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A Study on Changes of Slate Buildings' distribution in Korea using GIS - Case Study of Gang-won Province-

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Abstract
Asbestos is classified as Group 1 carcinogen, and its use is fully banned in Korea. However, there are many slate buildings that contain asbestos, which has become a social issue. In this study, the building registers for the year 2010 and 2015 are examined to see changes in regional distribution of slate buildings in Gang-won Province. The share of slate buildings was 20.73% in 2010 and 20.77% in 2015 by the number of building, 7.46% in 2010 and 7.73% in 2015 by building area. In ratio change of slate buildings by region, Hongcheon and Hwacheon saw the biggest drop at 2.9% and 2.8% based on ratio of number while Heongseong and Cheolwon saw the biggest drop at 7.5% and 4.4% in terms of ratio of building area. These changes were visualized by using ArcGIS across cities and districts of Gang-won Province.

Keywords: Slate, Slate Building, Building register, Distribution Characteristics

1. Introduction

Asbestos has been used since ancient times, owing to its heat-resistant, rot-proof, and insulating qualities, and its usage rapidly increased after the industrial revolution, as a result of the introduction of the steam engine [1]. However, as it became established that asbestos causes incurable illnesses such as pulmonary asbestosis, mesothelioma, and poor-prognosis lung cancer after a latent period of 20–50 years, the International Agency for Research on Cancer classified asbestosis as a class 1 carcinogen [2].

In Korea, asbestos has been imported since the 1960s, with the highest record of import, at 95,000 metric tons, in 1992; however, since then, its use has been continuously declining [3]. In addition after the amendment of the Industrial Safety and Health Act in 1990, which classified asbestos as a harmful substance, its use needed to be approved by the government. Finally, the Occupational Safety and Health Act revised in 2009 fully banned the use of asbestos [4]. All slates made in Korea during this time period comprised approximately 90% cement and 10% chrysotile (white asbestos) [5]. From 2011, local governments of Korea have been demolishing slate with support from the Ministry of Environment. Demolition support fund has been steadily rising to the point of covering 70% of actual demolition cost in 2011 [6]. However, there are still vast amount of remaining slate with differences among local government, which is causing social issues [7].

In this study, we examine building registers to identify buildings with asbestos-containing slate in the mountainous Gang-won Province where many antiquated buildings are located. This study gives a comparative analysis of how slate buildings in 2010 building register and 2015 building register are distributed by region, year and purpose. This is done by ArcGIS to identify how asbestos is controlled in Korea and suggest conclusion on changes in the distribution of asbestos slate.

2. Theoretical Consideration

2.1 Overview of Slate and Building register

In Korea, approximately 80% of imported asbestos were used as building materials [8]. In general, asbestos-based materials used for building interiors are not exposed to vibration, wind or rainfall, and subsequent dilapidation, and thus there is little concern for scattering of asbestos fibers [9]. However, slate is used for building exterior and has environmental impact, as it produces asbestos fibers as the surface is worn with time. [10] It can cause serious damage to residents nearby the slate buildings [11].

Building registers provide summaries of all buildings in Korea. According to Article 38 of the Building Act, basic data related to the construction or maintenance/management of every approved building should be recorded and stored in the building register [12]. The register contains information on the building and its owner, and thus provides useful information to identify buildings with slate roofs. It should be noted that the building register comprises event-based data, which are created during the construction approval process, so various errors may occur during the administrative process. Nevertheless, these data were still considered useful, especially if we take into consideration that complete enumeration was impossible and that there were no other, more accurate, available data. Accordingly, this registry was used in this study for creating the basic database [13].

2.2 Distribution by cities and counties in Gangwon-Province

Gangwon-Province, which is the subject province of the study, consists of 7 cities and 11 counties. Figure 1 presents distribution by cities and counties in Gangwon-province.

