EVALUATING THE PERFORMANCE OF THE GREENBELT POLICY FOR PRESENT AND FUTURE URBAN GROWTH MANAGEMENT AND ENVIRONMENTAL PROTECTION
A CASE STUDY IN THE SEOUL METROPOLITAN AREA OF SOUTH KOREA

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ABSTRACT

Evaluating the Performance of the Greenbelt Policy for Present and Future Urban Growth Management and Environmental Protection

A Case Study in the Seoul Metropolitan Area of South Korea

Albert T. Han

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This dissertation evaluates the effects of relaxing the growth management tool known as the greenbelt policy in the Seoul Metropolitan Area (SMA) of South Korea. The policy effect is measured by employing a series of spatial and statistical analyses on four urban sprawl measurement criteria: 1) physical containment, 2) housing affordability, 3) community service provision costs, and 4) commuting costs. Based on the analyses, I concluded that as a result of the greenbelt relaxation, the SMA has lost substantial amounts of farmland, forestland, pastureland, and wetlands to development between 1990 and 2010. Despite the considerable land consumption, not much land fragmentation has occurred, meaning that the new developments took place near the existing built-up areas, especially near the satellite cities and New Towns outside the greenbelt. The greenbelt relaxation did contribute to mitigating the land price and property value increases throughout the SMA compared to the urban core in Seoul. Although the relaxation guided new developments inside the greenbelt and lowered the tax collection and expenditure outside the greenbelt, the community service costs are expected to be higher outside the greenbelt because more developments continued to happen outside the greenbelt regardless of the relaxation policy. The commuting destination analysis and the mode share statistics showed that the SMA as a whole is facing substantial transportation challenges in both cost and level of service.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

CHAPTER 1. INTRODUCTION

1.1. Problem Statement

For the first time in history, the world's urban population surpassed the rural population in 2008. The United Nations (UN) estimates that approximately 66% of global population will be living in urban areas by 2050. Urbanization that prevailed in industrialized countries such as the United States (US) and the United Kingdom (UK) in the 19th and early 20th century is now increasing at a rapid pace in developing countries such as China and India. The UN has projected that urban population growth will continue in both developed and developing regions of the world. By 2050, urban dwellers will constitute about 86% of the total population in the more developed regions and 67% in the less developed regions (United Nations Human Settlements Programme 2010). Along with the global urbanization phenomenon, suburbanization that shaped the unique urban form of North American metropolitan regions in the last half of the 20th century, especially in the US, is increasingly occurring in developing countries that are mimicking the American suburban lifestyle. Urban sprawl is voraciously consuming a substantial amount of land near cities around the world including Antananarivo in Madagascar, Beijing in China, Johannesburg in South Africa, Cairo in Egypt and Mexico City in Mexico (United Nations Human Settlements Programme 2010).

The cost of urban sprawl has long been studied in the United States, which has the longest history of suburbanization. Daniels (2010) states that sprawling development intensifies dependence on automobiles and imported oil, exacerbates air and water pollution, and increases the loss of wildlife habitat, farmland, and forestland (Daniels 2010; Burchell et al. 2005). In addition, the fiscal costs of sprawl are substantial, requiring extensive infrastructure including roads, sewer and water lines, schools, police, and fire station. Compared with compact development form, current pattern wastes natural and human resources (Daniels 2010; R. Burchell et al. 1998; Newman and Jennings 2008). In light of the proliferation of sprawl, a study of key policy measures that mitigate its negative impacts will inform public and private decision-makers. Ever since the emergence of urban planning, public decision-makers have engaged several policy approaches to shape urban form, including infrastructure investment, regulating land-uses, acquiring land for development, and restricting land development through conservation actions. Several countries including the United Kingdom (UK), Canada, Australia, the US, and South Korea have directly controlled urban form by establishing urban limits and defining the edge of urbanization – a policy commonly known as the greenbelt policy (Hack 2012).

Greenbelt policy around the world has achieved different results depending on each country's social, economic, and political circumstances. For example, in the UK politicians and the public strongly supported the greenbelt policy regardless of the escalating development pressure on urban fringe areas caused by population growth, which has so far resulted in the rigid maintenance of the greenbelt areas (Amati and Taylor 2010; Hack 2012). Canada took a different approach in the creation and management of its greenbelt policy. In the case of Ottawa, the city took a regional approach to preserving greenbelt areas for ecosystem services and promoting smart growth (Gordon and Scott 2012). Similarly, Toronto's greenbelt has been managed via regional comprehensive planning and aggressive land preservation efforts by the provincial government (Amati and Taylor 2010; Deaton and Vyn 2010). Australia's greenbelt policy was almost dismantled in the 1950s because both the public and private property owners desired development more than the protection of the natural environment (Evans and Freestone 2010). South Korea arbitrarily established greenbelts under an authoritarian government in the 1970s. The nation then went through substantial reform and relaxation of the greenbelt policy at the beginning of the 21st century because of the democratization of the political system and the emergence of private property rights (Hack 2012; Bae and Richardson 2011). In the US, private property rights have been protected by constitutional law, which limited the implementation of the greenbelt policy in the early 20th century. Nevertheless, some counties have successfully incorporated the greenbelt policy into American land use planning (Daniels 2010).

The populations of the cities in these countries are expected to grow substantially over the next two decades, which poses a serious threat to managing urban growth while maintaining the greenbelt to protect the environment. Therefore, it is important to analyze how effectively the greenbelt policies have managed urban growth and protected the environment and how future population growth would affect urban growth and the natural environment. In fact, development pressures are escalating in many countries with greenbelts causing side-effects such as unaffordable housing, leapfrog developments, and high commuting costs (Hack 2012; Amati and Taylor 2010; Amati 2008; Morrison 2010; Watts 20:28; Bae and Jun 2003). In such countries, relaxing the greenbelt policy has been on the table for discussion to determine whether the benefits of maintaining the greenbelt are still greater than the costs. That is, do the costs of maintaining the greenbelt overshadow the greenbelt's function of avoiding the costs of sprawl?

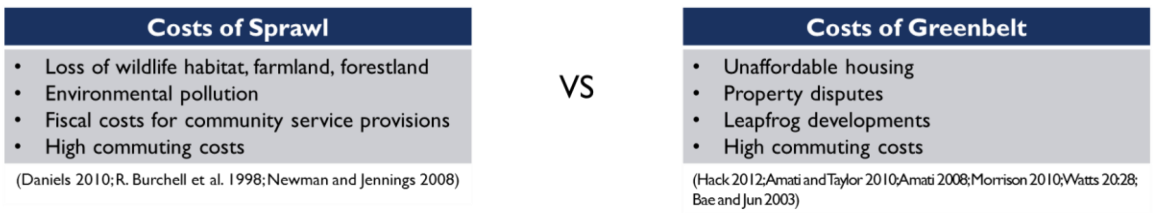
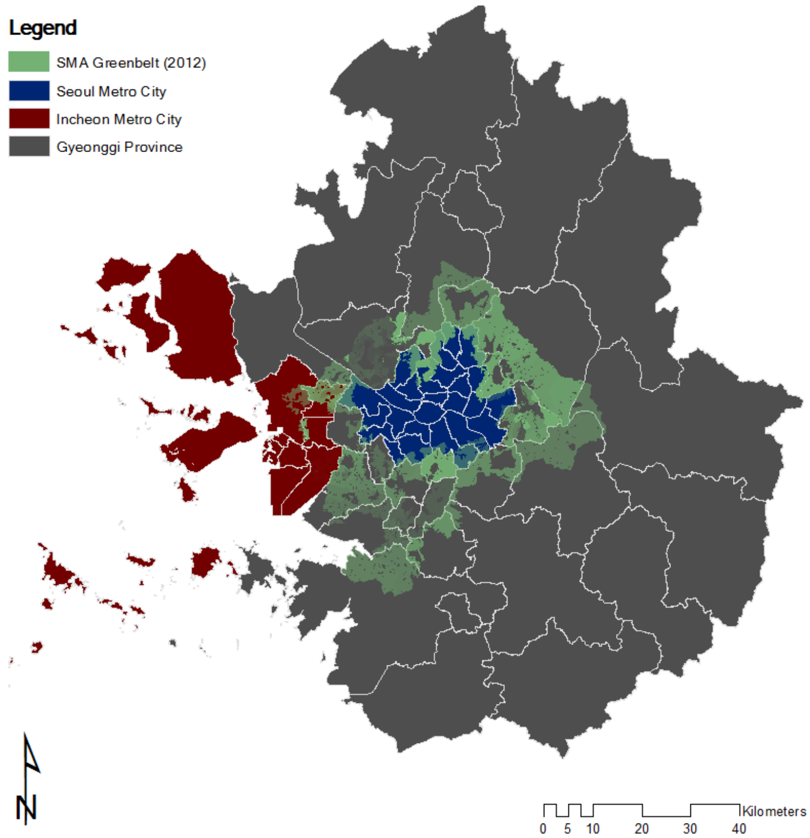


Figure 1-1. Costs of Sprawl vs. Costs of Greenbelt

Using the case of the Seoul Metropolitan Area of South Korea, this study evaluates the performance of the greenbelt policy in managing growth. Since the greenbelt relaxation policy was adopted in the early 2000s, the government has released 1,507 km^2 of greenbelts countrywide, which represents a reduction of 28% of the original greenbelt areas. Greenbelt releases in the Seoul Metropolitan Area, which consists of Seoul Metropolitan City, Incheon Metropolitan City, and Gyeonggi Province, were 144.3 km^2, 9% of the total (South Korea Ministry of Land, Transport and Maritime Affair 2013). The South Korean case is unique in that the country's greenbelt has experienced significant changes since it was first established. Transitioning from a rigid form of greenbelt to a more relaxed one to ease development pressures has significantly changed the metropolitan landscape. Studying the effects of the greenbelt relaxation can help determine the effectiveness of the policy, as well as provide significant insights for other countries that are experiencing substantial development pressures imposed by greenbelts.

1.2. Study Area

The geographic setting of this dissertation research is the Seoul Metropolitan Area (SMA) of South Korea which consists of two metropolitan cities – Seoul Metropolitan City and Incheon Metropolitan City – and one province – Gyeonggi Province. The province consists of several municipalities known as “Si” and “Gun”. The two metropolitan cities consist of municipalities called “Gu”. Currently there are a total of 66 “Si”, “Gun”, and “Gu” in the region all of which have their own elected form of government. It is important to note that the “Gu”s of metropolitan cities were differentiated from “Gu”s in small and medium size cities in Gyeonggi in that first, the latter are too small to be compared to the former, and second, some cities in Gyeonggi Province have consolidated and annexed adjacent municipal governments to their “Gu”s making temporal comparisons difficult. These 66 municipalities will be hereafter noted as census districts since they are considered as the same unit of administrative boundary by The South Korean Census Bureau. These census districts include 25 “Gu”s from Seoul Metropolitan City, 10 “Gu”s from Incheon Metropolitan City, 4 “Gun”s and 27 “Si”s from Gyeonggi Province.



Source: Illustration by Author based on the spatial data retrieved from Statistics Korea (2014)

Figure 1-2. Geographic Boundary of the Seoul Metropolitan Area and the Greenbelt

Most of the inner areas of the greenbelt are under the jurisdiction of Seoul Metropolitan City with some census districts overlapping with parts of the greenbelt. The outer boundary of the greenbelt overlaps with the census districts of Gyeonggi Province and Incheon Metropolitan City. The area of Seoul is about 605.2 km^2, Incheon is about 1,047.6 km^2, and Gyeonggi Province is about 10,172.7 km^2 in size. As of December 2013, the greenbelt accounted for 24.9% of Seoul (150.8km^2), 8.5% of Incheon (89.0 km^2), and 11.6% of Gyeonggi Province (1,176.4 km^2). The total area of the greenbelt in the SMA all together is about 1,416.1 km^2 accounting for 36.6 % of total greenbelt area in the nation (Statistics Korea 2015). Geographic boundaries of the municipalities and the greenbelt are illustrated in Figure 1-2 above.

