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Spatiotemporal Analysis of the Formation of Informal Settlements in a Metropolitan Fringe: Seoul (1950–2015)

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Abstract: In many metropolitan areas, the urban fringe is defined by highly sensitive habitats such as forests and wetlands. However, the explosive growth of urban areas has led to the formation of informal settlements in the urban fringe, subsequently threatening these sensitive habitats and exaggerating several social and environmental problems. We seek to improve the current understanding of informal settlements and their formation in the metropolitan fringe through a comprehensive spatiotemporal analysis of the Guryong Area (GA) in the Gangnam District, Seoul, South Korea. We measured the land-use and land-cover (LULC) changes in the entire GA from 1950 to 2015, and then analyzed the changes in one specific land-use type defined as "spontaneous settlements". We then combined these changes with landform and slope data in 600-m-wide bands along the gradient of urbanization. The results showed spontaneous settlements distributed in small clusters in 1975, and the growth of this distribution into larger, more condensed clusters beginning in 1985. Between 1950 and 2015, the total area of spontaneous settlements decreased, while the settlement locations shifted from the urban core to the marginal area of the GA. Meanwhile, the locations selected for spontaneous settlements moved from plain areas with slopes of 2–7%, to more steeply sloped, remote areas such as the mountain foothills with slopes of 15–30%. These results suggest that the spatial characteristics of informal settlements are shown in the degree of aggregation and marginalized trend indicated from the analysis of spontaneous settlements. Finally, we hope the spatial analysis can be used as a basis and starting point for the evaluation process of informal settlement redevelopments in other areas of Seoul, as well as in other Asian cities.

Keywords: land use and land cover; hillside neighborhoods; transition analysis; gradient analysis; Gangnam district

1. Introduction

1.1. Informal Settlements in the Urban Fringes

Urban fringes are seen as unique land-use areas because of their geographic location, soil type, and topography [1]. In these areas, the complex mosaic of land use and land cover (LULC) produces sprawling settlements characterized by low-density residential areas, neighbored with agricultural plots and farmlands. These areas are often defined by highly sensitive habitats such as forests, wetlands, and rivers [2,3]. These existing natural habitats are worth being conserved because they can generate diverse ecosystem functions for cities, such as crop production, biodiversity, and carbon storage. However, the explosive growth of Asian mega-cities in the post-war decades has created a chaotic mixture of urban and rural land use in metropolitan fringes. It has provoked the formation of several informal settlements in such areas, which has resulted in heightened social and environmental problems [4,5].

Informal settlements—which are variously referred to as autonomous urban settlements, slums, barrios, bidonvilles, shantytowns, squatter settlements or favelas—have generally sprung up without, or in defiance of, government approval [6–12]. These settlements tend to share some common features globally [13], such as limited economic activities, difficult living conditions, lack of adequate housing, and residential infrastructure that tends to be unsafe and unhygienic. This living environment not only causes a social divide whereby settlement dwellers easily become impoverished and face social exclusion, but it also impacts the natural environment in often harsh and irreversible ways.

1.2. Spatial Analysis for Informal Settlements

To identify potential strategies and plans for the future management of informal settlements in the urban fringe, the process of spatial transformation must first be elucidated. Comprehensive spatiotemporal analyses of LULC offer a powerful tool for uncovering historical relationships between human activities and the environment [14–17]. This is useful for improving our understanding of informal settlement development in Asian cities. There have been many studies on informal settlements, which have used LULC change detection as a decision-making tool for urban planners and policy makers. The previous studies primarily concentrated on: (1) the impact of scale on land-cover fractions in informal settlements [18]; (2) the advantages of using high-resolution satellite images to identify informal settlements [19,20]; and (3) the detection of spatial and temporal patterns of informal settlement growth to inform future planning [21–23]. However, few studies have analyzed informal settlement formation through the LULC shifts for a specific urban region along the gradient of urbanization, for example, the urban fringe. In this study, examination at the local scale of small urban areas can provide more accurate information on the local characteristics of a specific targeted area [18,19,24–26].

1.3. Informal Settlements in the Seoul Metropolitan Fringe

In the late 1960s and 1970s, South Korea experienced immense economic growth, which was accompanied by expansive rural to urban migration across the country. During this time, due to the difficulty in accommodating the massive influx of people to urban areas, an estimated 20–30% of housing developments across South Korea were informal and deficient in adequate space and basic facilities [27]. In response, the city of Seoul began to focus primarily on controlled urban development [28]. As part of this planning, slum clearance projects were implemented in the 1970s. However, these projects led to further deterioration of the housing situation—leaving the poor with nowhere to go and forcing informal settlements to develop in the marginal areas of Seoul. In the early 1980s, after the ineffective slum clearance of the 1970s, communities labeled as, “newly built slum settlements,” “vinyl house communities,” or “hillside informal neighborhoods” began to spring up on vacant hillsides and in public open green spaces. These communities were characterized by poor housing conditions, overcrowding and a lack of land ownership and building permits [10]. One of the remaining settlements from that period, and the largest until 2015, is now known as the Guryong Slum Village (GSV).

The formation of the GSV resulted from the demolition of informal settlements near the stadiums built for the 1988 Olympic Games in the Gangnam District. To make space for the Olympic venues, the government demolished several illegal settlements near the stadiums. The former residents of these areas were not given alternative living spaces, and subsequently were forced to squat in illegal housing areas on the outskirts of Seoul [27]. This gave rise to the beginnings of the GSV, which is one of the few remaining informal settlements in the Seoul urban area, and is located on the outskirts of one of its wealthiest districts, Gangnam. In addition to the GSV, several other informal settlements, hosting approximately 2000 households, continued to exist as "hillside informal neighborhoods" near the fringe of the Gangnam District until 2011.

Seoul's metropolitan area and its surrounding districts are encompassed by mountains on all sides [29]. As a result, the urban fringe's informal settlements have impacted, and are impacted by, ecological characteristics of mountains. Previous studies on the "hillside informal neighborhoods" of Seoul have focused primarily on socioeconomic factors, including policy alternatives [30], housing regeneration [11,28], living conditions [10]. However, none of these studies have investigated the spatially explicit characteristics of informal settlements that result from specific site selections and their relationship with the topography, particularly in a marginal urban area.

In this study, we propose to improve understanding of informal settlements' formation at the metropolitan fringe through a comprehensive spatiotemporal analysis that considers the role of topographical characteristics. We have conducted this study using the Guryong Area (GA) in the Gangnam District, Seoul, Korea, as a case study. Through this study, we wish to answer the following four questions: What was the historical development of LULC from 1950 to 2015? What characteristics of informal settlement formation were revealed by the changes in LULC? How is the formation of informal settlements related to the topographical characteristics of the marginal area? And finally, what are the potential future implications of the historical and ecological research for urban planning and informal settlement redevelopments? We measured the changes in the LULC for a specific land-use type defined as "spontaneous settlements." This allowed us to interpret autonomous features of the targeted areas, considering the formation of informal settlements at two scales: the entire GA, and 600-m-wide bands of the area along the gradient of urbanization. In addition, we identified patches of spontaneous settlement that were gained or lost during four successive periods. We then examined the relationship between informal settlement formation and topographical characteristics.