Fig.1. Map of Gangwon-Province by administrative district

3. Building register Analysis

3.1 Changes in the general status of building in Gangwon-province

Changes in distribution of buildings by city and county in Gangwon-province were analyzed by tapping into building register of 2010 and 2015. 20,488 buildings and 4,344,186m2 of building area were newly added in Gangwon-province during the period. Roof materials of buildings in the province were analyzed based on materials classified in the building register. Buildings built with slate roof materials increased by 0.03% in number of buildings and 0.26% in building area. Table 1 shows buildings in Gangwon-province by roof materials and Table 2 shows total number of buildings and building area across Gangwon-province.

Table 1. Distribution of buildings in Gangwon-province by roof materials

Description		Asbestos Slate	Reinforced Concrete	Roofing tile	Other	Not reported
2010‘s Building Register	Number Standard	20.73%	32.74%	17.10%	27.34%	2.09%
	Area Standard	7.46%	47.30%	2.94%	40.78%	1.52%
2015‘s Building Register	Number Standard	20.76%	32.13%	16.62%	30.00%	0.48%
	Area Standard	7.73%	47.34%	4.08%	40.56%	0.29%

3.2 Changes in the general status of buildings in Gangwon-province

Changes in distribution of buildings listed in building register in Gangwon-province were analyzed by residential, facilities, factory, warehouse, stale and not-reported. Residential buildings increased by 2.44% in number and 2.4% in building area. Buildings classified as facilities decreased by 0.87% in number and 1.95% in building area. The following Table 3 shows distribution of all buildings across Gangwon-province by purpose.

Table 2. Distribution of all buildings in Gangwon-province by region

Area	2010‘s Building Register		2015‘s Building Register	
	Number	Building Area(m^2)	Number	Building Area(m^2)
Chuncheon	40,156	6,436,548	43,084	6,686,178
Wonju	43,011	6,423,464	46,278	7,246,918
Gangneung	39,114	5,426,250	42,689	5,679,324
Donghae	15,111	2,191,200	17,000	2,660,544
Taebaek	9,116	840,574	11,416	1,108,147
Sokcho	13,635	1,517,207	13,761	1,696,879
Samcheok	20,254	2,264,047	22,233	1,994,350
Hongcheon	28,491	3,246,609	23,259	3,423,950
Hoengseong	18,511	2,587,955	19,511	2,973,764
Yeongwol	17,210	1,975,905	18,872	1,664,372
Pyeongchang	21,301	2,804,721	22,937	3,342,213
Jeongseon	16,539	1,168,503	18,203	1,520,865
Cheorwon	16,530	2,245,859	16,907	2,297,060
Hwacheon	7,983	883,516	8,775	1,226,195
Yanggu	7,615	607,228	8,809	902,031
Inje	12,161	1,423,066	12,580	1,597,298
Goseong	12,180	1,009,356	12,610	1,253,066
Yangyang	11,356	1,310,634	11,838	1,433,673
Total	350,274	44,362,642	370,762	4,8706,828

Table 3. Distribution of all buildings across Gangwon-province by purpose

Description		House	Facility	Factory	WareHouse	Stale	Not Reported
2010’s Building Register	Number Standard	65.6%	21.4%	1.6%	4.2%	4.9%	2.2%
	Area Standard	33.7%	38.6%	9.9%	4.5%	11.4%	1.7%
2015’s Building Register	Number Standard	68.1%	20.5%	1.6%	4.5%	4.8%	0.4%
	Area Standard	36.1%	36.6%	9.9%	5.3%	11.8%	0.2%

What is notable is decreased ratio of buildings classified as not-reported in classification by purpose just like Table 1 in which buildings are classified by roof materials. This change is presumed to be the result of improved administrative record-keeping in the building register.

4. Changes in distribution of slate buildings and GIS-driven visualization

4.1 Changes in distribution of slate buildings by region

The study surveyed changes in distribution of slate buildings by region. Total number of slate buildings increased by 4,352 in Gangwon-province and building area by 454,837m^2. Taebaek showed the highest ratio of slate buildings out of all buildings in both 2010 and 2015 at 51.1% and 53.7%, respectively. Gangreung showed the lowest ratio at 9.9% and 11.1%. In terms of the ratio of building area, Cheolwon showed the highest ratio at 24.5% and 20.1% in both 2010 and 2015 while Donghae showed the lowest ratio at 1.3% and 2.0%. Table 4 below represents distribution of slate buildings in Gangwon-province.

