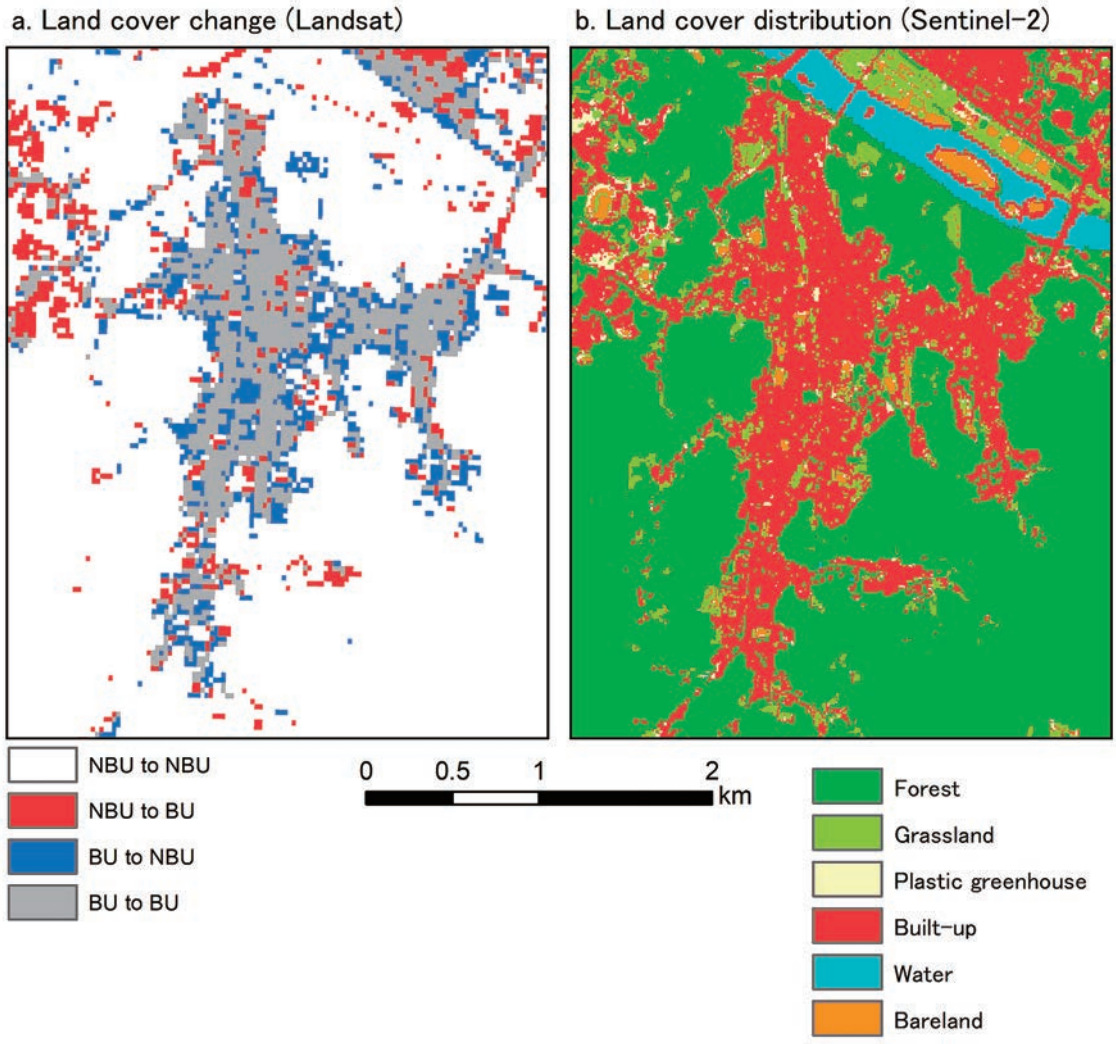

Fig. 5 Land cover change and distribution in central Gongju

environment.

In the existing built-up area of Naju, although the expansion of the built-up area into the surrounding area is more noticeable than in Gongju, there is also some change within the existing built-up area to a non built-up area (Fig. 6a). Many of them changed to grasslands, and some changed to barelands or others (Fig. 6b). Specifically, while some areas have been transformed into vacant lots after removal of buildings (Fig. 7) and unpaved parking lots (Fig. 8), there are also spaces where the construction of the park is progressing with restoration of historical buildings (Fig. 9).

6. Conclusion

This paper quantitatively ascertained the changes of population and spatial extent of built-up areas in 20 local cities with declining populations, and comparatively analyzed their characteristics. The results revealed that the degree of population decline varies from city to city, and that the built-up areas of all cities are significantly expanding. Conversely, while certain existing built-up areas had transformed to non built-up areas because of an increase in underutilized and unused lands, a phenomena called urban sponging, positive changes to non built-up areas were also confirmed due to the development of river environments and historical parks.