2. Materials and Methods

2.1. Study Area

The study area, the GA, extends from Guryongsan Mountain (Figure 1A) and Deamansan Mountain (Figure 1B) to the Yangjacheon River (Figure 1D). The area is approximately 825 ha. The GSV is located in a valley at the base of Guryongsan Mountain and Deamansan Mountain, facing the Yeongycheon stream.

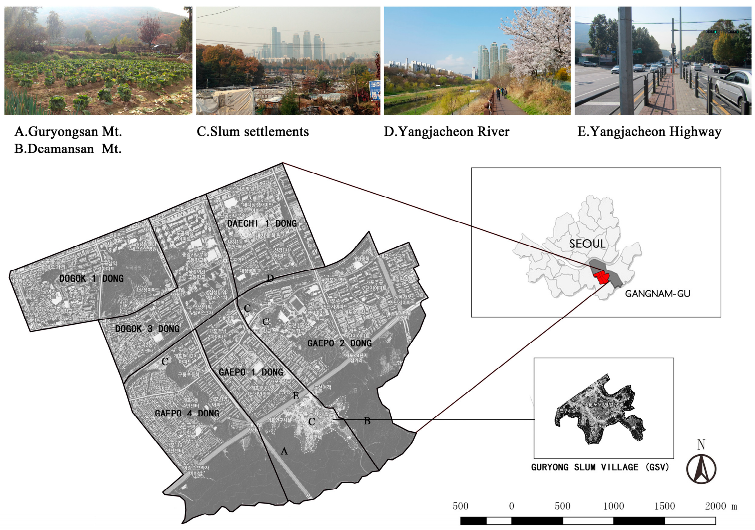

Figure 1. Map showing the location of the Guryong Area on the outskirts of Gangnam District. This includes the units: Dogok 1 Dong, Dogok 3 Dong, Daechi 1 Dong, Gaepo 4 Dong, Gaepo 1 Dong, and Gaepo 2 Dong.

2.2. Date Collection

A series of LULC maps were assembled using five historical maps with land-cover information from 1950 to 1994, and a contemporary digitized land-use map from 2015 [31–34] (Table 1). The topographical characteristics (landforms, slopes, and soil characteristics), were obtained using soil data from the Korean Rural Development Administration (RDA, 2010) [35].

Table 1. Maps used for land-use and land-cover (LULC) reclassification.

Year	Scale	Description
1950	1:50,000	Topographic map of Doonjeon; National Geographic Information Institute of the Republic of Korea.
1975	1:25,000	Topographic map of Doonjeon; based on aerial photos with 10 m and 5 m resolution and field survey; National Geographic Information Institute of the Republic of Korea.
1975	1:25,000	Land cover map of Doonjeon; based on topographic map of Doonjeon in 1975, National Construction Research Institue Ministry of Construction.
1985	1:25,000	Topographic map of Doonjeon, based on aerial photos with 10 m and 5 m resolution and field survey; National Geographic Information Institute of the Republic of Korea.
1994	1:50,000	Topographic map of Suwon, based on aerial photos with 10 m and 20 m resolution and field survey; National Geographic Information Institute of the Republic of Korea
2015	1:1000	Vector data of land use, Seoul Metropolitan Government.

2.3. Date Processing

2.3.1. Mapping and Re-Classifying the LULC

The first step in data processing involved standardizing and transforming the significant LULC types in each map into a common LULC classification with a unified legend covering the study periods (Figure 2). The LULC classifications were based on significant information interpreted from the historical maps [36]. They were then mapped as polygons in a vector-based geographical information system (GIS) using ArcGIS 10.2.2. Each LULC type was quantified to identify the nature of land cover and its transitions. Because historical maps differ in details, survey techniques, accuracy, and map content, there are some shortcomings of these maps. However, the transformation of specific map categories into a generic type is a common technique used in historical landscape analysis to make comparisons between time periods [36,37].

The study periods were selected to represent key periods in South Korea's history. Given the available historical data, five different years have been used to analyze the changes in the LULC: 1950, 1975, 1985, 1994, and 2015. Until the late 19th century, the original network of Seoul's primary streets remained unchanged [28]. The Korean War, a major historic turning point for the Korean Peninsula, lasted from 1950 to 1953, during which many natural habitats were destroyed. Following the war, the concentration of South Korea's population in Seoul accelerated the development of roads and residential land due to rapid industrialization. The Gangnam District developed rapidly during this time, as can be seen from the 1975 map [31]. The maps from 1985 and 1994 represent the periods before and after the Olympic Games, respectively [33,34]. Finally, the map from 2015 was chosen to represent the current status of the area [32].

A spatial-temporal database including the five time periods of 1950, 1975, 1985, 1994, and 2015 was created using the historical topographic maps and historical land use maps for the Gangnam districts. LULC patches in 1950 were digitized from a georegistered digital map, scanned from a hard copy of the 1950 topographic map of the Doonjeon area (Gangnam district's old name). The 1975 (Doonjeon area), 1985 (Doonjeon area) and 1994 (Suwon area) maps were paper works created from aerial photos, with a spatial resolution of 5 m, by the National Geographic Information Institute of the Republic of Korea. LULC patches in 2015 were digitized from aerial photos by the Seoul Metropolitan Government, with a spatial resolution of 5 m. Each map from 1950 to 1994 was digitized using image-to-image georeferencing methods in order to match the scales at a 5 m spatial resolution.