Table 4. General status of slate buildings in Gangwon-province

Area	2010's Building Register				2015's Building Register			
	Number	Rate (%)	Building Area (m2)	Rate (%)	Number	Rate (%)	Building Area (m2)	Rate (%)
Chuncheon	4,552	11.3	205,167	3.2	5,047	11.7	277,058	4.1
Wonju	5,788	13.5	486,544	7.6	5,928	12.8	397,834	5.5
Gangneung	3,869	9.9	203,796	3.8	4,749	11.1	215,002	3.8
Donghae	2,333	15.4	28,464	1.3	2,697	15.9	54,346	2.0
Taebaek	4,660	51.1	102,701	12.2	6,130	53.7	171,867	15.5
Sokcho	2,596	19.0	143,812	9.5	2,468	17.9	110,541	6.5
Samcheok	5,214	25.7	152,768	6.7	6,195	27.9	186,926	9.4
Hongcheon	4,448	15.6	300,068	9.2	2,951	12.7	274,771	8.0
Hoengseong	3,655	19.7	289,315	11.2	3,670	18.8	308,507	3.7
Yeongwol	5,656	32.9	118,040	6.0	6,371	33.8	177,304	7.2
Pyeong-chang	4,436	20.8	157,156	5.6	4,602	20.1	223,856	6.7
Jeongseon	4,766	28.8	69,520	5.9	4,960	27.2	129,731	8.5
Cheorwon	6,402	38.7	549,820	24.5	6,190	36.6	462,020	20.1
Hwacheon	2,497	31.3	92,660	10.5	2,500	28.5	209,698	17.1
Yanggu	2,696	35.4	37,508	6.2	3,429	38.9	128,046	14.2
Inje	3,455	28.4	249,997	17.6	3,241	25.8	233,405	14.6
Goseong	3,242	26.6	38,230	3.8	3,293	26.1	95,186	7.6
Yangyang	2,361	20.8	82,112	6.3	2,557	21.6	106,426	7.4
Total	72,626	20.7	3,307,687	7.5	76,978	20.8	3,762,524	7.7

4.2 Changes in slate buildings by purpose

Changes in distribution ratio of slate buildings by purpose were surveyed by classifying buildings listed in building register by residential, facilities, factory, warehouse, stale and not-reported. In terms of number of buildings, residential buildings and stales rose by 2.93% and 5.44% while facilities dropped by 2.83%. In terms of building area, residential buildings and stales rose by 4.86% and 5.44% while facilities dropped by 6.69%. Table 5 shows distribution of slate buildings in Gangwon-province by purpose.

Table 5. Distribution ratio of slate buildings in Gangwon-province by purpose

Description		House	Fac ility	Fac tory	WareHouse	Stale	Not Reported
2010's Building Register	Number Standard	76.5%	11.5%	1.0%	3.1%	5.5%	2.2%
	Area Standard	34.3%	22.3%	10.8%	5.9%	25.3%	1.3%
2015's Building Register	Number Standard	79.4%	8.7%	1.0%	3.1%	7.5%	0.4%
	Area Standard	39.1%	15.6%	7.8%	6.5%	30.8%	0.2%

Status of changes in distribution of buildings by purpose was surveyed with those not-reported moved to the sidelines as an exception. In terms of number of buildings, residential took up the largest share at 229,885 and factories the lowest at 5,649. In terms of building area, facilities occupied the largest size at 17,833,279 m^2 and warehouse the lowest at 600,354 m^2. Notably, both number of buildings and building area saw an increase. Residential and facilities showed the biggest increase in building area by 2,629,064m^2 and 728,212 m^2. Table 6 shows distribution of slate buildings by purpose.