1.3. Research Gaps and Research Question

Several scholars around the world have studied greenbelts. Amati and Taylor (2010) examined recent changes in the UK and Canadian greenbelts and identified challenges with integrating greenbelts and green infrastructure (Amati and Taylor 2010). Morrison (2010) conducted a case study of the greenbelt of Cambridge, UK and discussed the escalating pressure to review the greenbelt to ease development pressures (Morrison 2010). Daniels (2010) conducted a comparative case study of six metropolitan counties that have instituted a greenbelt policy in the US. He used demographic and land use statistics to evaluate the performance of the greenbelt (Daniels 2010). A majority of the greenbelt studies except the one conducted by Daniels (2010) seem to have taken a qualitative approach to examine and analyze the problems associated with greenbelt policy. Several studies have employed spatial and statistical analysis methods to analyze the impacts of other urban containment policies such as urban growth boundaries and priority funding areas, but not many quantitative studies have been done to comprehensively evaluate the performance of a greenbelt.

More specific to our study area, several researchers have employed different methodologies to analyze the performance of greenbelts in South Korea. Bae and Jun (2003) conducted a counterfactual analysis on Seoul’s greenbelt using monocentricity and polycentricity analysis methods. They found that the population and employment would have been much lower in the core city and the periphery if the greenbelt had not existed. They also confirmed that the greenbelt has contributed to densification and congestion within the greenbelt and caused leapfrog development (Bae and Jun 2003). Previously, the same research team had calculated the commuting costs associated with the greenbelt in the Seoul Metro Area using a density gradient for workers and residents; the researchers assumed that the greenbelt would cause a major discontinuity in these gradients. They concluded that eliminating the greenbelt would result in more workers and residents within the greenbelt and fewer outside considering the lower commuting costs (Jun and Bae 2000). Jun and Hur (2001) analyzed the commuting costs associated with the new towns that leapfrogged beyond the greenbelt and compared these costs to the scenario where the new towns were constructed within the greenbelt area. Their study found that the commuting costs would have been much lower if the South Korean government had developed the new towns within the greenbelt area (Jun and Hur 2001). Lee and Linnerman (1998) conducted time-series cross-sectional analyses of greater Seoul between 1970 and 1989 and found that the amenity value of Seoul's greenbelt was quite substantial, yet the marginal value of it had been decreasing since 1980 (Lee and Linneman 1998). In their comparative case study of urban containment policies in the UK, Korea, and the US, Dawkins and Nelson (2001) introduced a study conducted by Lee in 1999 in which the author found that the net social benefits of the greenbelt policy have substantially decreased over the years as the congestion effects of the greenbelt increased (Dawkins and Nelson 2002).

Although South Korean planners have conducted such quantitative research to analyze the performance of greenbelts in South Korea, there are research gaps that need to be filled. Some studies used counterfactual scenarios, but the impacts assessed in the models they used do not account for the spatial dynamics associated with the greenbelt and urban growth. Moreover, most of the South Korean greenbelt studies were conducted more than a decade ago and focused on the impacts of the conventional rigid greenbelt and called for an evaluation of the post-relaxation greenbelt policy. The South Korean government started to release the greenbelt lands for development when the perceived costs of maintaining the policy started to exceed the perceived benefits. The costs included property disputes, intensifying development pressure, leapfrogging developments, increasing commuting costs, and escalating development costs and housing prices (Bae, Jun, and Richardson 2011; Bae and Jun 2003; Jun and Hur 2001; Jun and Bae 2000). Now that over a decade has passed since The South Korean government started releasing the greenbelt lands for development, it is important to analyze whether the policy change has contributed to mitigating the costs of the greenbelt. Moreover, it is crucial to investigate whether the current relaxed greenbelt policy is functioning to serve its purpose of mitigating negative impacts of sprawl. Simply put, this dissertation aims to answer the following research question "Did the greenbelt relaxation produce the expected outcomes?".

1.4. Research Design and Hypotheses

This dissertation analyzes the policy effects of the greenbelt relaxation by adapting Ingram and Hong's research framework that was developed to measure the performance of smart growth policy in the US. Ingram and Hong evaluated the performance of state-level and local-level smart growth policies in the US using the following five criteria: 1) development density, 2) environmental quality, 3) transportation options, 4) housing affordability, and 5) net fiscal impacts (Ingram and Hong 2009). These criteria have long been discussed in the planning literature, especially for measuring the costs of sprawl. Several studies have provided empirical evidence to verify the costs of sprawl, notably the works of Daniels (2010), Newman and Jennings (2008), and Burchell et al. (2005). Ingram and Hong's work is distinctive and worthwhile to study because they took a comprehensive approach to evaluating the effectiveness of smart growth policies by employing various research methods and distinctive criteria. Unfortunately, not many planning scholars have taken such a comprehensive approach to measure the performance of greenbelt policy. Several scholars have measured the performance using one or two of the five criteria, but few researchers have attempted to holistically evaluate the effectiveness of the greenbelt.

By adapting the Ingram and Hong's research framework, this dissertation applies the following four criteria – 1) physical growth containment, 2) housing affordability, 3) community service costs, and 4) commuting costs – to analyze the policy effects of the greenbelt relaxation in the SMA. Ingram and Hong's "development density" and "environment quality" criteria were combined into "physical growth containment" since the modeling analyses examine land consumption, land fragmentation, development density, and development continuity. The following figure illustrates the conceptual model of this dissertation.

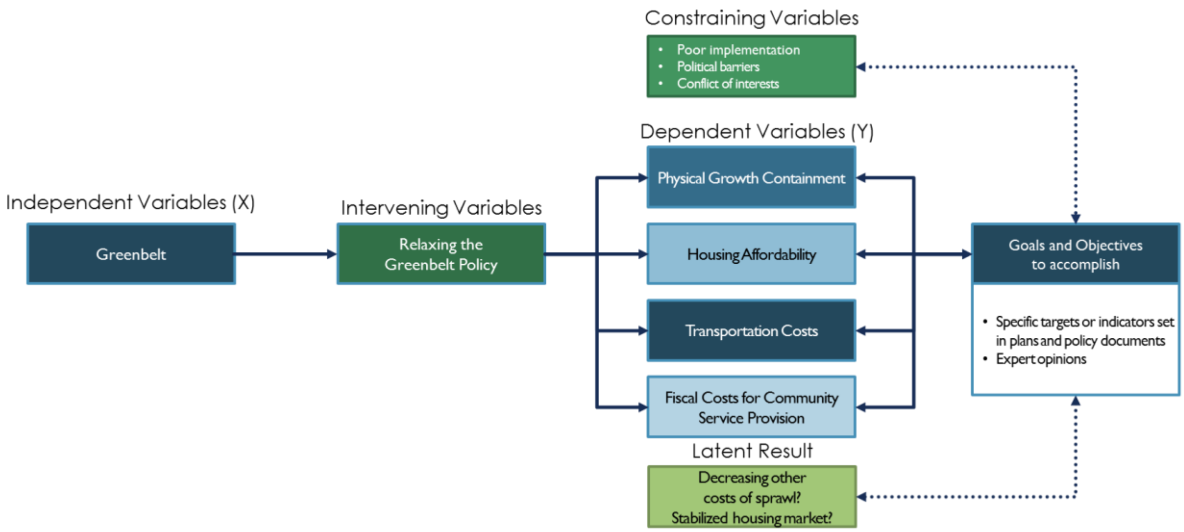


Figure 1-3. Conceptual Framework

The unit of analysis, the dependent variable (Y) from the conceptual framework, of this dissertation is the effects of the greenbelt relaxation on various urban growth management outcomes. The overall independent variables (X) are the greenbelt policy and the intervening variable is the relaxation of the policy. Upon completion of the empirical analyses using the four criteria, the resulting outcomes are compared to the goals and objectives established by the South Korean government. This is to see whether the greenbelt relaxation has fulfilled the South Korean government's policy goals and objectives.

The following six hypotheses were derived to evaluate the effects of the greenbelt relaxation on the five major performance evaluation criteria as illustrated in the conceptual framework above.

Hypothesis 1. *Greenbelt relaxation has urbanized farmland, forestland, and pastureland that used to be strongly protected under the original greenbelt policy*.

The first hypothesis tests what physical changes the relaxation has imposed upon the region. Considering the current development patterns, it is very likely that the SMA lost substantial amounts of farmland, forestland, pastureland, and wetland to new developments.

Hypothesis 2. *Greenbelt relaxation has made the urban landscape more continuous because the relaxation happened in the areas near existing urban areas, filling in the gaps.*

The Korean government has claimed that they specifically released greenbelt areas that are environmentally degraded because of illegal human settlements and activities. We hypothesized that such occupied areas are located near the existing urban areas where people can have access to existing public infrastructure such as roads, electricity, and perhaps water systems. If this holds true, releasing and developing those areas should have made the urban landscape more continuous as it connected the fragmented areas.

Hypothesis 3. *Greenbelt relaxation promoted new developments inside the greenbelt rather than the outside.*

Some scholars have argued that the rigidness of the previous greenbelt policy has resulted in leapfrogging developments (Kim and Kim 2012; South Korea Ministry of Land, Transport and Maritime Affairs 2011; Bae, Jun, and Richardson 2011). As the greenbelt relaxation occurred near existing urban areas, especially near Seoul, it may be possible that the relaxation has guided new developments to areas inside the greenbelt rather than the outside.

Hypothesis 4. *Greenbelt relaxation has eased development pressures near Seoul, thereby, slowing down the rate of increase in land and property values.*

One of the arguments against the greenbelt policy is that the greenbelt policy constrained land supply in the SMA, thus increasing land prices and housing prices (South Korea Ministry of Land, Transport and Maritime Affairs 2011). If this argument is true, increasing the land supply through the greenbelt relaxation should have produced lower the land and housing prices in the region.

Hypothesis 5. *The greenbelt relaxation has guided new developments to areas inside the greenbelt, thereby, intensifying the fiscal impacts associated with the community service provisions at a greater degree inside than the outside after the relaxation.*

Costs for community service provisions can be a proxy to measure development patterns. If we see more local fiscal activities and new public infrastructure inside the greenbelt rather than the outside after the relaxation, we can determine that the policy change has contributed to guiding new developments to areas inside the greenbelt, thus preventing further leapfrogging developments.

Hypothesis 6. *Greenbelt relaxation and the new housing developments that followed have provided homes closer to the jobs in Seoul, thereby, mitigating the jobs-housing mismatch and lowering transportation/commuting costs.*

Several studies have revealed that the original greenbelt policy increased the overall commuting costs in the SMA region (Jun and Bae 2000; Jun and Hur 2001). One of the expected outcomes of the greenbelt relaxation is mitigating the job-housing mismatch by providing homes closer to Seoul where major job centers are located. Testing this hypothesis will allow us to determine whether the relaxation is justifiable on the ground of mitigating the overall transportation costs.

By testing these hypotheses, we can answer the main research question on whether the greenbelt relaxation contributed to mitigating the problems of greenbelt (e.g., unaffordable housing and leapfrogging developments) while minimizing the costs of sprawl (e.g., loss of farmland, forestland, wetland, and wildlife habitat; increasing commuting costs; burdensome fiscal costs for providing new community services).

CHAPTER 2. LITERATURE REVIEW

Greenbelt policies have evolved in many countries such as the UK, Canada, Australia, the US and South Korea. It is useful to compare the common challenges these countries have faced to maintain greenbelts and manage urban growth. The comparative case study revealed that the South Korean government has taken drastic measures in response to the common challenges that several greenbelt countries have been facing, notably intensifying development pressures and worsening housing problems in the region. This part of the dissertation provides a background on the greenbelt policies of the five countries, compares the unique characteristics of each policy, and explains the significance of studying the South Korean greenbelt.

2.1. Comparative Case Study of Greenbelts around the World

1. The United Kingdom

Starting with the establishment of the oldest greenbelt around London in 1938, the United Kingdom (UK) has created fourteen greenbelts around cities that include London, Liverpool, Manchester, Leeds, York, and Birmingham (Morrison 2010). Creation of the greenbelt around London, in particular, was carried out by Town and Country Planning Association vice president Sir Patrick Abercrombie who included a greenbelt in his Greater London Plan of 1944. Abercrombie's initiatives in London provided momentum to the creation of greenbelts in other parts of the UK. Later on, Abercrombie founded the Council for Preservation of Rural England to expand his role in preserving the environment (Town and Country Planning Association 2014). Now the entire greenbelt areas of the UK constitute 16,716 km^2 or 13% of England and 163 km^2 of Scotland (Hack 2012).