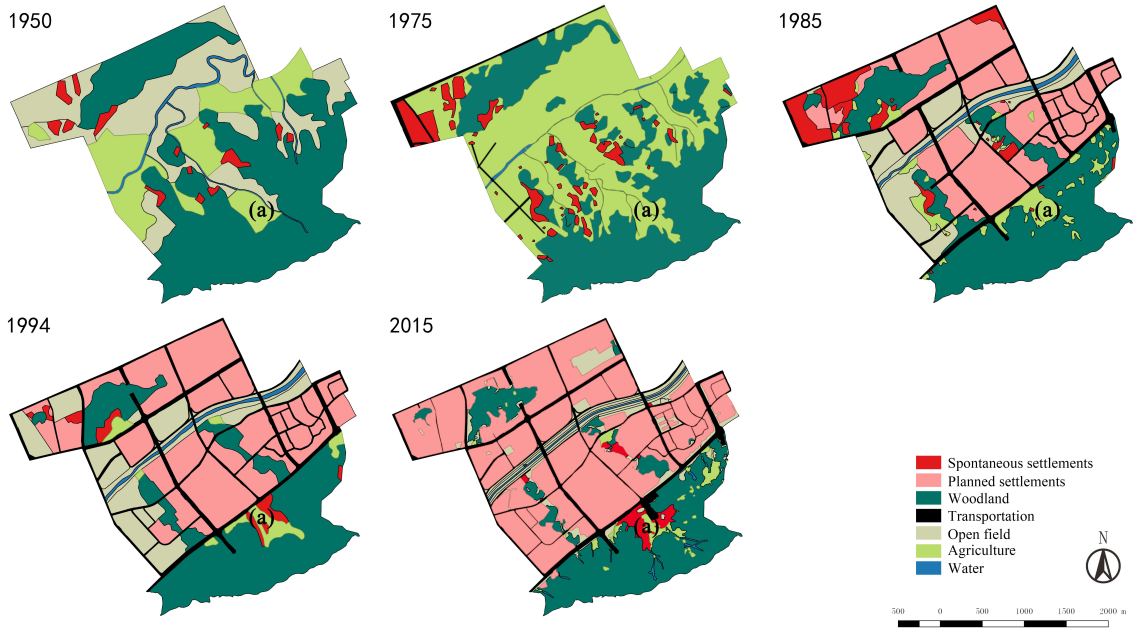

Figure 2. Reclassified maps of land use and land cover (LULC) in 1950, 1975, 1985, 1994, and 2015; (a) is the location of the Guryong Slum Village (GSV).

The new LULC classification patches were interpreted and digitized based on a series of criteria that were defined for land cover delineation (Table 2). These were identified as the following LULC categories: agriculture, woodland, transportation, open field, water, planned settlements, and spontaneous settlements. The most significant LULC type for this study was the category "spontaneous settlements" (Table 2-01) (Figure 3A). This LULC type is useful for examining changes in settlements that form spontaneously during urbanization. As mentioned in the introduction, "autonomous urban settlements" were generally occupied through the processes of informal occupation rather than through formal planning or construction [12]. This in turn manifested into spontaneous spatial patterns. However, due to the limited accuracy of historical data, some of the unidentifiable autonomously formed settlements were included (Figure 3c). Therefore, we use the term "spontaneous settlements" to denote the characteristics of informal settlements (Figure 3b).

Table 2. Reclassification of LULC types used in the analysis.

No.	Land Cover Class	Class Description
01	Spontaneous settlement	Autonomous urban settlements, informal settlements including slums or squatter settlements and unplanned settlements ; other unidentifiable settlements with spontaneously formed characteristics.
02	Planned settlements	Urban residential, commercial or industrial areas according to official urban planning.
03	Transportation	Roads, large scale/public parking lots.
04	Agriculture	Cultivated field, open agricultural land.
05	Woodlands	Forest or parks with clustering trees.
06	Water	River, stream, pool, canal.
07	Open field	Planned or designed green spaces; Un-developed or unused lands, heath.

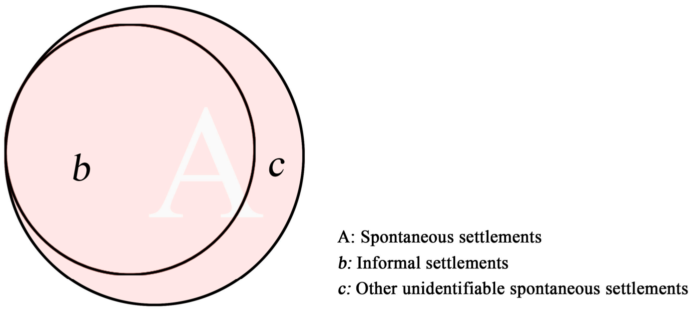

Figure 3. The conceptual figure of the relationship between "spontaneous settlements" and "slum settlements". (**A**) Spontaneous settlements are not *(**b**)* informal settlements, because of *(**c**)* other unidentifiable spontaneous settlements.

2.3.2. Mapping the Topographical Characteristics

In the second step of data processing, the topographical characteristics were assessed. The topographical characteristics were derived from soil codes from the Korean soil information system (http://soil.rda.go.kr/soil/index.jsp). This included the topographical landscape types, slopes, and recommended use for each soil code. In 1964, the Korean government launched a National Soil Survey Project, testing and documenting soil types throughout South Korea, and increasing the amount of detail each year. Each soil type is defined by its physical and chemical properties, as well as its landscape parameters [29]. Although landforms and slopes changed significantly during periods of rapid urbanization, the primary landscapes types determined from the soil characteristics retained their natural status. Thirty-two soil codes were identified in the GA and 10 soil codes were found in GSV (Table 3). Using the topography type attached to each of the soil codes as an index, the soil types were grouped into eight topographical types throughout Seoul [29]. Five of these eight topographical types were found in the Gangnam District and in the GA: local alluvial, alluvial plain, mountain foothill, rolling or hill, and mountain or hill. Similarly, six slope classifications were identified: 0–2%, 2–7%, 7–15%, 15–30%, 30–60%, and 60–100% (Figure 4) [35]. The landforms were closely related to slope type, and some landforms included diverse slopes; for example, the local alluvial included slopes of 2–7% and 7–15%.

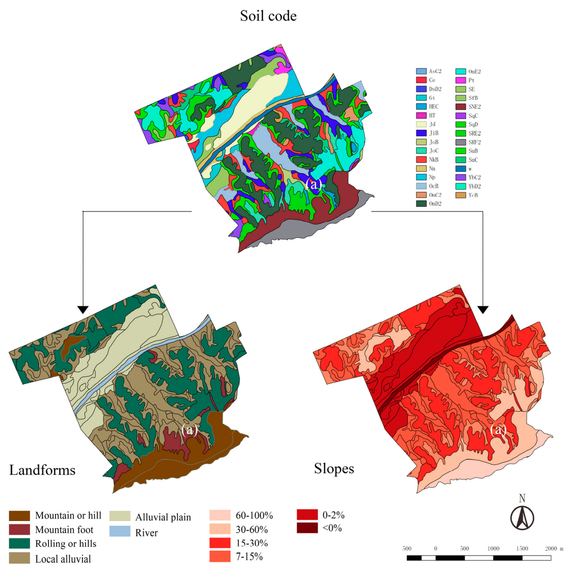

Figure 4. Maps of landforms and slopes based on soil data downloaded from the database of Agricultural and Soil Information of South Korea; (a) shows the location of Guryong Slum Village (GSV).

Table 3. Soil types and their description in the Guryong Area (GA).