4.3 Visualization of distributional change

The study visualized distribution of slate buildings in Gangwon-province and the distributional changes with ArcGIS for regional comparison. Database of each region specified above was retrieved to develop a distribution map. Number of slate buildings dropped in Sokcho, Hongcheon, Cheolwon and Injae. Slate building area dropped in Wonju, Sokcho, Hongcheon, Cheolwon and Injae. Figure 2 is image of slate buildings recorded in building register by region. Figure 3 is image of slate building area by region.

Table 6. Distribution of slate buildings by purpose (No. of buildings, building area: m^2)

Description		House	Fac ility	Fac tory	Ware House	Stale
2010's Building Register	Number Standard	229,885	74,867	5,649	14,865	17,465
	Area Standard	14,956,538	17,105,067	4,426,038	2,032,478	5,061,608
2015's Building Register	Number Standard	252,369	76,015	5,902	17,036	17,786
	Area Standard	17,585,602	17,833,279	4,851,014	2,600,354	5,725,059

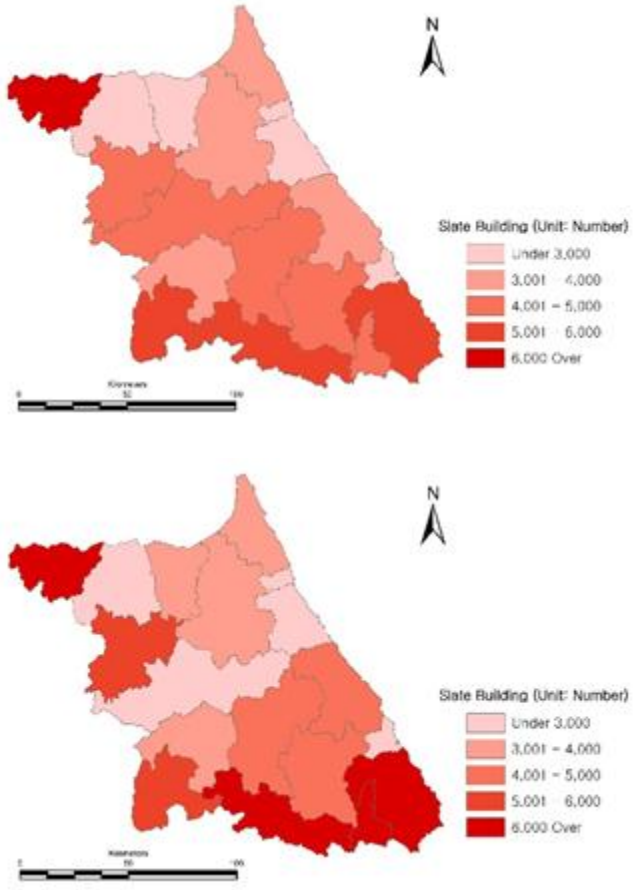
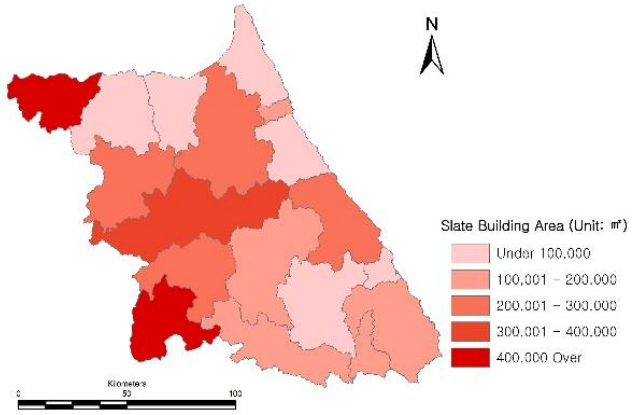


Figure 2. Number of slate buildings specified in 2010 building register (up) and 2015 building register (down) by region