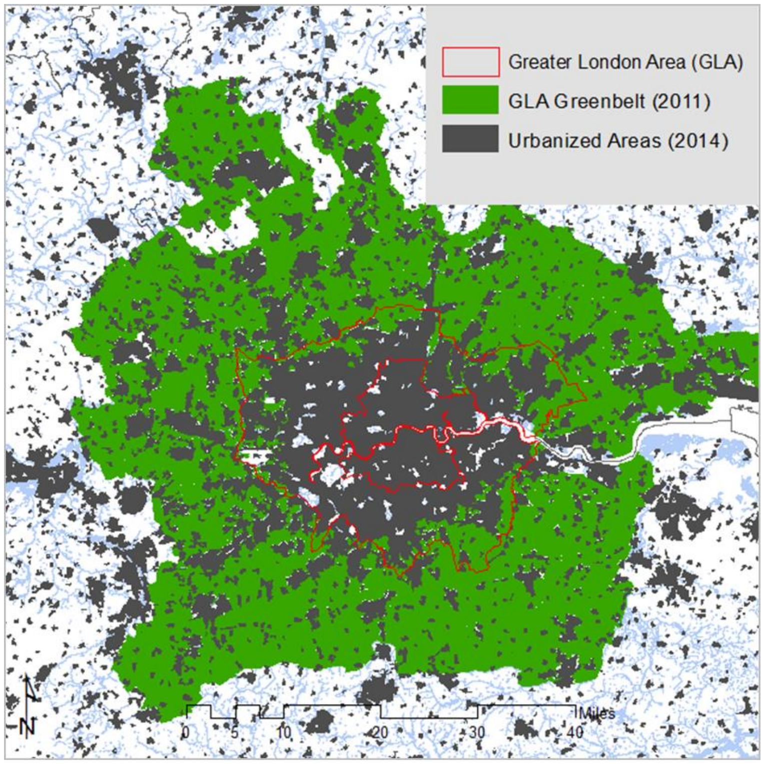


Figure 2-1. Greenbelt in Greater London Area[1]

Along with the greenbelt policy, the UK established the New Town development policy which was an expanded and evolved version of Howard's Garden City to curb land developments outside the greenbelts. Abercrombie and the London County Council also included New Town development plans in the 1944 Greater London Plan. Then the New Town Act of 1946 and the Town and Country Planning Act of 1947 were enacted to

[1] Greater London Authority Department for Communities and Local Government (2014a), *http://data.london.gov.uk/dataset/area-designated-green-belt-land*

provide a legal basis for the New Town policy (Town and Country Planning Association 2014). Since the adoption of these acts, a total of 32 New Towns were built in the UK accommodating over 2 million people. The New Town Development Corporation, an arm of the central government, was in charge of the New Town development projects. Over time, some New Towns located near old industrial cities experienced decline while those located near economically prosperous cities continued to grow. The population in the New Towns varies from 42,000 in Welwyn Garden City (pre-World War II) to 164,000 in Peterborough New Town (post-World War II) all of which exceeded the 32,000 limit set in Ebenezer Howard’s original Garden City idea (Town and Country Planning Association 2011).

No additional New Towns have been built since the government abolished the New Town development policy in the 1990s, but the greenbelt policy remains strongly intact. It has served its original purpose of “controlling unrestricted sprawl, preventing neighboring towns from merging into one another, assisting in safeguarding the countryside from encroachment, preserving the setting and special character of historic towns, and assisting in urban regeneration” (Hack 2012). The policy has received strong political support from all political parties along with prominent lobbying efforts taken by environmental groups to protect the countryside. It seems the policy is firmly settled in English planning regulation (Amati 2008; Amati and Taylor 2010).

Although the London greenbelt has been rigidly maintained over the past seven decades, it has been under stringent criticism from several English planners for its inherent unsustainability. Common arguments of the anti-greenbelt proponents are that constrained land supply has increased densities and prices in existing urban areas, thus directing the new developments beyond the greenbelt areas causing increased commuting distances, auto-dependency and air pollution (Morrison 2010; M. J. Elson et al. 1993; M. Elson 2002; A. Evans 2004; A. W. Evans, Hartwich, and Policy Exchange (Firm) 2006). In addition, some scholars have pointed out that the amenities believed to be provided by the greenbelt policy have actually diminished in association with environmental degradation, low-value agricultural land, landscape quality decline and limited public access (Morrison 2012; Gallent et al. 2006). Other scholars such as Sir Peter Hall, Michael Breheny, and John Herrington argue that the government's growth containment policies have caused leapfrog development beyond the greenbelts invading the surrounding countryside, and could potentially cause housing shortages especially in the South-East region near London. The most recent critiques by the TCPA and the UK government's Barker's Reviews have addressed escalating housing affordability problems near major urban areas (Amati 2008).

In response to the urban problems that are arguably caused by the greenbelt policy, the British government adopted plans in 2013 to construct more than 150,000 homes on greenbelt land. In addition, another 1,000 acres of the land would be lost to office blocks, warehouses and HS2 rail links. The Planning Minister stated that the proposed developments in the greenbelt areas are "unavoidable" because of the substantial population increase in Britain. Despite the government plans to develop some areas of the greenbelts, the Conservative parties and the environmental lobby groups who have advocated for the greenbelt policy have strongly opposed the development plans (Watts 2013). In 2014, the TCPA published a report called *New Towns Act 2015* in which they argue for the New Town Act to be enhanced to allow large-scale development projects to resolve the current housing problems (Town and Country Planning Association 2014). In short, some scholars and planners have stressed the importance of rethinking the greenbelt in the UK. Although the greenbelt has been publicly and politically supported for many decades, some planners now believe that the policy is too restrictive and inflexible, doing more harm than good. To solve the housing affordability issue, they have proposed that the government redesignate for development greenbelt areas those that are undesirable to the public, promote new developments near existing infrastructure, and utilize brownfield sites to accommodate growth in the cities (Wicks 2014). Whether the British government will pursue these proposed plans and policies has yet to be determined; however, the emergence of a school of thought to rethink the greenbelt policy is quite noteworthy.

2. Canada

The first Canadian greenbelt was established in Ottawa – the capital of Canada when many capital cities around the world were influenced by Abercrombie's 1944 Greater London Plan. As part of Jacques-Henri-Auguste Greber's 1950 Plan for the National Capital, the national government purchased 200 km^2 of land in 1958 to secure open space and control development. The federal government spent approximately $40 million in

1966 dollars ($250 million in 2005 dollars) to complete the land acquisitions (Gordon and Scott 2012). The government leased back some of the lands to their original owners for farming, parks and recreation, and low-intensity government uses. The New Town of Kanata was constructed outside the greenbelt bringing some level of negative impacts of leapfrog development, but the government has also added environmentally sensitive areas to the greenbelt over the years (Hack 2012). Gordon and Scott (2012) stated that Ottawa's greenbelt program is only a partial success in that it failed to contain urban growth as it had originally intended to by allowing some level of leapfrog developments, but it managed to secure open spaces, park systems, and farmlands via land acquisition programs (Gordon and Scott 2012).

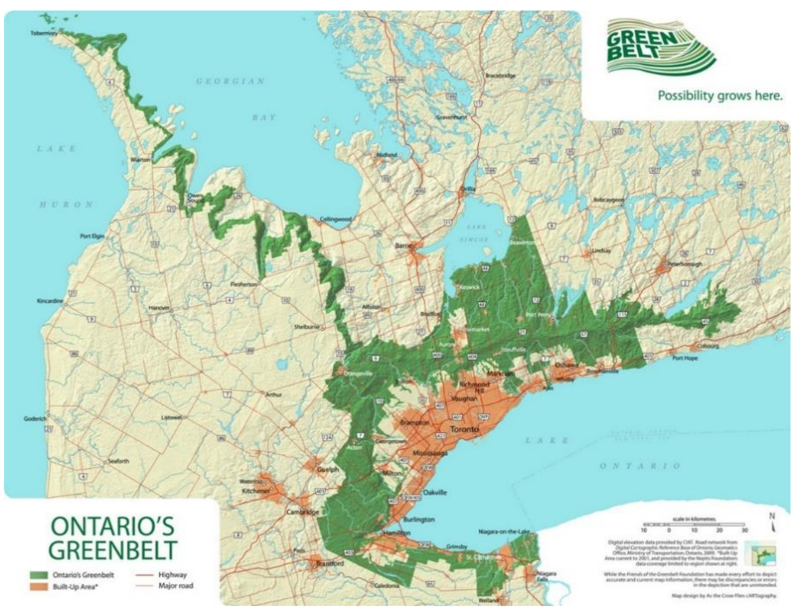


Figure 2-2. Greenbelt in Greater Toronto Area[2]

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[2] The Friends of the Greenbelt Foundation (2009), *http://www.greenbelt.ca/maps*

The most recent greenbelt was established in the Greater Toronto Area also known as the Greater Golden Horseshoe. Under the provincial act of 1985, Toronto designated 7,285.6 km^2 of land spanning about 320 km from the eastern edge of Toronto to Niagara Falls and extending northward to Lake Simcoe. The Toronto greenbelt is managed by the Greenbelt Foundation created under the Greenbelt Act which promotes the use of the reserved lands and invests in the transition to high-value agricultural uses. The policy instruments designed to protect the agricultural and the natural heritage systems were embedded into municipal codes and requirements (Hack 2012). In 2006, the Government of Ontario adopted the Growth Plan for the Greater Golden Horseshoe (GGH) to implement the province's vision to build stronger, prosperous communities by managing growth in the region. The plan built on the existing Greenbelt Plan, Planning Act, and the Provincial Policy Statement to manage growth while preserving the natural environment. It states that any proposed expansion of settlement areas should meet the requirement of the "Greenbelt, Niagara Escarpment and Oak Ridges Moraine Conservation Plans" which implies that the provincial conservation initiatives supersede the development (settlement) plan in Ontario. The plan also states that the greenbelt and other preservation initiatives had been enhanced since their establishment (Ontario Ministry of Infrastructure 2013). The regional growth plan of Ontario represents the provincial government's strong commitment to maintain the greenbelt to promote a healthy natural environment with clean air, land and water. The greenbelt of the Golden Horseshoe has faced substantial opposition from developers; however, the traditional hierarchy of governance where provincial authority has power over local governments made it possible for Ontario to enforce the greenbelt (Hack 2012). In both cases of greater Ottawa and greater Toronto, the greenbelts have become more than a mere urban containment tool, but a natural asset providing open space and ecosystem services on a regional sale (Gordon and Scott 2012).

3. Australia

In Sydney, Australia, the greenbelt policy was first introduced in the Planning Scheme for the County of Cumberland (PSCC) proposed by the Cumberland County Council (CCC) in 1948 as a part of a regional open space recommendation. The Greenbelt component of the plan was an emulation of Abercrombie's Greater London Plan. The total area of Sydney's original greenbelt was about 332 km^2 (127 sq miles) accounting for nearly 10% of the County Cumberland. Similar to the UK's policy, major functions of the Sydney greenbelt included preventing suburban sprawl, keeping rural land in agricultural production, and preserving scenic landscapes. The government's attempt to control privately owned lands in the greenbelt areas provoked a backlash from the public and even from local councils who wanted to expand residential zones. After a series of petitions and litigations, about 5% of the greenbelt (16km^2) was released for development in 1957. This triggered a chain reaction and the CCC encountered even stronger pressure from private developers and government agencies to release more lands for development. Eventually, the CCC succumbed to the pressures and proposed to release a total of 57km^2 of land for development accounting for 17% of the original greenbelt area. The Ministry of Local Government, who reviewed this proposal, concluded that the county would need more land to accommodate the projected population of 250,000 and made their final decision to release a total of 119km^2 of greenbelt areas. Much of the designated greenbelt areas contained less environmental, scenic, and agricultural values compared to the British greenbelt. And many believe that it did more harm than good by delaying development and causing premature subdivision (Evans and Freestone 2010).