Soil-Code	Soil-Series	Soil Order	Landforms	Slope	Recommended Use	In GSV
SRF2	Songsan	Inceptisols	Mountain or Hill	60~100	Forest	
OnD2	Osan	Inceptisols	Rolling or Hill	15~30	Orchard and mulberry	△
HEC	Hoegog	Entisols	Local alluvial	7~15	Paddy	△
SqD	Suam	Entisols	Mountain foot	15~30	Native Pasture	△
JoB	Jigog	Inceptisols	Local alluvial	2~7	Cultivated upland	△
JiB	Jisan	Inceptisols	Local alluvial	2~7	Paddy	△
NkB	Noegog	Inceptisols	Local alluvial	2~7	Cultivated upland	
JOC	Jigog	Inceptisols	Local alluvial	7~15	Cultivated upland	△
SuC	Sangju	Inceptisols	Local alluvial	7~15	Cultivated upland	
SuB	Sangju	Inceptisols	Local alluvial	2~7	Cultivated upland	
YbC2	Yesan	Inceptisols	Rolling or Hill	7~15	Cultivated upland	
SqC	Suam	Entisols	Mountain foothill	7~15	Cultivated upland	
SfB	Sachon	Inceptisols	Local alluvial	2~7	Paddy	
SE	Seogcheon	Inceptisols	Alluvial plain	0~2	Paddy	
OnC2	Osan	Inceptisols	Rolling or Hill	7~15	Cultivated upland	
Gt	Gangseo	Inceptisols	Alluvial plain	0~2	Paddy	
Jd	Jungdong	Entisols	Alluvial plain	0~2	Cultivated upland	
OnE2	Osan	Inceptisols	Rolling or Hill	30~60	Native Pasture	△
OcB	Ogcheon	Inceptisols	Local alluvial	2~7	Paddy	△
Np	Nampyeong	Inceptisols	Alluvial plain	0~2	Paddy	
SNE2	Songsan	Inceptisols	Mountain or Hill	30~60	Native Pasture	△
YbC2	Yesan	Inceptisols	Rolling or Hill	7~15	Cultivated upland	
YbD2	Yesan	Inceptisols	Rolling or Hill	15~30	Cultivated upland	
Pt	Pyeongtaeg	Inceptisols	Alluvial plain	0~2	Paddy	
Nn	Nagdong	Entisols	Alluvial plain	0~2	Cultivated upland	
HT	Hwasu	Inceptisols	Alluvial plain	0~2	Paddy	
DsD2	Dosan	Entisols	Mountain or Hill	15~30	Native pasture	
AsC2	Asan	Entisols	Rolling or Hill	7~15	Cultivated upland	
YcB	Yeongog	Inceptisols	Mountain foothill	2~7	Cultivated upland	
SRE2	Songsan	Inceptisols	Mountain or Hill	30~60	Native pasture	
Ce	Cheongweon	Inceptisols	Alluvial plain	0~2	Paddy	△
DsD2	Dosan	Entisols	Mountain or Hill	15~30	Native pasture	

△: the soil code exists in the location of GSV.

2.4. Date Analysis

2.4.1. Determination of Changes and Transition Analysis

The spatial pattern development in the GA over time was analyzed at two spatial scales: the entire GA, and bands extending from the core of the GSV to the upper end of the GA. The analysis of the bands demonstrated the variability in the spatial patterns of the LULC [38–40], especially that of spontaneous settlements, along the gradient of urbanization in the Gangnam District [39]. Six 600-m-wide bands at intervals of 3.3 km were defined, beginning at the core of the GSV and extending out towards the urban core of the GA (Figure 5). The size of each distance band was defined using the size of GSV and the average width from the core of the GSV to the border of the GA [38].

To determine changes in spatial pattern, and to identify the "from–to "nature of the transitions in spontaneous settlement land-cover types, changes in land cover were examined using successive periods: 1950–1975, 1975–1985, 1985–1994, and 1994–2015. By overlaying the spontaneous settlement patch layers from two successive periods, we identified trends in land-cover transitions. For example, an area was defined as "lost" if spontaneous settlement cover occurred in the earlier sample period, but not in the later one.

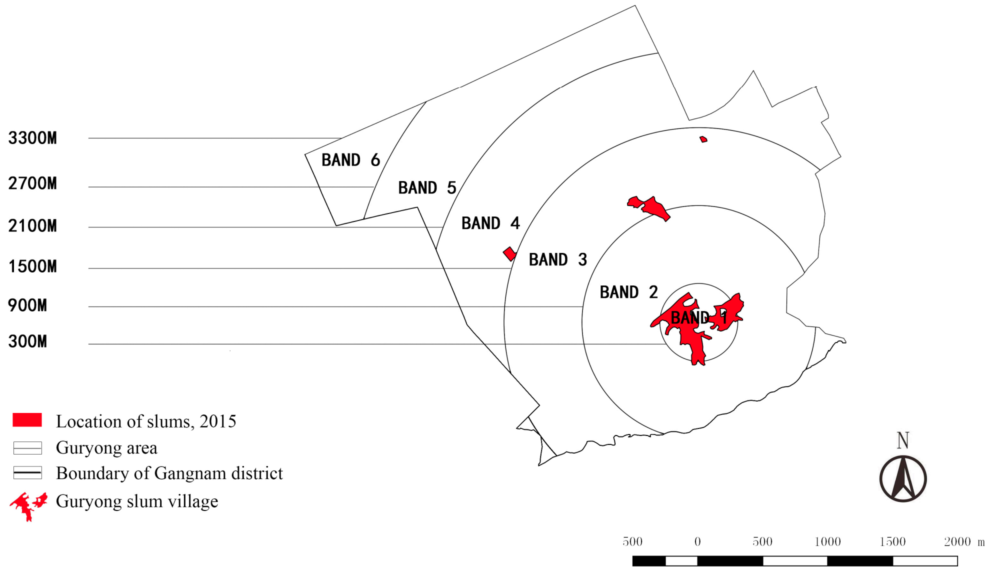

Figure 5. Bands separated by 3.3 km starting from the core of GSV, and extending to the upper end of the Guryong Area (GA) toward the urban core of the Gangnam District. There were six bands in total; each band was 600 m wide.

2.4.2. Analysis of Relationships between LULC Changes and Topographical Characteristics

The band analysis also examined the association of topographical characteristics with the location of spontaneous settlements. We overlaid the spontaneous settlement layers with the maps of landforms and slopes to investigate their relationships within the specific bands.

3. Results

3.1. Changes in Land Cover Types over Time

3.1.1. Changes in the Time Series across the Entire GA

The changes in LULC for the entire GA are presented in Figure 6. The most significant change was the transformation of other land-cover types into planned settlements and transportation. Approximately 405 ha of the GA were planned settlements areas in 2015, compared with 284 ha in 1985. Additionally, the area occupied by road construction increased 3.3-fold between 1975 and 2015. The second most significant change occurred in agriculture. The percentage of agricultural land increased 1.63-fold between 1950 and 1975, but decreased by 90% between 1975 and 1985. The area of agricultural land was larger in 1975 than in all other sample periods, occupying almost 50% of the entire GA. However, by 2015, only a small amount of agricultural land remained in the outskirts of the district. The third most significant change occurred in woodland cover, which decreased year by year. Most of the loss occurred in the periods 1950–1975 and 1975–1985, when the percentage of woodland cover decreased by 17% and 25%, respectively, subsequently decreasing by a further 15% between 1994 and 2015 (Figure 6).