This paper merely performed a relative comparison of changes in built-up areas through macro-scale data analysis, therefore, it did not reveal the actual state of decline or revitalization in central districts of the local cities where populations are decreasing. In the future, we will analyze and consider it through detailed fieldwork in selected case cities.

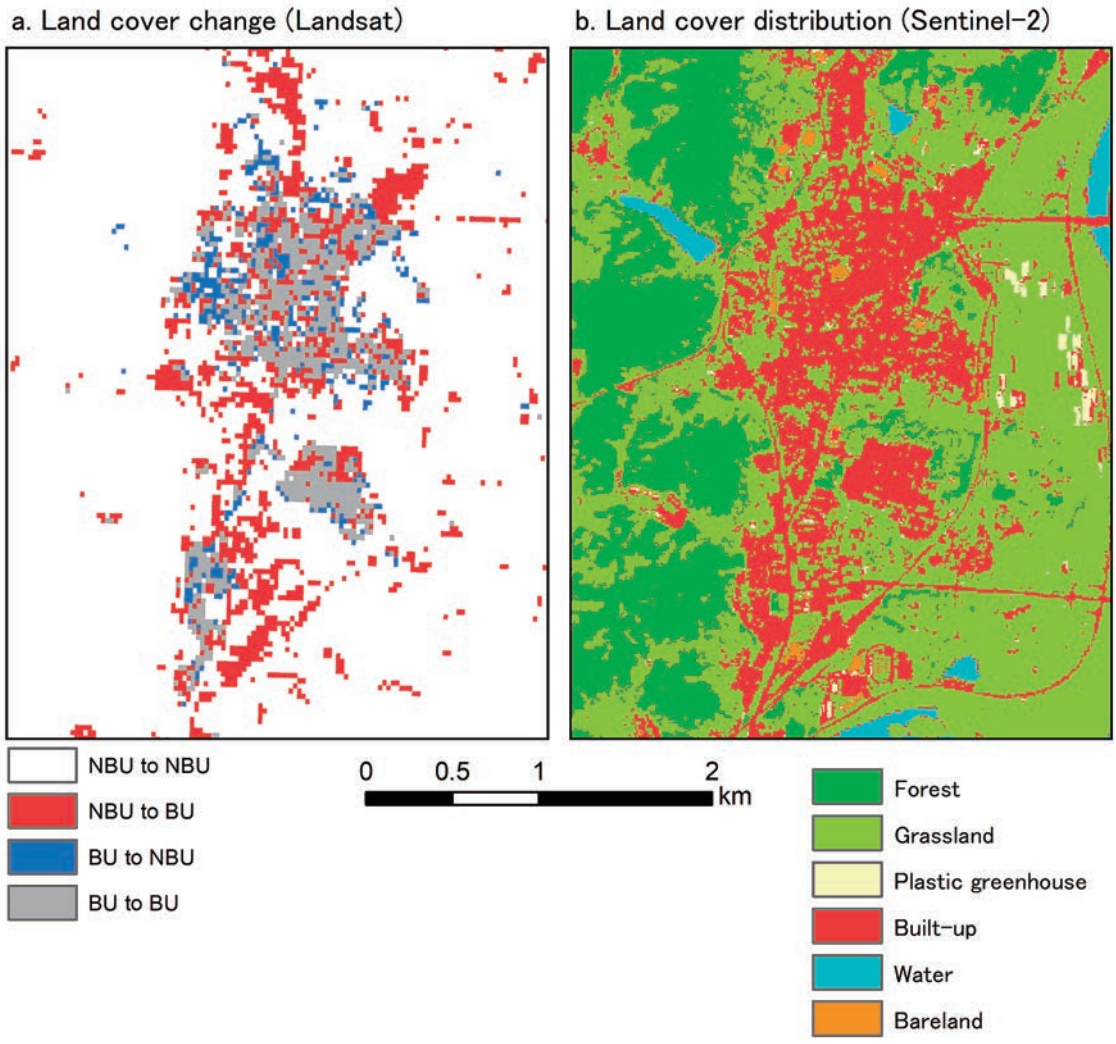

Fig. 6 Land cover change and distribution in central Naju

Fig. 7 Vacant lot in central Naju. Taken by Yamashita in March 2023

Fig. 8 Unpaved parking lot in central Naju. Taken by Yamashita in March 2023

Fig. 9 Historical park under construction in central Naju. Taken by Yamashita in March 2023

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