Despite the unsuccessful attempt to implement the greenbelt policy in Sydney, a unique form of greenbelt was implemented in Melbourne, the capital city of Australia. The Melbourne and Metropolitan Board of Works (MMBW) and the state government of Victoria together implemented a metropolitan strategic plan from 1954 to 1993 during which the green wedges surrounding the city were established to "contain metropolitan growth and provide breaks to continuous urban development, enable the continuation of agriculture close to the city, protect areas of high natural value including landscapes, protect deposits of minerals and other resources, provide locations for infrastructure and major public utility installations or large institutions, and locations for recreation and the reservation of public open space" (Melbourne and Metropolitan Board of Works 1967, 14-16). With political support from the state Liberal government, the Melbourne's green wedges evolved to serve these functions in conjunction with the strategic plans until the early 1990s. The non-urban areas including the nine green wedges surrounding the city constituted approximately 2,400 km^2 and the region maintained the perimeter of the greenbelt for nearly 40 years since its first establishment in 1971. Both the metropolitan and the state governments held firm to prohibit developments of rural areas in the green wedges despite strong opposition from the landowners (Buxton and Goodman 2012).

Figure 2-3. Green Wedges in Melbourne[3]

Under the governance of the new neo-liberal political party, Melbourne adopted a new strategic plan in the early 1990s which shifted the government's approach to land use planning from traditional regulatory planning to limited and reduced governmental interventions. Considerable land use planning power was transferred to the local governments empowering them to rezone and develop lands in the green wedges. The

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[3] State Government of Victoria Department of Sustainability and Environment (2005), *http://www.nre.vic.gov.au/melbourne2030online/content/implementation_plans/06a_about.html*

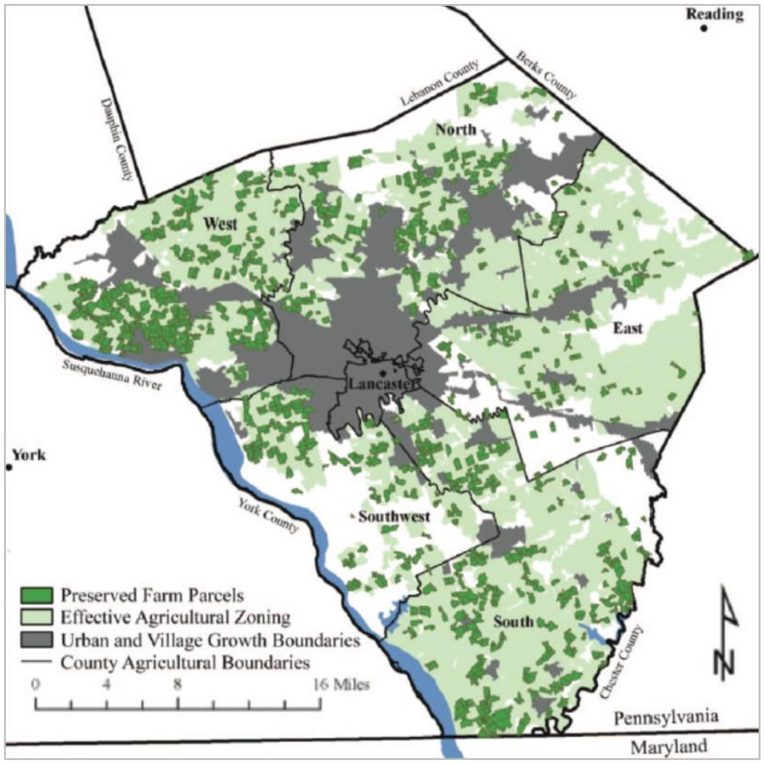
proceeding administration damaged the green wedges even more extensively by including plans to develop the green wedges in the regional strategic plans. Between 1990 and 2002, approximately 149 km^2 of green wedges were added to the urban corridors or approved for development. Between 1996 and 2002 alone, 4,324 hectares (43.24 km^2) of green wedge lands were converted to 16,000 residential lots (Buxton and Goodman 2012).

To fix the damage already been done, the Victorian government reasserted its intervention and control authority over the planning for Melbourne's non-urban areas through its new metropolitan policy called *Melbourne 2030*, adopted in 2002. Together with the new Planning and Environment Act on Metropolitan Green Wedge Protection adopted in May, 2003, the policy for protecting the green wedges was greatly enhanced. This new legislation mandated the establishment of an Urban Growth Boundary (UGB) and required "prior ministerial approval before councils could initiate planning scheme amendments, and parliamentary ratification for any change to the UGB and subdivision controls protecting 12 green wedges in a total of 17 fringe area planning schemes" (Buxton and Goodman 2012). It is noteworthy that the government extended the green wedge from the inner metropolitan boundary defined by the UGB to the outer boundaries of the rural fringe areas. As a result, the green wedge expanded from 5,029 km^2 in 1971 to 8,829 km^2. Buxton and Goodman (2012) argue that Melbourne's green wedge is a mix of managed and inflexible greenbelt. While the new strategic plan and legislation strongly protected the green wedge lands and rural areas, the government has expanded the UGB and allowed new developments along the urban corridors designated in the long-term plan. However, as the state government adopted the Smart Growth paradigm, the UGB was expanded by 34% increasing the number of residential lots inside the boundary from 180,500 to 225,000. Buxton and Goodman argue that the same level of growth could have been accommodated by increasing the residential density from 10 dwelling units per hectare to 15 dwelling units per hectare. After having its ups and downs, Melbourne lost a total of 28,442 hectares (284.42 km^2) of green wedges (Buxton and Goodman 2012).

4. The United States

Unlike the UK, Australia, and Canada, the US does not have a national level urban containment or greenbelt policy (Daniels 2010; Dawkins and Nelson 2004; Bassok 2008). In the US, land use decisions are made by states and local governments and the private sector (Daniels 2010; Freilich 2003). The first greenbelt of the US, the one commonly known as the Emerald Necklace, was created around Boston, Massachusetts in 1878 on 4.4 km^2 of lands consisting of public parks. Daniel Burnham's famous 1909 Plan of Chicago led to the creation of 120 km^2 of Forest Preserve Districts which have functioned as recreation areas and community separators. The US was also influenced by the Ebenezer Howard's Garden City idea. Three greenbelt towns were built during the New Deal era of the 1930s – Greenbelt, Maryland; Greenhills, Ohio; and Greendale, Wisconsin. Benton Mackaye's Appalachian Trail plan designed to protect the countryside from urban development became a reality in 1937. The 3,300km long trail was created along the Appalachian Mountains from Maine to Georgia (Daniels 2010).

Several attempts have been made to set aside open spaces at the urban periphery, but many were unsuccessful. Unlike other countries, private property rights in the US are strongly protected by federal law. Although the right to develop land can be regulated under the Tenth Amendment of the US Constitution – the use of police power to protect public health, safety, and welfare – a landowner's right to develop his land is also protected by the Fifth Amendment – prohibition of government from taking private property without just compensation. The diminution of land value through government regulation is permissible, but a regulation can go too far and deprive a land owner of all reasonable use of the property. The tension between the 5^{th} and 10^{th} Amendments has raised many disputes over local government wielding zoning power over private property rights. In addition, the zoning regulation has been under criticism for its tendency to promote rather than discourage sprawl and its lack of permanency to maintain open spaces (Daniels 2010). Hack (2012) also describes obstacles that have made securing open space on the urban periphery difficult in America, including "the real estate interests that control the land, agricultural interests that are threatened by regulations, the problem of multiple jurisdictions, which has made coordinated strategies difficult to implement, and conflicting interests of promoting growth, making adequate land available for housing, and protecting valuable ecological resources" (Hack 2012). According to Daniels (2010), sprawling development patterns due to prioritizing rural residential and commercial strip development over farming and forestry have fragmented the land base, and hindered the creation of greenbelts in the US. In addition, rapid population growth has been a great challenge for planners seeking to establish long-rage greenbelt plans (Daniels 2010).



Source: Daniels (2010)

Figure 2-4. Greenbelt in Lancaster County, Pennsylvania

Nonetheless, some counties have managed to create greenbelts and control urban growth. In his case studies, Daniels (2010) evaluated the greenbelt performance of six metropolitan counties in the US including Baltimore County, Maryland; Boulder County, Colorado; Fayette County, Kentucky; Lancaster County, Pennsylvania; Marin County, California; and Sonoma County, California. In his research, he concluded that their greenbelt programs have generated some positive outcomes such as more preserved farmland relative to developed land after the greenbelt was created, and increased value of agricultural output.

Planning tools applied in the studied areas included the purchase of development rights, enforcement of strict agricultural zoning in their rural areas, and establishment of growth boundaries to restrict urban and suburban expansion and rural residential sprawl (Daniels 2010). This representative study shows that a greenbelt policy has the potential to effectively control sprawling development and preserve farmland and the natural environment with the right combination of regulations – urban growth boundary and zoning regulations – and market-based incentives – purchase of conservation easement and transferable development rights.

5. South Korea

South Korea is one of the few non-western countries that has adopted the UK greenbelt model. As part of a national economic development plan of the 1970s, South Korea created a greenbelt around Seoul and 13 other metropolitan cities and mandated the construction of New Towns to accommodate the rapidly growing urban population (Hack 2012). The purpose of the South Korean greenbelt policy was to prevent sprawl, protect the natural environment and ecosystem services, provide for recreational areas, and strengthen national security with defense installations within the areas. Originally, a total of 5,397.1 km^2 of land was set aside for greenbelts which accounted for 5.4% of the entire land area of South Korea (South Korea Ministry of Land, Transport and Maritime

Affairs 2011). About one quarter of the greenbelt lands were located around the Seoul Metropolitan Area (SMA) where approximately half of the nation's population resides. The greenbelt designation was not based on a rational analysis but rather by an order from the authoritarian President Park Chung-Hee in the 1970s. The greenbelt was rigidly maintained for almost 30 years until it went through a substantial reform in 1999. Similar to the UK experience, the greenbelt policy had raised many controversies over the social, economic and political impacts. Some researchers have argued that the SMA greenbelt restricted economic growth, substantially increased the cost of development, distorted land values, and increased the commuting distance, while the others claimed that the environmental externalities of the greenbelt are substantially positive (Bae and Richardson and Jun 2011).

In 1998, the Constitutional Court upheld individual property rights over the outdated stringent regulation established under the authoritarian Park government. The evolving democratization and the emerging concerns for private property rights brought significant changes to the planning arena in South Korea. The court case along with the strong political will of the then president Kim Dae Jung resulted in the creation of the Greenbelt Reform Council in 1999 under which a total of 446.2 km^2 of the greenbelt areas (7.7% of the original greenbelt areas) were identified for release (Bae and Richardson and Jun 2011). Since the reform, there have been many more relaxations to make more land available for development. Between 1999 and 2011 the government released 1,507 km^2 of greenbelts countrywide which represents a reduction of 28% of the original greenbelt areas. Greenbelt releases in the Seoul Metropolitan Area that consists of Seoul Metropolitan City, Incheon Metropolitan City, and Gyeonggi Province were 144.3 km^2, 9% of the total (South Korea Ministry of Land, Transport and Maritime Affair 2013). Interestingly, the origin of the greenbelt relaxation was led by the enhancement of individual property rights in South Korea not by the need for housing to accommodate growing population.