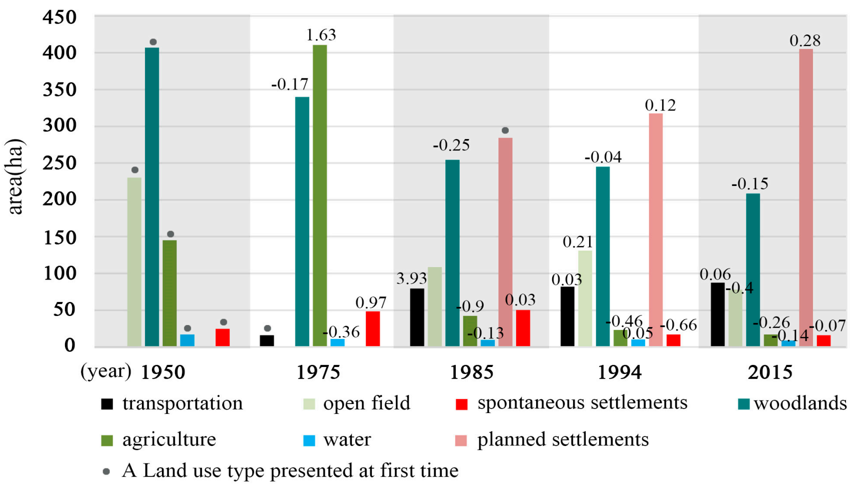

Figure 6. The total area of LULC types for five sampling periods. Annual rates of LULC change by class from 1950 to 2015 in percent (decimal fraction).

3.1.2. Changes within the Bands across the Entire GA

The percentages of various land-cover types within each band changed over time (Figure 7). The area of natural landscape cover decreased along the gradient of urbanization over time. This is illustrated by the decrease in the water and woodland land-use types and corresponding increases in the planned settlements area and transportation categories. The water landscape type disappeared in bands 1 and 2 by 1985, but reappeared in band 2 in 2015. This is interpreted in Figure 2, where maps from 1950 and 1975 show a tributary stream originating from the Daemosan and Guryongsan Mountains, and flowing through the GSV to the Yangjacheon River. In the 1985 map, the tributary is no longer visible. The loss of this tributary is also reflected in the decrease in water area from 17.07 ha in 1950 to 9.55 ha in 1985 (Figure 6). Furthermore, the shape of the water corridors was more diverse and natural in 1950 than in 1975. The reappearance of the water landscape type in band 2 in 2015 is due to the Korean government building several canals in the Guyongsan and Deamansan Mountains for hydrological projects.

Most of the woodland area was located in bands 1, 2, 3, and 5. The percentage of woodland cover decreased, with increasing distance from the core of the GSV. This was true particularly in bands 4 and 5, in which it decreased from more than 10% (17.30 ha) and 60% (73.02 ha) in 1950 to less than 4% (5.96 ha) and 25% (22.54 ha) in 2015. The area of woodland in bands 1 and 2 decreased from more than 35% (11.04 ha) and 80% (174.17 ha) to less than 30% (7.78 ha) and 55% (115.66 ha), respectively. Between 1985 and 2015, the highest percentage of woodland was maintained in the bands where the GSV is located. While the percentage of woodland decreased, the percentage of transportation and planned settlements areas increased correspondingly. Road construction began near the urban core (band 6) in 1974, then spread to the marginal area (band 2) in 1994, and finally occupied approximately 20% of each band in 2015. The planned settlements area gradually increased correspondingly from bands 6 to 1.

The agricultural area almost completely disappeared with urbanization. It peaked in 1975 from band 1 to band 4. However, during the period of rapid development from 1975 to 1985, large areas of agricultural land were lost in bands 3, 4, and 5. Currently, agricultural activities remain only in bands 1 and 2. Agricultural activities often developed alongside built-up villages. We examine this feature in the following section, where we analyze spontaneous settlements.