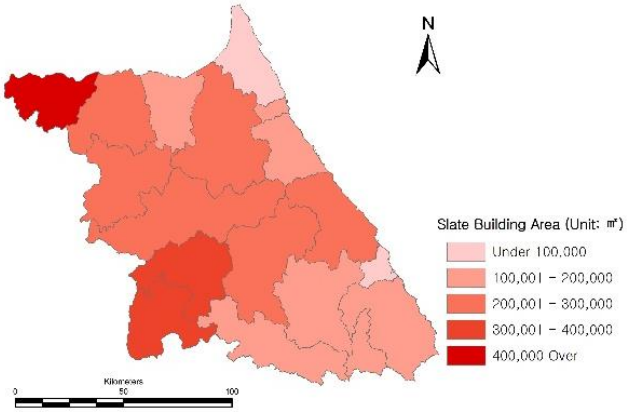
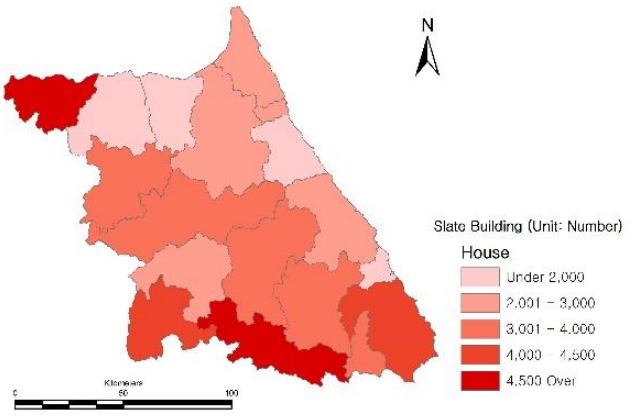


Figure 3. Slate buildings area specified in 2010 building register (up) and 2015 building register (down) by region

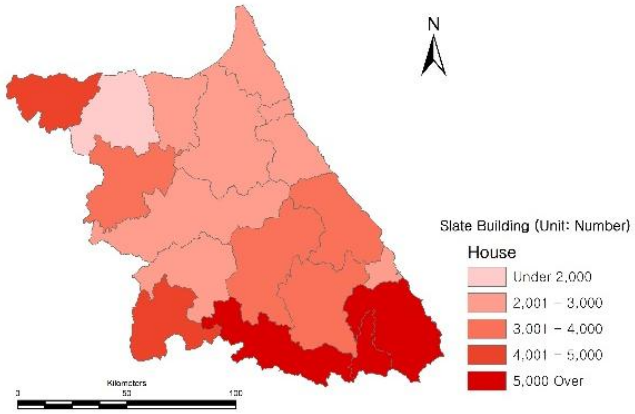
Figure 4 below is an image of distributional changes of slate buildings by purpose. Residential buildings that is most densely distribution is a, a-1, b, b-1. Distribution map of facilities that occupy the largest building area is c, c-1. a, a-1 in Figure 4 is distribution map showing number of residential buildings. Taebaek and Samcheok saw an increase in residential buildings while Hongcheon and Cheolwon saw a decrease. b, b-1 is the distribution map of building area of residential buildings, which saw a significant increase with the biggest observed in Hwacheon. c, c-1 is the distribution map of building area of facilities' buildings. The biggest increase was observed in Wonju, Chooncheon and Taebaek indicating bigger boost primarily in urban areas.

Changes in the ratio of slate buildings out of total number of buildings in Gangwon-province were analyzed by region based on comparison of building register in 2010 and 2015. In terms of ratio of number, Hongcheon and Hwacheon dropped the most at 2.9% and 2.8% while Taebaek, Samcheok and Yanggu posted a high growth of 2.6%, 2.1% and 3.5%. In terms of ratio of building area, Heongseong and Cheolwon dropped the most at 7.5% and 4.4% while Yanggu and Hwacheon posted a high growth of 8.0% and 6.6%, respectively. Figure 5 below is an image of change in the ratio of slate building area and number of slate buildings by region in Gangwon-province from 2010 to 2015.