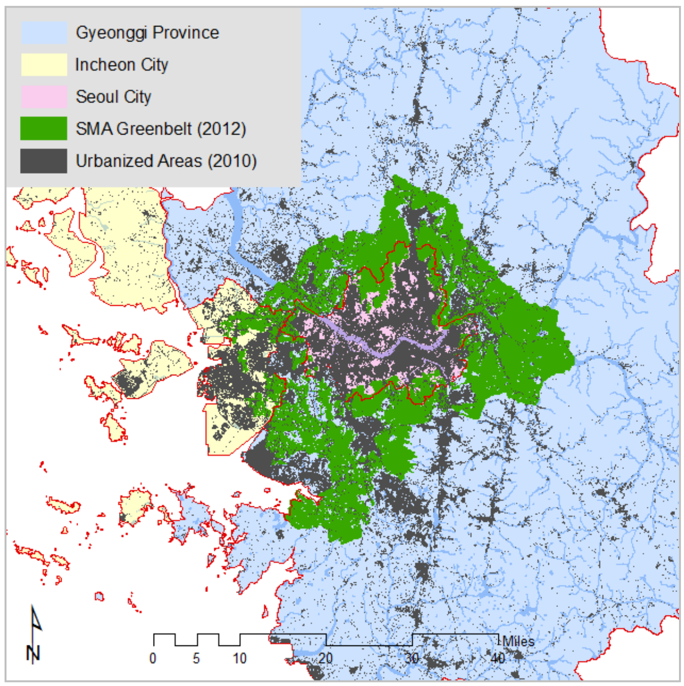


Figure 2-5. Greenbelt in the Seoul Metropolitan Area[4]

[4] Illustration by author using data obtained from South Korea Ministry of Environment in 2014 (South Korea Ministry of Environment 2014)

Very much like the UK greenbelt model, the South Korean greenbelt policy accompanied New Town developments to accommodate the escalating population of greater Seoul. Since the 1980s, a total of 18 New Towns have been constructed in 12 satellite cities in the SMA within a 60 km radius of the center of Seoul to accommodate a population over 2.9 million in 954,200 housing units (South Korea Ministry of Land, Transport and Maritime Affairs 2012). The first phase of the New Town development was planned in the late 1980s and implemented in the 1990s to accommodate the growing population of greater Seoul. It was the South Korean government's intention to distribute the population of Seoul to other areas in the region to resolve the problems of overcrowding. At the time, the South Korean government chose to maintain the original perimeter of the greenbelt and direct new developments to areas beyond the greenbelt. Initially, The South Korean government built five New Towns outside of greenbelt – Bundang, Ilsan, Pyeongchon, Sanbon, and Jungdong. In the first New Town project, a total of 292,000 housing units were built on 51 km^2 of lands located outside the greenbelt, but within a radius of 30 km from the center of Seoul (South Korea Ministry of Land, Transport and Maritime Affair 2012).

The second phase of the New Town development was initiated in the beginning of the millennium in response to escalating housing prices and deficient housing supply in the SMA. The Ministry of Land, Transportation, and Maritime Affairs (MLTM) planned these towns to be self-sustained and assigned certain urban functions of Seoul. By increasing the housing supply, the government expected to alleviate the sky-rocketing housing prices of Seoul, especially in Gangnam-Gu where housing demand was disproportionately high compared to other census districts in the region. Upon completion of the second New Town project, a total of 652,700 housing units will be constructed outside the greenbelt areas within a radius of 60km from the city center of Seoul (South Korea Ministry of Land, Transport and Maritime Affairs 2012).

Table 2-1. New Town Projects in the SMA

Period	New Town	Located City	Area (km^2)	Population	Housing Units	Distance from the CBD of Seoul (radius)
Phase I 1990s	Bundang	Seongnam-Si, GG	19.6	390,000	97,600	30km
	Ilsan	Goyang-Si, GG	15.7	276,000	69,000	20km
	Pyeongchon	Anyang-Si, GG	5.1	168,000	42,000	20km
	Sanbon	Gunpo-Si, GG	5.1	168,000	42,000	20km
	Jungdong	Bucheon-Si	5.5	166,000	41,400	20km
		Total	51.0	1,168,000	292,000	-
Phase II 2000s - Present	Pangyo	Seongnam-Si, GG	8.9	88,000	29,300	20km
	Dongtan 1	Hwaseong-Si, GG	9.0	126,000	41,300	40km
	Dongtan 2	Hwaseong-Si, GG	24.0	286,000	116,100	40km
	Gimpo	Gimpo-Si, GG	11.7	168,000	60,700	30km
	Paju Unjeong	Paju-Si, GG	16.6	215,000	87,100	30km
	Gwanggyo	Suwon-Si; Yongin-Si, GG	11.3	78,000	31,100	30km
	Yangju	Yangju-Si, GG	11.2	163,000	58,300	30km
	Wirye	Songpa, Seoul; Hanam-Si,Seongnam-Si, GG	6.8	108,000	43,600	20km
	Gumdan	Incheon Metro City	11.2	117,000	70,800	30km
	Goduk	Pyeongtaek-Si, GG	13.4	141,000	56,700	60km
	Asan	Chungnam Province	8.8	88,000	33,200	> 60km
	Do-ahn	Daejun Metro City	6.1	69,000	24,500	> 60km
		Total	139	1,647,000	652,700	-

Source: South Korea Ministry of Land, Transport and Maritime Affair (2015)

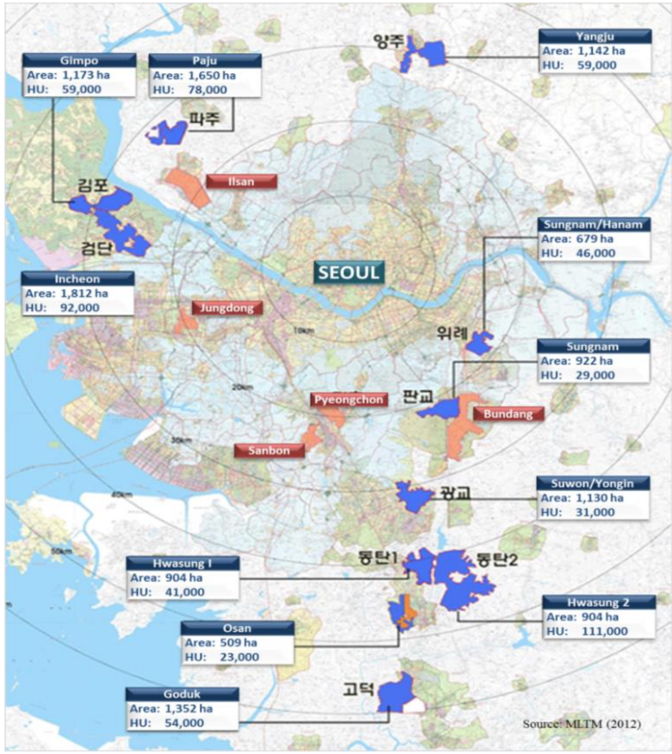
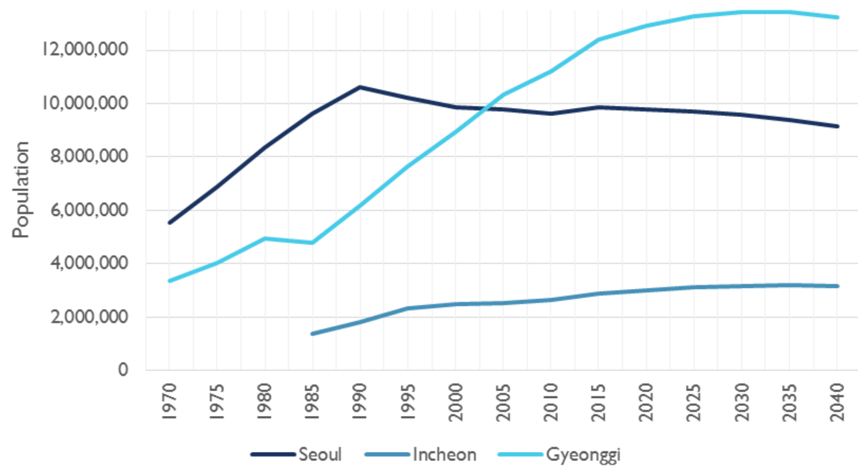


Figure 2-6. New Towns in the SMA

The greenbelt and the New Town policies have evolved in response to the population trends of the SMA. The population of the region grew exponentially during the latter half of the 20th century when South Korea was experiencing rapid economic growth. As the country transitioned from a developing country to a developed one, the population growth rate started to diminish and modern urban problems started to appear. The implementation of the greenbelt policy took place during a time of rapid economic growth and the alteration of the policy took place in response to the aftermath of that growth. The aftermath included housing affordability problems, increasing commuting costs owing to a growing jobs-housing mismatch, and a loss of environmental areas in the region (Jun and Hur 2001; Kwon et al. 2006).



Note: Populations from 2015 to 2040 are projected numbers.

Figure 2-7. Population Growth of the SMA (1970 – 2040)

Table 2-2. Population Growth of the SMA (1970 - 2010)

Unit: Thousands

Location	1970	1975	1980	1985	1990	1995	2000	2005	2010
Seoul	5,525	6,879	8,351	9,626	10,603	10,217	9,854	9,763	9,631
Incheon	-	-	-	1,385	1,816	2,304	2,466	2,518	2,632
Gyeonggi	3,353	4,035	4,930	4,793	6,154	7,638	8,938	10,341	11,196
SMA* (B)	8,879	10,914	13,281	15,803	18,574	20,159	21,258	22,621	23,460
National (A)	31,435	34,679	37,407	40,420	43,390	44,554	45,985	47,041	47,991
Share (B/A)	28.2%	31.5%	35.5%	39.1%	42.8%	45.2%	46.2%	48.1%	48.9%

* Population of SMA is sum of Seoul, Incheon, and Gyeonggi.
Source: Statistics Korea (2015)

Table 2-3. Population Growth Rate of the SMA (1970 - 2010)

Location	1970-1975	1975-1980	1980-1985	1985-1990	1990-1995	1995-2000	2000-2005	2005-2010
Seoul	24.5%	21.4%	15.3%	10.2%	-3.6%	-3.6%	-0.9%	-1.3%
Incheon	-	-	-	31.2%	26.9%	7.0%	2.1%	4.5%
Gyeonggi	20.3%	22.2%	-2.8%	28.4%	24.1%	17.0%	15.7%	8.3%
SMA	22.9%	21.7%	19.0%	17.5%	8.5%	5.5%	6.4%	3.7%
National	10.3%	7.9%	8.1%	7.3%	2.7%	3.2%	2.3%	2.0%

* Growth rate is calculated using numbers in Table 2-2.

The population of Seoul was about 6.9 million in 1975 when the greenbelt was established. At the time, Incheon Metropolitan City was part of Gyeonggi Province and the total population of the province was around 4.9 million. The population of Seoul had grown steadily until it peaked in 1990, and then started to decline. Meanwhile, the populations of Incheon and Gyeonggi have grown steadily. As the result of the continuous growth, the population of Gyoeggi Province surpassed Seoul in 2005. Despite the decline in the population of Seoul, the population growth of Incheon and Gyeonggi increased the overall population of the region. In 2010, nearly 50% of the national population resided in the SMA.

Migration statistics indicate that the population decline of Seoul was caused by the increased migration of Seoulites to other areas in Gyeoggi and Incheon where New Towns and satellite cities are located. As shown in Table 2-4 and Figure 2-8, the out-migration of population from Seoul to other areas of the SMA exceeded the in-migration population from the SMA to Seoul between 1990 and 2011.

Table 2-4. In-migration and Out-migration Pattern of Seoul (1990-2011)

Year	In-migration from SMA* to Seoul	Out-migration from Seoul to SMA*	Net Migration
1990	326,161	577,422	-251,261
1995	304,494	662,106	-357,612
2000	358,586	488,402	-129,816
2005	351,864	460,933	-109,069
2010	321,633	456,817	-135,184
2011	305,415	425,412	-119,997

*SMA includes Incheon and Gyeonggi Province, statistics of Seoul was excluded.
Source: Statistics Korea (2015)

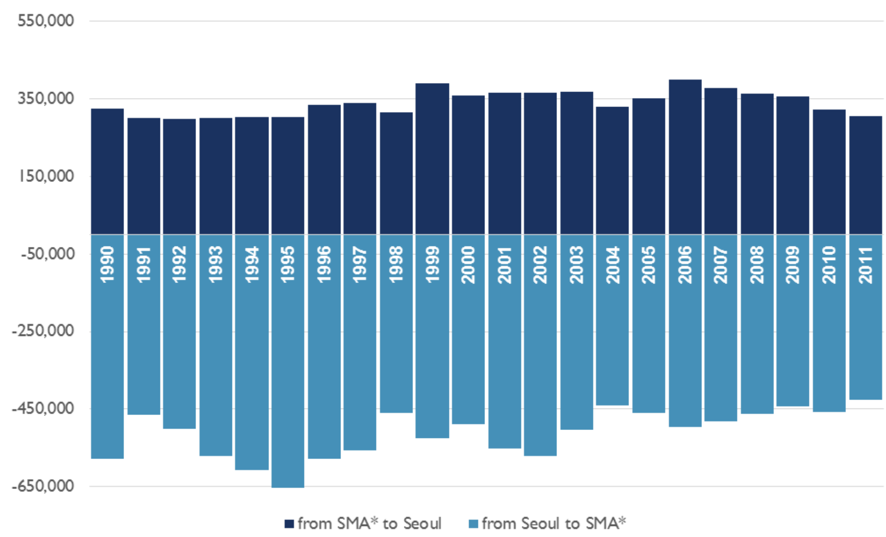


Figure 2-8. Migration of Population between Seoul and Other Areas in the SMA

These statistics suggest that the New Towns along with other satellite cities located outside the greenbelt have absorbed the population from Seoul during the last two decades. And the New Towns have completely changed the urban form of the SMA by accelerating urban sprawl, the very problem that the greenbelt policy was adopted to prevent. The New Towns constructed in the 2000s have moved further away from Seoul and the maximum distance from the center of Seoul has increased from 30km to 60km. As illustrated in Figure 2-6, the second phase of New Towns were built along the major expressway that runs from north to south in the region. The development pattern shown in Figure 2-6 is a clear indication of urban sprawl.