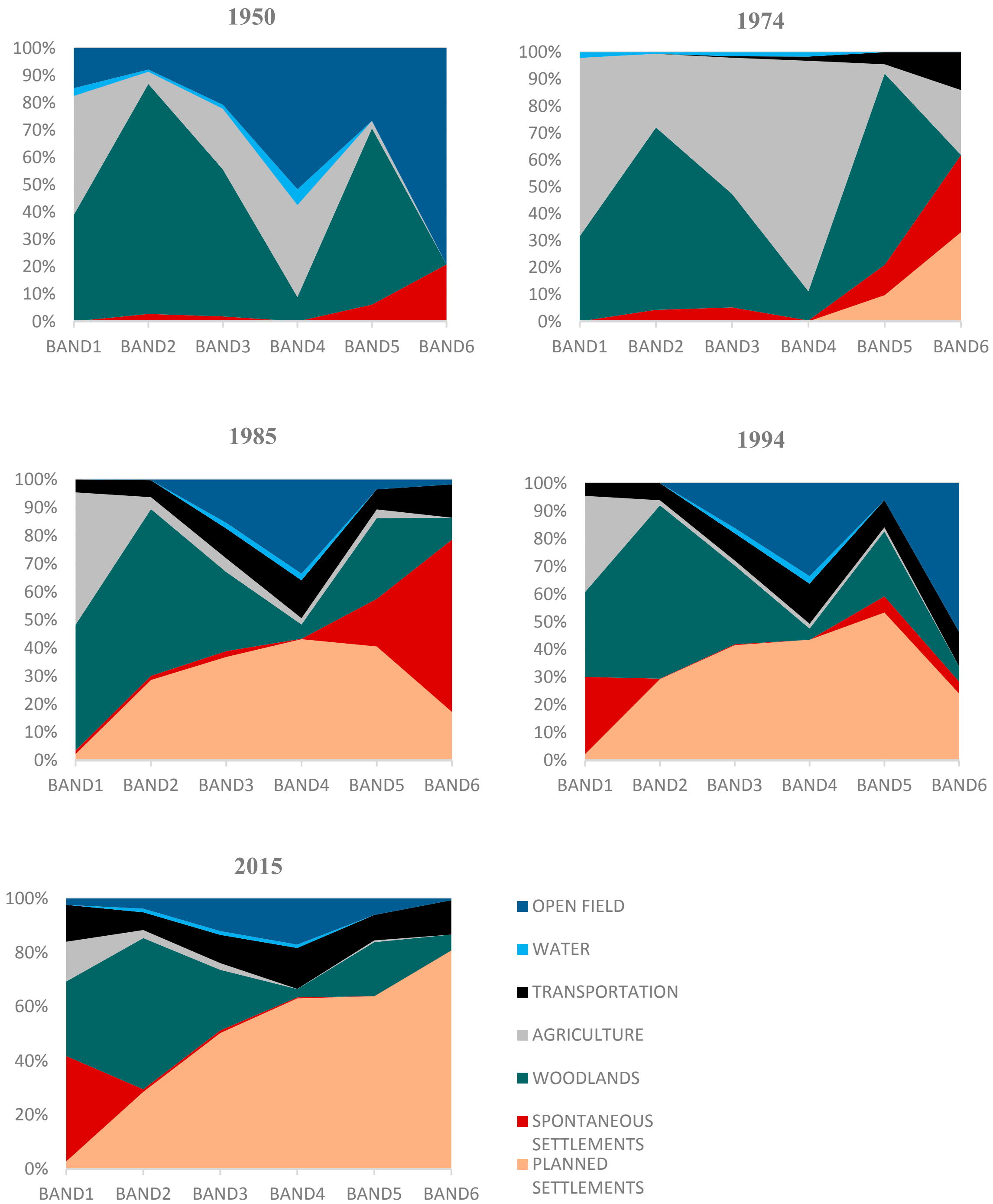

Figure 7. The proportion of LULC types within the 6 distance bands.

3.2. Changes in Spontaneous Settlement Cover over Time

3.2.1. Transition Analysis of Spontaneous Settlements: The Entire GA

The changes in spontaneous settlements in the bands between two successive sample periods were mapped to highlight differences. These maps illustrated not only where changes in spontaneous settlement cover occurred, but also whether spontaneous settlement cover was lost, which LULC types they were converted to and, if spontaneous settlement cover increased, which LULC types they replaced [41]. Figure 8a shows that the area of spontaneous settlements increased by about 26 ha between 1950 and 1985. However, it decreased markedly by approximately 33 ha between 1985 and

1994, subsequently decreasing by a lesser amount between 1994 and 2015. Spontaneous settlement land cover developed alongside agricultural activities, yet the area is only shown to increase significantly in the 1975 map (Figure 6). In the 1985 map, the area of spontaneous settlements increased by a lesser amount, but the area of agricultural land dramatically decreased at the same time. The size of a mean patch in 1985 was almost double that in 1975, indicating that settlements were more clustered in 1985 than in 1975 (Figure 8a). Although the percentage of spontaneous settlements was largest in 1985, that was a transition period before the total urbanization of the GA. The settlements built in the present-day location of the GSV first appeared in 1985. In 2015, not only the GSV but also the remaining area of spontaneous settlements were informal settlements.

Transition analysis indicated significant turnover in spontaneous settlement cover. The increase in spontaneous settlement land varied from 21% between 1985 and 1994 to 144% between 1950 and 1975, whereas the decrease varied from 36% between 1950 and 1975 to 89% between 1985 and 1994 (Table 4). The largest decrease (89%) from 1985 to 1994 represented conversion to planned settlements land use (28.2 ha) during the period of rapid urbanization. Subsequently, only 4.26 ha was left unchanged from 1994 to 2015, compared with the 26.01 ha left unchanged from 1975 to 1985 (Table 4). The GSV occupied the largest percentage of unchanged land from 1994 to 2015, after being converted from the land-cover types of agriculture and woodland since 1985 (Figure 8b). The substantial area of spontaneous settlements that replaced woodland was due to rapid urbanization in earlier years. However, this phenomenon continued in the period from 1994 to 2015, indicating that the formation of spontaneous settlements occupying natural land continued after the period of rapid urban development.

Table 4. Summary of results from the transition analysis of changes in spontaneous settlement areas for four periods.

	1950–1975	1975–1985	1985–1994	1994–2015
Unchanged Land Cover (Ha)	14.35	26.01	4.05	4.26
Loss of Spontaneous Settlements Cover (Converted to) (Ha)				
Transportation	0.35	3.03	0.31	2.49
Open field	0	2.52	12.58	0.12
Woodland	1.6	2.35	1.87	2.79
Agriculture	6.81	3.21	1.5	0.64
Water	0	0	0	0
Planned settlements	0	11.5	28.2	6.58
Total *	8.76	22.61	44.46	12.62
Percent **	0.36	0.47	0.89	0.74
Gain of Spontaneous Settlements Cover (Regenerated from) (Ha)				
Transportation	0	0	0	0
Open field	19.87	0	0.15	0.15
Woodland	12.8	6.1	4.69	6.46
Agriculture	2.68	17.93	5.83	5.12
Water	0.35	0	0	0
Planned settlements	0	0	0	0
Total *	35.7	24.03	10.67	11.73
Percent **	1.44	0.5	0.21	0.68

* Total: the total area of spontaneous settlements gained or lost during the period between two successive sampling periods; ** Percent: the percentage total area of spontaneous settlements gained or lost compared to the previous sample year.

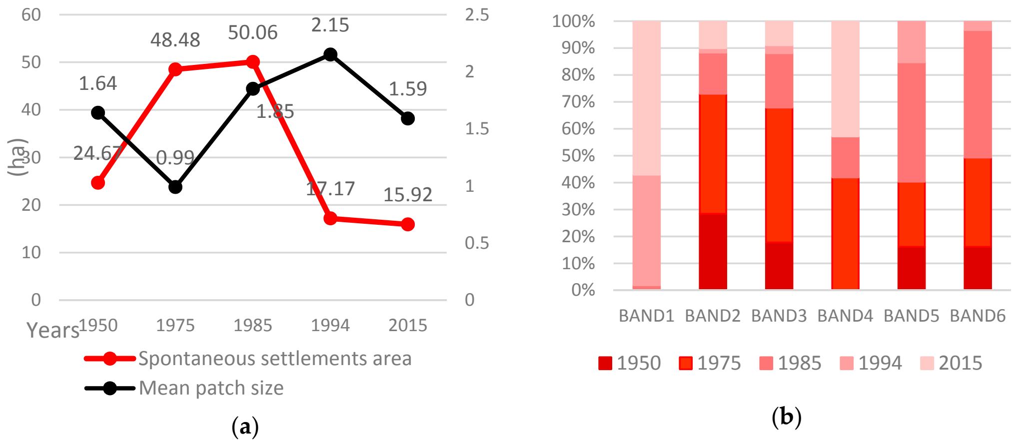

Figure 8. (**a**) Changes in total spontaneous settlement area, and changes in the mean size of spontaneous settlement patches from 1950 to 2015 in the GA; (**b**) percentages of spontaneous settlement patches in different bands.

3.2.2. Changes in Patches of Spontaneous Settlements within Bands

The total percentage of spontaneous settlement cover in the different bands showed not only differences in location during different periods but also the marginalization that accompanied the process of urbanization. The annual rate of change in spontaneous settlement cover varied significantly among the bands. When patches began to appear in band 1 in 1985, the percentage of spontaneous settlement cover in the other bands (2–6) decreased gradually with increasing distance from the GSV. In 2015, most spontaneous settlements were in bands 1 and 3 (Figures 7 and 9). The GSV initially consisted of small fragmented areas of inhabited land, which subsequently expanded in size from 1985 to 1994 and finally shaped into one of the biggest urban informal settlement areas between 1994 and 2015. In 2015, the GSV covered the largest percentage of land in band 1, farthest away from the urban core of the GA (band 6) (Figures 7 and 9).