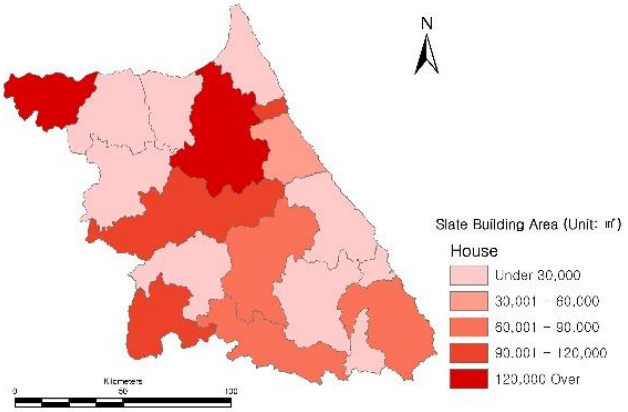
What draws attention is the slight decrease in the ratio of slate buildings out of total number of buildings in Gangwon-province despite an increase in the number of slate buildings and their building area. This is presumed to be the result of an overall increase in the number of buildings in Gangwon-province even though slate is no longer produced and some addition of buildings newly specified in the building register.



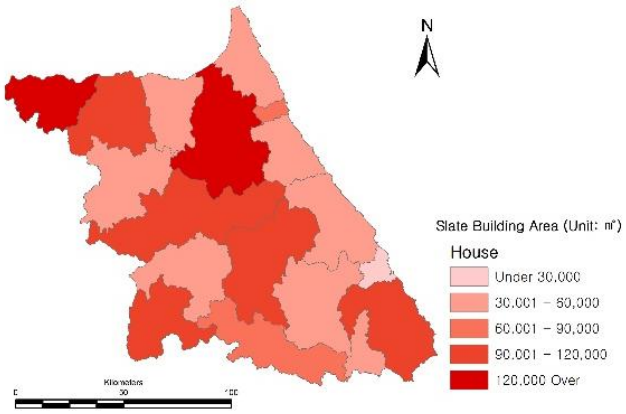
a) Distribution map by purpose (2010's House)`



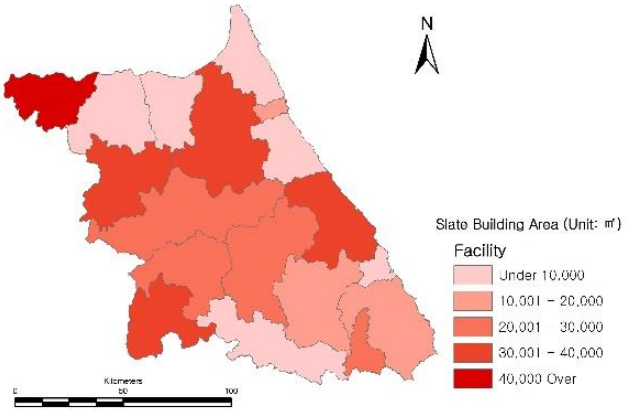
a-1) Distribution map by purpose (2015's House)



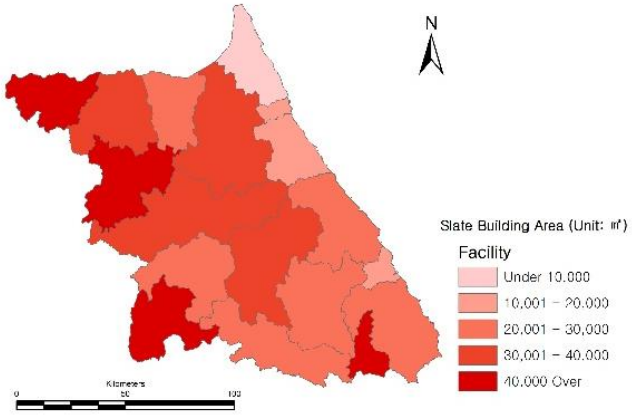
b) Distribution map by purpose (2010's House)



b-1) Distribution map by purpose (2015's House)



c) Distribution map by purpose (2010's Facility)



c-1) Distribution map by purpose (2015's Facility)