Although massive amounts of new housing have been supplied to the region through the New Town program, the housing problem continues to be one of the region’s primary planning concerns. Speculations by the wealthy on the newly developed and redeveloped properties in and near the city, the failure of government's housing policies, and the impacts of the 2008 Global Recession together have substantially increased the housing prices in the city and in well-established New Towns, making the urban living unaffordable to many people. Intensifying public unrest made the housing issue one of the main political agendas of the former and current presidents. To resolve the housing problem and stabilize the housing market, the former president, Lee Myung-bak, initiated a massive public housing project on the relaxed greenbelt areas in 2009 which has raised great controversies among scholars and planners over the preservation of the environment and the stabilization of the land and housing markets in the Seoul Metropolitan Area (South Korea Ministry of Land, Transport and Maritime Affairs 2011). Currently, the Korea Land and Housing Corporation and Gyeonggi Urban Innovation Corporation, both public corporations, are constructing 333,759 units on 48.1 km^2 of released areas near Seoul. The government is targeting the units to low income households including the elderly, families with three or more children, and newly-weds in the form of rent-controlled long-term leases (South Korea Ministry of Land, Infrastructure and Transport 2010).

In September, 2013, the current president, Park Geun-hye, announced the central government plans to construct a total of nine high-technology industrial parks on the greenbelt land of which two will be located near the SMA (G. Kim and Hong 2013). Two years later, the president announced that the government will ease the development restriction regulations on greenbelts for the sake of economic development. One of the notable changes includes the elimination of the oversight function of the central government on greenbelt relaxation and development. The current policy mandates that the local government to establish plans to develop greenbelt areas to accommodate growth. The Ministry of Land, Infrastructure and Transport (MOLIT) holds the power to either reject or accept the proposal during the review process. The new policy eliminated this final review process to allow local governments to make their own decisions on the greenbelt developments. Moreover, the new policy will make the greenbelt relaxation in urban fringe areas easier. As a safeguard, the government states that this exception will only be applicable to greenbelt sites smaller than 30,000 m^2. In the same press release, President Park reaffirmed her vision to construct high-tech industrial complexes and logistic distribution centers on the greenbelt lands to promote both local and national economic developments (Lee, Na, and Chung 2015). Clearly, the current government's priority is on economic development rather than the environmental protection. Ironically, the greenbelt established by the father over forty years ago is now being dismantled by his very daughter.

2.2. Common and Unique Greenbelt Challenges

The greenbelt policy of each studied country faced a different fate depending on their unique social, economic and political circumstances. Opposition from developers and private property owners has been a great challenge in creating and maintaining the greenbelts in most countries. Despite the recent challenges on accommodating population growth, the UK has managed to maintain the greenbelt policy since its adoption in the early 20th century thanks to the post World War II nationalization of development rights in land, the strong political will of the government, and the support of the general public. This was the similar case in Canada where most of the land technically still belongs to the English Crown (Daniels 2010). On the contrary, the US, where landowners' development rights are strongly protected by constitutional law has faced great difficulty adopting the UK greenbelt model. However, some counties have customized the greenbelt model to the US land use regulations and planning tools such as zoning regulation, urban growth boundaries, transferable development rights, and use of conservation easements. In South Korea, the greenbelt policy was rigidly maintained under the strong central government system until the landowners gained the power to exercise private property rights under the Constitutional Court ruling. Considering that almost 80% of the greenbelt areas are privately owned properties, the recent events of the greenbelt relaxation and the on-going development projects may lead to a chain reaction of other landowners claiming their development rights unless other policy instruments are established. Drastic appeasement of the landowners in the greenbelts without fully considering the positive function of the greenbelt is quite worrisome. Melbourne's green wedge has gone through similar changes in the early 2000s from which the region lost substantial amount of green wedges to residential developments (Buxton and Goodman 2012). The South Korean government should be aware of the implications of the Melbourne's case.

Despite the positive outcomes shown in the US cases, several challenges remain to implement greenbelt policies around other metropolitan cities in the US. Daniels (2010) states in his research that the challenges in the US are "the large number of local governments and their small size, especially in the Northeast and Midwest regions, which impedes cooperation and coordination in land use policies necessary to create greenbelts; the reluctance of many local governments to adopt strict zoning in the countryside to limit sprawl—often for fear of lawsuits from landowners; and a reluctance to raise and spend large amounts of money to purchase development rights to farmland". Along with the impermanency of conventional zoning regulations, the land preservation process in the US can also be a challenge for establishing a greenbelt (Daniels 2010, 269). The US case suggests that transferring the greenbelt management authority to local governments may not be a good idea. Melbourne faced notable setbacks from temporarily transferring the authority to the local governments, which led to fragmented and inconsistent land use decisions. Thus, the South Korean government's decision to localize the greenbelt management authority may result in negative outcomes similar results in the US and Australia.

In the US, land preservation is mostly voluntary so preservation may not occur in the ideal pattern of large blocks to function as greenbelts (Daniels and Lapping 2005). Therefore, counties and other local governments should balance the establishment of a growth boundary, enforcement of zoning regulation, and the purchase of development rights and conservation easements to ensure the successful growth management and environmental protection within a framework of long-term comprehensive planning (Daniels 2010). Some local governments may lack local fiscal capacity to purchase development rights and conservation easements. Unlike the US, other countries' greenbelt policies have been implemented at the national level, which may put them in a better position to secure resources to utilize the advantages of the US greenbelt model. This may offer some solutions to the countries struggling to maintain their greenbelts that are under substantial development pressure such as the UK and South Korea. In order to successfully incorporate the success factors of the US cases into other countries' greenbelt policies, more study needs to be conducted to assess the applicability of greenbelts accounting for each country's unique political, social, and economic conditions.

The functionality of the greenbelts is quite similar in the reviewed countries. All greenbelt policies focus on managing urban growth and preventing sprawling development. Farmland preservation is more emphasized in the US and Canada whereas open space and scenic value are underscored in the UK and Australia. In addition to these common functions of the greenbelt, the South Korean greenbelt has defense purposes, especially in the SMA which is in close proximity to North Korea.

South Korea is the only country that still develops New Towns, another legacy of Ebenezer Howard's Garden City, to curb the development beyond the greenbelt while the UK abolished the policy. With many urban functions and amenities still concentrated in Seoul, the New Towns have brought the negative effects of urban sprawl such as increased commuting distances, loss of environmental sensitive areas, and air pollution (Bae, Jun, and Richardson 2011; Jun and Hur 2001).

Table 2-5. Greenbelt Comparison Summary

County	Greenbelt Area			Administered by	Function and Land Use
	Location	Original	Current		
UK	London	4,977.9 km^2	4,859.9 km^2	National/Local	Agriculture, Recreation, Open Space, ESA[2]
Canada	Ottawa	200.0 km^2	200.0 km^2	National	Agriculture, Recreation, Open Space, ESA
	Toronto	7,285.6 km^2	7,285.6 km^2	Provincial	
Australia	Sydney	332.0 km^2	213.0 km^2	County	Agriculture, ESA
	Melbourne	5,029 km^2	8,829 km^2	State	Agriculture, Recreation, Open Space, ESA
US	6 counties	1,177.9 km^2	1,069.3 km^2	County	Agriculture, ESA
Korea	Seoul	1,566.8 km^2	1,422.4 km^2	National/Local	Agriculture, Recreation, Open Space, ESA, Defense (SMA)

1. Six counties include Baltimore County, Maryland; Boulder County, Colorado; Fayette County, Kentucky; Lancaster County, Pennsylvania; Marin County, California; and Sonoma County, California. Greenbelt areas in the studied counties of the US are also knows as the farmland preservation areas surrounding the metropolitan counites.
2. Environmental Sensitive Areas (ESA) include wetland, prairie, forestry, and other lands conserved for environmental protection.
3. Melbourne's green wedge was expanded, but about 284 km^2 of green wedge land has been developed.

The greenbelt policy of the UK and Canada has managed to survive the escalating criticisms from developers and economists that the policy has restrained development rights and the local real-estate economy. Unlike the US, Australia, and South Korea, strong support from politicians and the public who have enjoyed the greenbelt amenities such as open space and recreation areas has outweighed the criticisms. However, it is important to note that as the population grows and cities become more densely settled, it is very likely that the countries will face challenges such as unaffordable housing and traffic congestion as South Korea did. As discussed above, planners and local governments are already considering developing some portion of the greenbelt areas in the UK. And in the case of Melbourne, Australia, the state government changed the policy to be more flexible to accommodate necessary growth while maintaining some level of oversight. However, the policy became too flexible resulting in expansion of the UGB before the inner city areas reached appropriate urban density.

Table 2-6. Population Projection in the Study Area (2010 - 2031)

Country	City/County	2010 ~ 2012	2030 ~ 2031	Increase	% Increase
UK	Greater London Area	8.20 million	9.95 million	1.75 million	21.3%
Canada	Greater Toronto Area	6.40 million	8.90 million	2.50 million	39.1%
Australia	Sydney Metropolitan Area	4.28 million	5.82 million	1.54 million	36.0%
	Greater Melbourne Area	4.17 million	5.96 million	1.79 million	42.9%
S. Korea	Seoul Metropolitan Area	24.46 million	26.18 million	2.72 million	11.6%
US	Total	2.19 million	2.48 million	0.29 million	13.2%
	Boulder County, CO	295,605	390,228	94,623	32.0%
	Baltimore County, MD	805,029	862,200	57,171	7.1%
	Fayette County, Kentucky	295,803	375,986	80,183	27.1%
	Lancaster County, PA	59,322	62,870	3,548	6.0%
	Sonoma County, CA	484,084	534,439	50,355	10.4%
	Marin County, CA	252,731	253,026	295	0.1%

Source: Greater London Authority Department for Communities and Local Government (2014b); Ontario Ministry of Finance (2013); Statistics Korea (2013); Christopher Wood (2013); Maryland Department of Planning (2012); Kentucky State Data Center (2011); Lancaster County Planning Commission (2012); California Department of Finance (2013)

According to the population projections conducted by major cities of the studied countries, all of these cities will experience substantial population increases in next two decades. As summarized in Table 2-6, the population in the Greater London Area will grow by 1.75 million between 2011 and 2031, reaching 9.95 million in 2031 (Greater London Authority Department for Communities and Local Government 2014b). The population of Greater Toronto Area is estimated to increase from 6.4 million in 2012 to 8.9 million in 2036 (Ontario Ministry of Finance 2013). In the Sydney Metropolitan Area, the population is expected to increase from 4.28 million in 2011 to 5.815 million in 2031 (New South Wales Department of Planning and Infrastructure 2013). The population of Greater Melbourne Capital Area is expected to grow from 4.17 million in 2011 to 5.96 million in 2031 (State Government of Victoria Department of Transport, Planning and Local Infrastructure 2014). As noted above, the population of the Seoul Metropolitan Area is expected to grow by 2.72 million reaching over 26.2 million in 2030 (Statistics Korea 2015). The aggregated population of six counties in the US that have implemented the greenbelt policy is expected to grow by 32% reaching 2.48 million in total in 2030 (Christopher Wood 2013; Maryland Department of Planning 2012; Kentucky State Data Center 2011; Lancaster County Planning Commission 2012; California Department of Finance 2013).