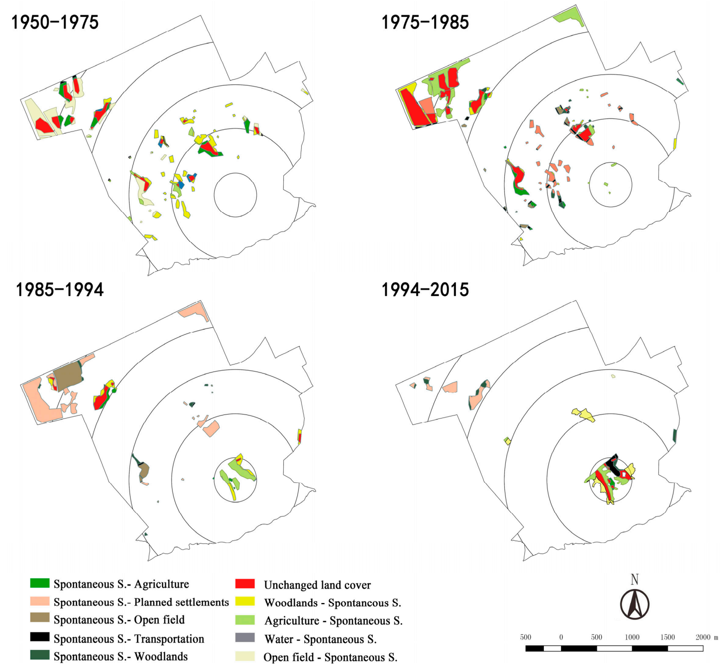

Figure 9. Maps of spontaneous settlement cover lost to other land-cover types, and replacing other land-cover types during five successive sampling periods.

3.3. Relationships between Topographical Characteristics and Spontaneous Settlements Cover among Bands

The locations of spontaneous settlements in Figure 10 show a clear pattern, generally occurring in the landforms of rolling or hill, local alluvial, or slopes of 2–7% and 7–15%. Although the area covered by spontaneous settlements in the mountain foothills was insignificant in all the historical sample periods, it did increase approximately fourfold (2.71 ha) by 2015 compared with that in 1975 (0.7 ha) (Figure 10a). Rolling hill soils occur along the ridgelines of both mountains, spreading north, in linear patterns towards the Yangjaecheon River (Figure 4). Local alluvial soil fills the valleys between these mountain ridges (Figure 4). Mountain foothills soil occur along the ridges of the Guryongsan and Daemosan Mountains (Figure 4).

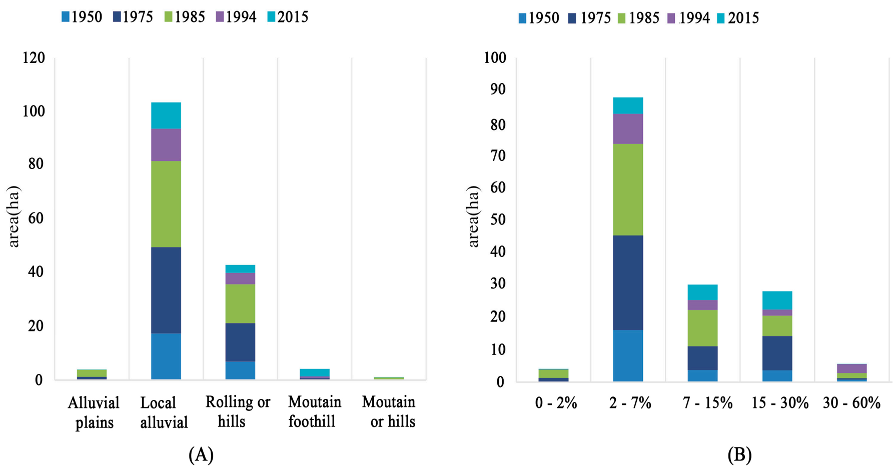

Figure 10. Quantification of five landforms (**A**) and six slope types (**B**) overlaying with spontaneous settlements for five successive sampling periods.

The distribution of landforms and slope types overplayed by the spontaneous settlements in the bands reveals that before 1985 most spontaneous settlement areas were located on local alluvial land (2–7% and 7–15%) in bands 3 and 6 (Figure 10). There was subsequent development in a few areas of band 3 that were rolling or hill (15–30%) and in band 1 with diverse landforms of local alluvial, rolling or hill, and mountain foothill (15–30%), followed by other mountain or hill (30–60%) areas by 2015 (Figure 10). This indicates that the locations selected for spontaneous settlements moved from plain areas to more steeply sloped and remote areas during the urbanization process.

4. Discussion

4.1. Historical LULC Changes from 1950 to 2015

The mountain–river integrated landscape system was dominant in the GA prior to urbanization. Before 1950, and up until the period when Gangnam rapidly developed in the mid-1970s, the Gangnam District consisted of an integrated landscape system with the Yangjaecheon River and Guryong Mountain. This landscape system was comprised of intact, persistent ecosystems, with scattered areas of agricultural use. Daemosan Mountain and Guryongsan Mountain were completely covered with forests between 1950 and 1975 (Figure 2). The historical maps show an undisturbed, continuous area of vegetation up to the boundary of the valley where the present-day GSV is located. However, with rapid urbanization, much of this forested landscape disappeared [41]. Large areas of natural land were lost when constructed areas dramatically increased. For example, between 1975 and 2015, the woodland cover decreased by approximately 39%, while the transportation cover increased by 3.3-fold (Figure 6).

4.2. The Spatial Characteristics of Informal Settlement Formation in the GA as Indicated by Topographical Characteristics

The spatial characteristics of spontaneous settlements were shown through the degree of aggregation and locational shifts. While the total area occupied by spontaneous settlements in 1975 was almost equivalent to that in 1985, the mean size of the patches was markedly smaller (Figure 8a). This indicates that the informal settlements were distributed at a smaller scale with decentralized agricultural activities in 1975, but in 1985, they began to form larger clusters (Figures 8a and 9). The band analysis indicated that the rates of change in spontaneous settlements varied significantly depending on the distance from the urban core to the GSV. The trend of marginalization was reflected in the increasing spontaneous settlements in bands 1 and 2 since 1985 (Figure 8b). When patches began to appear in band 1, the percentage of spontaneous settlements in the other bands (2–6) decreased gradually with increasing distance from the GSV. Since 1994, the location of spontaneous settlements has moved away from most planned urban areas and into natural areas such as the mountains. In addition, the transition analysis revealed a similar trend, which found that most of the new areas of spontaneous settlements in 1994 and 2015 had once been woodland cover in the outskirts of the district (Figures 7 and 9).