Figure 4. Slate distribution by purpose, region

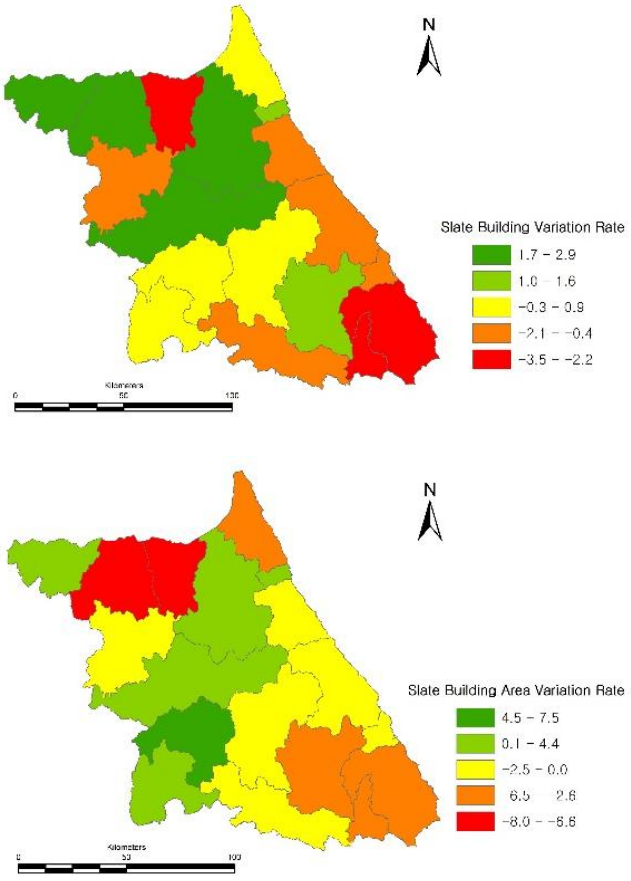


Figure 5. Change in the ratio of number of slate buildings by region (left), change in the ratio of slate building area by region (right) from 2010 to 2015

5. Conclusions

This study analyzed distributional changes of slate buildings by region and purpose. 2010 and 2015 building registers were used for the analysis and arrived at the conclusion below.

First, number of buildings and building area in Gangwon-province rose by 20,488 and 4,344,186 m^2. Number of slate buildings and building area in Gangwon-province rose by 4,352 and 454,837m^2.

Second, number and building area of slate buildings decreased by 0.03% and 0.26%, respectively in terms of ratio change of slate buildings.

Third, slate ratio was highest in Taebaek in both 2010 and 2015 at 51.1% and 53.7% in terms of number of buildings while it was lowest in Gangreung at 9.9% and 11.1% during the same period. It was highest in Cheolwon in both 2010 and 2015 at 24.5% and 20.1% in terms of building area while it was lowest in Donghae at 1.3% and 2.0%.

Fourth, ratio of slate buildings by region in Gangwon-province dropped the most in Hongcheon at 2.9% and Hwacheon at 2.8% based on number of buildings while Taebaek, Samcheok and Yanggu saw the biggest increase at 2.6%, 2.1% and 3.5%. In terms of ratio of building area, Heongseong and Cheolwon saw the biggest drop at 7.5% and 4.4% while Yanggu and Hwacheon saw the biggest increase at 8.0% and 6.6%, respectively.

Fifth, distribution ratio of slate buildings in each region shows a big deviation, which suggests demolition/disintegration plan that takes into account distribution ratio of slate buildings in each region.

The study shows different distribution and distributional change of asbestos slate buildings by region. Improvements in building registers that do not support complete enumeration and demolition/disintegration policy of slate buildings by region should be taken into consideration. The study findings are presumed to be a solid basis for formulating policies related to demolition/disintegration of slate roof materials in the future.

Acknowledgments

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