It is very likely that the metropolitan cities and the US counties will face more urban growth challenges. Few studies have estimated the impacts of future population growth on urban growth patterns and the natural environment protected by the greenbelt, but there are some indications that show such problems are already happening. Amati and Taylor (2010) showed that the housing affordability issue has started to appear since the creation of the greenbelt in greater Toronto and leapfrogging has already happened in greater Ottawa; and Morrison (2010) showed how the greenbelt policy has collided with the growing pressure to expand around Cambridge, UK (Amati and Taylor 2010; Morrison 2010). The recent debates on the greenbelt development in the UK imply that the traditional greenbelt model might not be suitable for cities where the development density has reached a certain point that the geographic boundary can no longer accommodate the growing population. Melbourne's case shows that there is a fine line between sustainable growth and urban sprawl depending on how flexible the policy is. In that respect, the South Korean government's decision to relax and develop greenbelts might have been a rash judgement.

2.3. The Greenbelt Relaxation Policy of the South Korea

The South Korean greenbelt, particularly the one surrounding Seoul, is a case worth studying because of the drastic changes made to the greenbelt and development policies over the past two decades. South Korea maintained a rigid and command-and-control type of greenbelt policy for nearly 30 years and then drastically released substantial amounts of greenbelt lands for development. As summarized in Figure 2-9, the South Korean government drastically reformed the greenbelt policy in 1999 to protect the individual property rights and initiated large-scale development protects in 2009 to address the regional housing problem. While the housing stocks have increased owing to the New Town developments, the South Korean government has kept on developing housing on the released greenbelt lands.

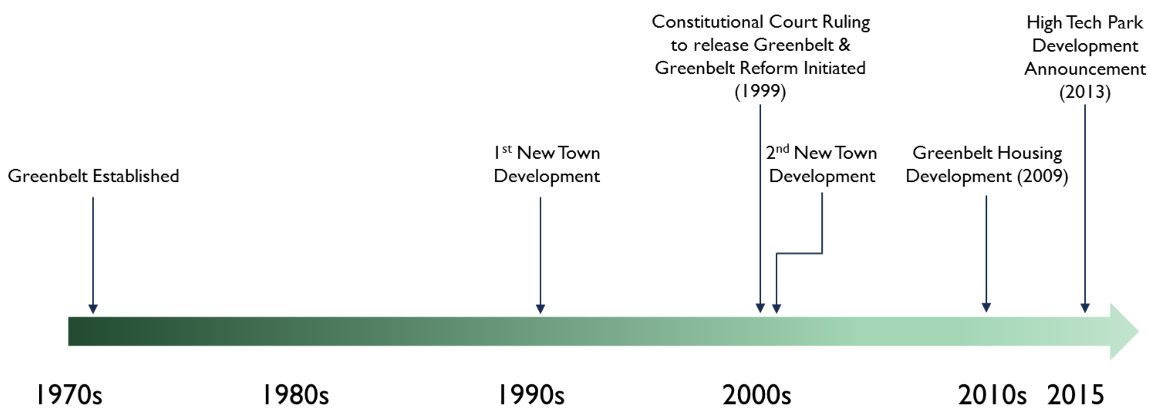


Figure 2-9. Chronology of the Korean Greenbelt Policy

By releasing and developing greenbelt lands, the South Korean government sought to resolve the following four problems: 1) increasing land and housing prices due to insufficient land supply; 2) increasing commuting costs due to residential developments beyond the greenbelt perimeter where lands are affordable; 3) burdensome investment in public infrastructure due to the leapfrogging developments; and 4) rising property disputes. In order to resolve these problems, the South Korean government established six policy objectives of the greenbelt relaxation as listed in Box 2-1 (South Korea Ministry of Land, Transport and Maritime Affairs 2011).

Box 2-1. Policy Objectives of the Greenbelt Relaxation

1. Release of greenbelts should only happen in areas that are assessed to have low environmental values.
2. Developments in released areas should be based on thorough land use planning to prevent reckless and sprawling developments.
3. Capital appreciation from the greenbelt developments should be invested in providing community services by means of impact fees and taxes.
4. Unreleased greenbelt areas should be strongly protected.
5. People who have owned the greenbelt lands prior to the establishment of the policy should be properly compensated. Governments may purchase the lands via impact fees, development fees, or issuing bonds.
6. Excessive speculation and rent-seeking activities accompanying the greenbelt developments should be monitored by the governments. An additional land transaction tax may be applied.

Source: South Korea Ministry of Land, Transport and Maritime Affairs (2011)

The South Korean government has conducted a series of nationwide environmental assessments since 2005 to identify greenbelt lands for release. The government graded lands into five classes depending on their environmental values. The Class 1 lands are high-priority preservation areas where developments are strictly prohibited requiring permanent preservation; Class 2 lands are high-priority preservation areas where small scale developments are allowed under certain conditions; Class 3 lands are areas where conditional developments are allowed only if they do not impose negative impacts on the surrounding environment; Class 4 lands are areas that are already being developed and certain areas may be subject to preservation; and Class 5 lands are areas where all types of developments are allowed (South Korea National Environmental Information Network System 2015).

Table 2-7. Environmental Assessment Land Classification

Land Class	Description
Class 1	High-priority preservation area where developments are strictly prohibited Requires permanent preservation for ecosystem protection
Class 2	High-priority preservation areas where small scale developments are allowed under certain condition
Class 3	Conditional developments are allowed acting as buffers between preserved and developed areas. Developments should not impose negative effects on the surrounding environment.
Class 4	Areas that are already being developed. Certain areas may be subjected for preservation.
Class 5	Areas where developments are completely allowed. Planned developments are strongly recommended.

South Korea National Environmental Information Network System (2015)

The government established the following protocol for releasing greenbelt areas. When local governments find the need to release the greenbelt areas in their jurisdictions, they have to establish both regional and local comprehensive plans based on the environmental assessments to justify the release. The planning processes include two public hearings and two reviews by both local and central (national) planning commissions. Once the plans are approved, then the local governments can release the greenbelt lands for development.

Box 2-2. Decision Making Protocol for Releasing Greenbelt Lands for Development

1. Conduct Environmental Assessment
2. Local governments review the Environmental Assessment
3. Local governments and the central government agency together draft the Regional Comprehensive Plan
4. Facilitate public hearing
5. Coordinate with the relevant government agencies that may be affected by the plan
6. Adopt the Regional Comprehensive Plan
7. Local governments draft Local Comprehensive Plan
8. Facilitate local public hearing
9. Local Urban Planning Commission reviews the plan
10. Central Urban Planning Commission reviews the plan
11. Make the final decision on implementing the plans that include provisions on releasing and developing greenbelt lands.

Source: South Korea Ministry of Land, Transport and Maritime Affairs (2011)

While the greenbelt being released and developed, the South Korean government has continued to construct New Towns. Considering that about 652,700 new housing units are being constructed to accommodate 1.65 million people, it makes us wonder whether South Korea made the right decision to relax the greenbelt to build more housing units. Several planners have warned that the South Korean government's greenbelt housing development project did not fully account for the housing demand, causing a significant mismatch between housing demand and supply (D.-S. Kim and Kim 2005).

It seems that the South Korean government established precautionary measures to minimize the negative effects of the greenbelt relaxation. Now that over a decade has passed since the relaxation policy was implemented, the South Korean case raises a series of interesting research questions. One may ask whether the relaxation has diminished the positive effects of the original greenbelt such as preservation of natural areas, urban growth containment, and other sprawl prevention effects. Others may ask whether the relaxation has eased the development pressures and stabilized the housing market in the region. This dissertation aims to answer these questions by conducting a comprehensive evaluation of the greenbelt relaxation policy.

CHAPTER 3. MODELING ANALYSIS I – LANDCOVER ANALYSIS

3.1. Hypotheses

Both land conversion and land continuity analyses were conducted to analyze the physical containment effects of the greenbelt relaxation policy. The land conversion analysis tests the first hypothesis **"Greenbelt relaxation has urbanized farmland, forestland, and pastureland that used to be strongly protected under the original greenbelt policy"**. This hypothesis is to test what physical changes the relaxation has imposed upon the region. Considering the current development patterns, it is very likely that the SMA lost substantial amounts of farmland, forestland, pastureland, and wetland to new developments especially in the greenbelt areas.

The land continuity/fragmentation analysis tests the second hypothesis **"Greenbelt relaxation has made the urban landscape more continuous since the relaxation happened in the areas near existing urban areas filling in the gaps"**. The South Korean government has claimed that they specifically released greenbelt areas that are environmentally degraded because of illegal human settlements and activities. We hypothesized that such occupied areas are located near the existing urban areas where people can have access to existing public infrastructure such as roads, electricity, and perhaps water systems. If this holds true, releasing and developing those areas should have made the urban landscape more continuous as it connected the fragmented areas.

3.2. Methodology

As shown in the conceptual model, land consumption/conversion analysis using ArcGIS was conducted to test Hypothesis 1 and land fragmentation/continuity analysis using FRGASTATS was conducted to test Hypothesis 2.

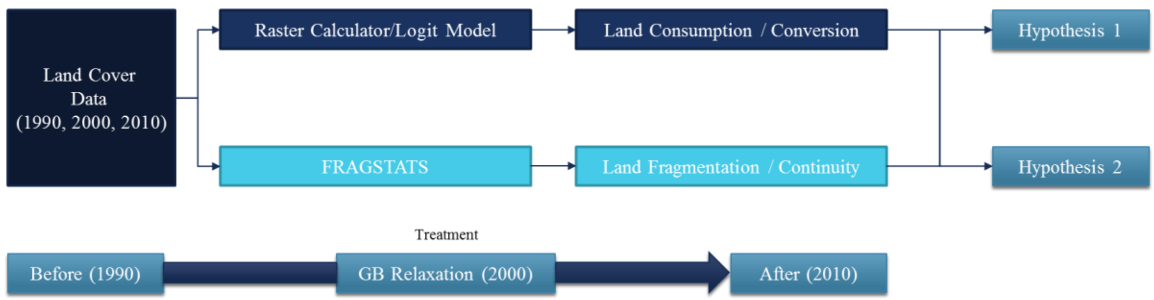


Figure 3-1. Conceptual Model for Land Cover Analysis

Conducting these two analyses requires time series land cover datasets showing the changes in the land cover types such as urban areas, farmland, forestland, wetland, and pastureland. Land cover datasets of the SMA covering 1990, 2000, and 2010 were retrieved from the South Korea Ministry of Environment. The datasets were available in the formant of GRID raster files which were originally processed from the LANDSAT satellite images of each period. Other sets of raster datasets used in the land conversion analysis are the environmental assessment maps for year 2005 and 2010. The South Korean government has claimed that they released the greenbelt areas that were identified to be environmentally degraded based on the environmental assessments that have been conducted since 2005. By analyzing the land conversion, we seek to evaluate whether the greenbelt relaxation has occurred as the government intended to.

1. Land Conversion Analysis using ArcGIS

The land conversion analysis is a simple computation of how much environmental area (including farmland, forestland, pastureland, and wetland) has been converted to urban areas using ArcGIS software. Boolean logic rules were applied to the ArcGIS Raster Calculator to calculate the land cover changes. Urban changes between 1990 and 2000 and between 2000 and 2010 were first calculated to compare urbanized areas before and after the greenbelt relaxation. The Boolean logic used in this calculation was "areas that were urban areas in 2000, but non-urban areas in 1990" and "areas that were urban areas in 2010, but non-urban areas in 2000". The same logic was applied to calculating urban areas that used to be farmland, forestland, pastureland, or wetland ten years ago. When using the environmental assessment data, we applied Boolean logic to compute "Class 1 areas – high-priority preservation areas – of 2005 that were converted to urban areas between 2000 and 2010. The same computation was made for the other four classes of land.

2. Land Conversion Analysis using Logit Model

In addition to calculating the land consumption and conversion, we ran two simple binomial logistic regression models on the urban change between 1990 and 2000, and the urban change between 2000 and 2010 to identify what spatial variables affected the urbanization in the SMA. The variables used in this modeling analysis included land cover variables for years 1990 and 2000 (e.g., farmland, forestland, pastureland, wetland), distances to transportation facilities (e.g., railroad, major roads, rail stations), distance to waterways, development constraint variables (e.g., steep slope, inside greenbelt), distances to greenbelts and New Towns, and distances to major employment and retail centers. Distances to major facilities and environmental features were calculated using Euclidean Distance function of Spatial Analyst extension in ArcGIS. All of the spatial data were converted to raster files and then joined to a single dataset using Sample function of Spatial Analyst extension in ArcGIS. A series of statistical diagnostics were conducted to select variables that can make the models with the best goodness-of-fit and statistical significance. The following table is the descriptive statistics of the variables used in the analysis.