From 1945 to 1961, many refugees from the Second World War and the Korean War settled in the hillside green spaces around Seoul. This was the beginning of the hillside informal neighborhoods that appear in the 1950 map of the GA (Figure 2). Han et al. (2004) have concluded that most of the citizens of new informal settlements and squatter settlements in the urban fringe of Seoul in the 1980s came from the 1970's inner-city government's slum clearance projects. This accounts for the trend of marginalization in the GA. In general, city governments have often turned to abolishment as a solution to the informal settlements, subsequently transferring and displacing residents [42]. Yet, without a clear understanding of the potential needs of the affected residents, the results have often led to a vicious cycle of forced relocation and informal settlement development [10].

Firey (1946) has argued that the isolation from other highly developed areas plays a key role in the process of informal settlement formation. The city of Seoul is spread across an intricate landscape defined by watersheds, mountains, and rivers [29], and the topographically isolated areas, particularly the mountains, have often been chosen by low-income citizens. Our analysis of the relationships between spontaneous settlements and topographical characteristics showed that the early sites of spontaneous settlements were in flat, plain areas (0–2%, 2–7%) (Figure 10b). However, as urbanization spread from the north side of the city to the south, informal settlements were established on steeper slopes (15–30%), in areas such as the mountain foothills (Figure 10). These areas had little construction and were relatively undeveloped. Therefore, they were easily ignored by the government, which motivated informal city inhabitants to choose these sites for their living areas. As an example of this trend, the GSV is surrounded by forest vegetation to the east, west, and south. There is only one entrance to the village, which is located at the north end, the side closest to the urban Gangnam District.

4.3. Implications for Urban Planning and the Redevelopment of Informal Settlements

La Rosa et al. (2014) have indicated that urban fringes were comprised of the complex LULC types including some highly sensitive habitats such as forests, wetlands, and rivers. The GA supported a complex pattern of LULC types with different ecological characteristics that were related to persistent features [41]. The transition analysis, as well as the historical preference for settlement construction in mountain areas, showed that the spontaneous settlements of the GA took place primarily in the forests and on agricultural lands (Figure 9). This trend suggests that advantageous soil fertility was offered by forests, paddies, and croplands. Figure 4 shows the natural areas of rolling hill and local alluvial soil extending from the mountain toward the Yeongjaecheon stream. The linear pattern of this soil type represents a continuous vegetation system that extends from the Daemosan and Guryongsan Mountains all the way to the Yeongjaecheon stream, offering a natural landscape corridor (Table 3). Furthermore, the southern area of the Yangjaecheon offers an excellent habitat for wild birds since it contains forest linking the Daemosan and Guryongsan Mountains [43]. This implies that the urban fringe landscape of the GA has retained high biodiversity potential [44]. Thus, development planning approaches should be unique to metropolitan fringe areas and should consider the biodiversity of the area [45]. The existence of the natural resources represents an asset to urban fringes, which should, in turn, be considered in the redevelopment of informal neighborhoods.

Despite this notion, much of Seoul's rapid population growth was accommodated via informal settlements, with little attempt being made to limit the risk of environmental impairments [46]. Previous strategies for the preservation or restrained upgrading of informal settlements commonly focused on fluctuating elements of the settlements or communities, such as citizen demands, facilities, and economic development regarding social issues and regional economies [4,11,47–50]. These strategies placed little value on the areas' natural and permanent features. The GSV and other remnant informal settlements in the GA have neighbored with persistent forest landscapes for decades. In addition, the soil system directly beneath the GSV is unique in that the rolling hill and local alluvial soil types appear further up the mountains, and the soil types are more diverse in the GSV area than in any other area in the Gangnam District (Table 3). This suggests the potential for a wide range of vegetation types to exist within the small area of the GSV. For example, the mountain foothill soil is suitable for sustaining a healthy forest with diverse tree communities including *Quercus acutissima* and *Betula schmidtii* [43]. Therefore, it is important for future policy-making to consider the ecological potential both in urban fringe developments and in the redevelopment of informal settlements.

5. Conclusions

This study aims to improve understandings of informal settlement formation in a metropolitan fringe, through a comprehensive spatiotemporal analysis of topographical characteristics, using the case study of the Guryong Area (GA) in the Gangnam District of Seoul, South Korea. The LULC changes indicated that (1) large areas of natural land were lost due to the dramatic increase in constructed areas (Figure 6); and (2) spontaneous settlements occupying natural lands continued to emerge after the period of rapid urban development (Table 4). The transition analysis showed that while the total area occupied in 1975 by spontaneous settlements was almost equivalent to that in 1985, the mean size of the development patches was markedly smaller (Figure 7a). The band analysis indicated that the trend of marginalization was reflected in increasing spontaneous settlements in bands 1 and 2 since 1985 (Figure 7), while the percentage of spontaneous settlements in the other bands (2–6) decreased gradually with increasing distance from the GSV (Figures 8b and 9). The analysis of the relationship between spontaneous settlements and topographical characteristics showed that early spontaneous settlements developed in flat areas, while later settlements were established at the district's border in steeper areas with slopes of 15–30%, such as the mountain foothills (Figure 10).

These results suggest that the spatial characteristics of informal settlements are shown in the degree of aggregation and marginalized trend indicated from the analysis of spontaneous settlements. The results also support the idea that isolation from other highly developed areas plays a key role in the process of informal settlement formation during the urbanization process. However, the informal settlements at the urban fringe are location-specific, and the urban fringe landscape often retains high ecological potential. For example, the soil system directly beneath the GSV is unique in that the rolling hill and local alluvial soil types are ideal for a wide range of plant communities. Therefore, we suggest that the development of the urban fringe should consider ecological potential as an ecotone bridging the natural and urban systems. This idea can be applied to urban planning and policy-making for informal settlements in the metropolitan fringe.

Understanding the strategies of informal settlement redevelopment in rapidly expanding cities requires not only the assessment of the site's current living environments or social structures, but also land-use history and landscape systems. Although the comprehensive spatiotemporal analysis is a useful tool for understanding informal settlement development, there are still limitations to this study. The less accurate nature of historical data required us to use the term "spontaneous settlements" (Figure 3A) to research and speculate the characteristics of informal settlements (Figure 3b). Also, we chose not to focus on the sociopolitical issues concerning informal settlements in hopes of homing in on specific spatial and ecological factors. However, we believe the political and social implications of informal settlement development are integral to the field and this study should be considered alongside socioeconomic studies of informal settlements. We hope to pave the way for future studies that can further elucidate the relationship between informal settlement development and complex social factors. Finally, we hope the spatial analysis can be used as a basis and starting point for the evaluation process of informal settlement redevelopments in other areas of Seoul, as well as in other Asian cities.

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