Table 3-1. Descriptive Statistics for the Land Cover Logit Model

Variables	1990-2000					2000-2010				
Binary Variable	**MEAN**	**SD**	**MIN**	**MAX**	**SUM**	**MEAN**	**SD**	**MIN**	**MAX**	**SUM**
Urban Change	0.020	0.142	0	1	195101	0.041	0.199	0	1	542234
Farmland	0.161	0.367	0	1	1532460	0.269	0.443	0	1	3539740
Forestland	0.760	0.427	0	1	7248871	0.512	0.5	0	1	6740556
Pastureland	0.028	0.164	0	1	262499	0.055	0.229	0	1	729000
Wetland	0.004	0.067	0	1	42681	0.011	0.103	0	1	141102
Barren Land	0.006	0.075	0	1	54452	0.036	0.185	0	1	468480
railstation_1m	0.052	0.223	0	1	498264	0.126	0.332	0	1	1653787
Slope > 15	0.193	0.395	0	1	1843017	0.229	0.42	0	1	3010905
Inside Seoul	0.019	0.137	0	1	183090	0.051	0.221	0	1	674682
Inside Greenbelt	0.055	0.227	0	1	520002	0.116	0.32	0	1	1519954
Continuous Variable	**MEAN**	**SD**	**MIN**	**MAX**	**MED**	**MEAN**	**SD**	**MIN**	**MAX**	**MED**
Distance to Railroad	10.609	6.395	0.000	41.886	12.618	9.396	8.747	0.000	42.087	6.765
Distance to Major Roads	1.308	2.183	0.000	16.292	0.342	1.461	1.964	0.000	16.292	0.870
Distance to Major Employment Center	25.542	12.579	0.000	54.211	32.885	13.319	11.829	0.000	54.211	8.733
Distance to Major Retail Center	5.039	2.893	0.000	20.477	5.341	3.788	3.079	0.000	20.477	2.992
Distance to Waterways	1.700	1.433	0.000	13.985	1.930	1.093	1.426	0.000	13.985	0.721
Distance to Greenbelt	22.027	11.468	0.000	53.881	26.890	16.979	13.842	0.000	53.881	15.610
Distance to New Towns	39.290	15.909	0.000	74.173	48.491	26.224	17.547	0.000	74.173	22.961

3. Land Continuity and Fragmentation Analysis using FRAGSTATS

Several scholars have considered the fragmentation or continuity of urban development as one of the key descriptive elements of urban sprawl (Bereitschaft and Debbage 2014; Jabareen 2006; Jiang et al. 2007; Ewing 2008; Torrens 2008; Jaeger et al. 2010). A spatial pattern analysis program called FRAGSTATS was employed to analyze the land continuity and fragmentation of developed areas as well as natural areas including farmland, forestland, pastureland, and wetland (McGarigal and Marks 1995). There are several studies that have employed FRAGSTATS to analyze land fragmentation and continuity. Beritschaft and Debbage (2014) conducted a similar research in which they analyzed urban fragmentation among 86 metropolitan areas and 19 megapolitan areas (Bereitschaft and Debbage 2014). Ji et al. (2005) used the landscape metrics of the program to analyze the effects of urbanization on the forestland and non-forest vegetation (Ji et al. 2006). Yu and Ng (2006) analyzed the fragmentation of urban areas in Guangzhou, China (Yu and Ng 2007). There are several studies that used FRAGSTATS to analyze the fragmentation of lands in South Korea, but none of the existing studies has analyzed fragmentation and continuity of both urban areas and natural areas (Kwon, Choi, and Lee 2012; E. Lee 2003; Cho, Cho, and Lee 2009). In addition, few studies have used the tool to analyze the effects of greenbelts on land fragmentation and continuity.

This dissertation adopts the spatial metrics used in Beritschaft and Debbage's research to analyze the continuity and fragmentation of five land cover types: urban areas, farmland, forestland, pastureland, and wetland. The spatial metrics include Perimeter-Area Fractal

Dimension (PAFRAC), Landscape Shape Index (LSI), Clumpiness Index (CLUMPY), Contiguity Index (CONTIG), Edge Density (ED), Largest Patch Index (LPI), and Percentage of Like-Adjacencies (PLADJ) (McGarigal and Marks 2014; McGarigal and Marks 1995). These metrics were applied to each of 1990, 2000, and 2010 land cover datasets to analyze the temporal changes in land fragmentation and continuity. By analyzing the degrees of the fragmentation of lands for each year, we can compare the effects of the policy change on the physical containment between the time before and after the greenbelt relaxation. Descriptions of these FRAGSTATS metrics are summarized in Table 3-2.

Table 3-2. FRAGSTATS Metrics

Perimeter-Area Fractal Dimension (PAFRAC)
1 ≤ PAFRAC ≤ 2
PAFRAC approaches 1 for shapes with very simple perimeters such as squares, and approaches 2 for shapes with highly convoluted, plane-filling perimeters. PAFRAC employs regression techniques and is subject to small sample problems. However, this is not the case in this research.

Landscape Shape Index (LSI)
LSI ≥ 1, without limit.
LSI = 1 when the landscape consists of a single square patch of the corresponding type; LSI increases without limit as landscape shape becomes more irregular and/or as the length of edge within the landscape of the corresponding patch type increases.

Clumpiness Index (CLUMPY)
-1 ≤ CLUMPY ≤ 1
CLUMPY equals -1 when the focal patch type is maximally disaggregated; CLUMPY equals 0 when the focal patch type is distributed randomly, and approaches 1 when the patch type is maximally aggregated. Note, CLUMPY equals 1 only when the landscape consists of a single patch and include a border comprised of the focal class.

Contiguity Index (CONTIG)
0 ≤ CONTIG ≤ 1
CONTIG equals 0 for a one-pixel patch and increases to a limit of 1 as patch contiguity, or connectedness, increases.

Edge Density (ED)
ED ≥ 0, without limit
ED = 0 when there is no class edge in the landscape; that is, when the entire landscape and landscape border, if present, consists of the corresponding patch type and the user specified that none of the landscape boundary and background edge be treated as edge.

Largest Patch Index (LPI)
0 < LPI ≤ 100
LPI approaches 0 when the largest patch of the corresponding patch type is increasingly small. LPI = 100 when the entire landscape consists of a single patch of the corresponding patch type; that is, when the largest patch comprises 100% of the landscape. LPI at the class level quantifies the percentage of total landscape area comprised by the largest patch. As such, it is a simple measure of dominance.

Percentage of Like Adjacencies (PLADJ)
0 ≤ PLADJ ≤ 1
PLADJ equals 1 when the patch types are maximally disaggregated and there are no like adjacencies. PLADJ = 100 when all patch types are maximally aggregated, and the landscape contains a border comprised entirely of the same class.

Source: McGarigal and Marks (2014)

3.3. Land Cover Analysis Results

1. Land Conversion Analysis using ArcGIS

As the summary of land cover statistics indicates, urban areas in the SMA have increased substantially between 1990 and 2010. The statistics summarized in Table 3-2 describe the areas of seven land cover types calculated based on the number of raster cells. Each cell in the land cover dataset is 30 meters by 30 meters. The areas of each land cover type were calculated by multiplying the number of cells by 0.0009 km^2/cells (0.03 km × 0.03 km). Between 1990 and 2000, the time before the greenbelt relaxation, urban areas in the SMA increased by 46.0% from 691.6 km^2 to 1,009.8 km^2. Meanwhile, total farmland decreased by 9.2%, forestland decreased by 2.3%, and wetlands decreased by 14.3%. One of the notable changes during this period was the substantial decrease in the water area. Total water area declined by 24.1% from 395.1 km^2 in 1990 to 299.9 km^2 in 2000. The decrease in both water areas and wetlands likely resulted in part from the land reclamation projects that were conducted in the 1990s and 2000s to secure more land for large-scale development projects. For example, Incheon International Airport, which opened in 2000, was built on reclaimed land on the west coast of the SMA. A number of newly planned cities such as Songdo and Cheongra were built on the reclaimed lands in the vicinity of the new airport. While the region lost substantial amounts of farmland, forestland, and wetlands, total pastureland increased by 5.9% and total barren land increased by 119.3%. This result suggests a widespread idling of actively farmed land and forestland while the landowners anticipate the eventual sale of their land for development. Also, given that the barren land includes areas that have been cleared for future development, it seems that a lot of new developments were being planned during this period.

Table 3-3. Land Cover Statistics and Changes (1990, 2000, 2010)

(Unit: km², %)

Land Cover Type	1990	% Change (`90 – `00)	2000	% Change (`00 – `10)	2010
Urban	691.6	46.0%	1,009.8	22.1%	1,233.1
Farmland	3,606.2	-9.3%	3,272.7	-0.3%	3,263.9
Forestland	6,416.5	-2.3%	6,267.4	-1.9%	6,148.1
Pasture	667.1	5.8%	706.1	-3.8%	679.6
Wetland	153.3	-9.3%	139.0	-28.4%	99.6
Barren	197.0	119.3%	432.0	-4.9%	410.9
Water	395.1	-24.1%	299.9	-2.7%	291.7
Greenbelt	1,383.5	-0.5%	1,376.6	-8.8%	1256.0

Source: Processed by author based on the spatial data retrieved from the Ministry of Environment

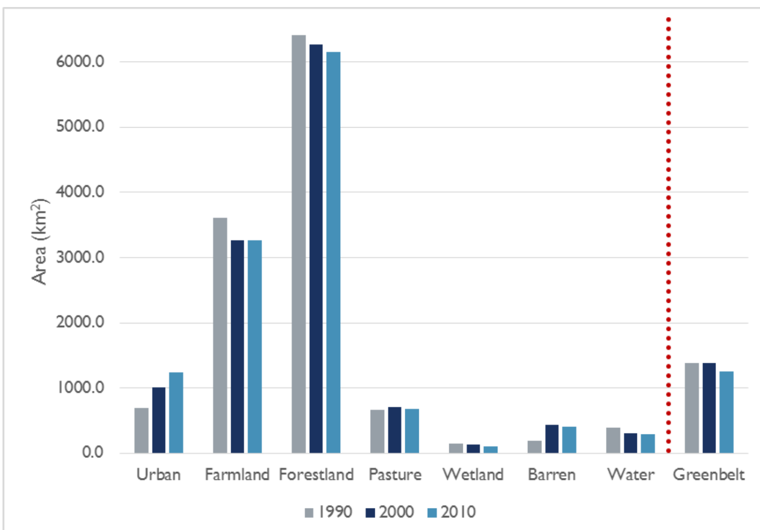


Figure 3-2. Land Cover Change (1990, 2000, 2010)

Although the SMA continues to urbanize, the rate of urbanization between 2000 and 2010 was found to be lower than the preceding decade. The percent change of urban areas decreased from 74.7% between 1990 and 2000 to 48.9% between 2000 and 2010.

The SMA lost much less farmland compared to the previous decade. This could have been influenced by the global economic slowdown from 2007 to 2010 as well as the economic recession in 1997. Total farmland decreased by 0.3% from 3,272.7 km^2 in 2000 and 3,263.9 km^2 in 2010. The forestland conversion rate is slightly lower than the previous decade. A notable difference between the two periods is the much less loss of water area and the much greater decrease in wetlands after the relaxation of the greenbelt policy. Between 2000 and 2010, the region's wetlands decreased by 28.4%, a loss of about 39.4 km^2 (9,736 acres). This is owing to the land reclamation and developments that continued during the 2000s. Another notable change is the loss of pastureland. Compared to the previous year, the SMA's pastureland decreased by 3.8% from 706.1 km^2 in 2000 to 679.6 km^2 in 2010. While the region was losing substantial amounts of farmland, forestland, and wetland, the SMA's greenbelt area also shrank. Between 1990 and 2000, the total greenbelt area decreased by 0.5% from 1,383.5 km^2 to 1,376.6 km^2. But from 2000 to 2010, the greenbelt decreased by 8.8% to 1,256 km^2. This indicates the overall relaxation of the greenbelt policy. Yet, ironically, more rural land was converted to urban areas in the 1990-2000 era than in the 2000-2010 period. The release of 120 km^2 of greenbelt land between 2000 and 2010 meant that there was less need to develop farmland and forestland outside the greenbelt.

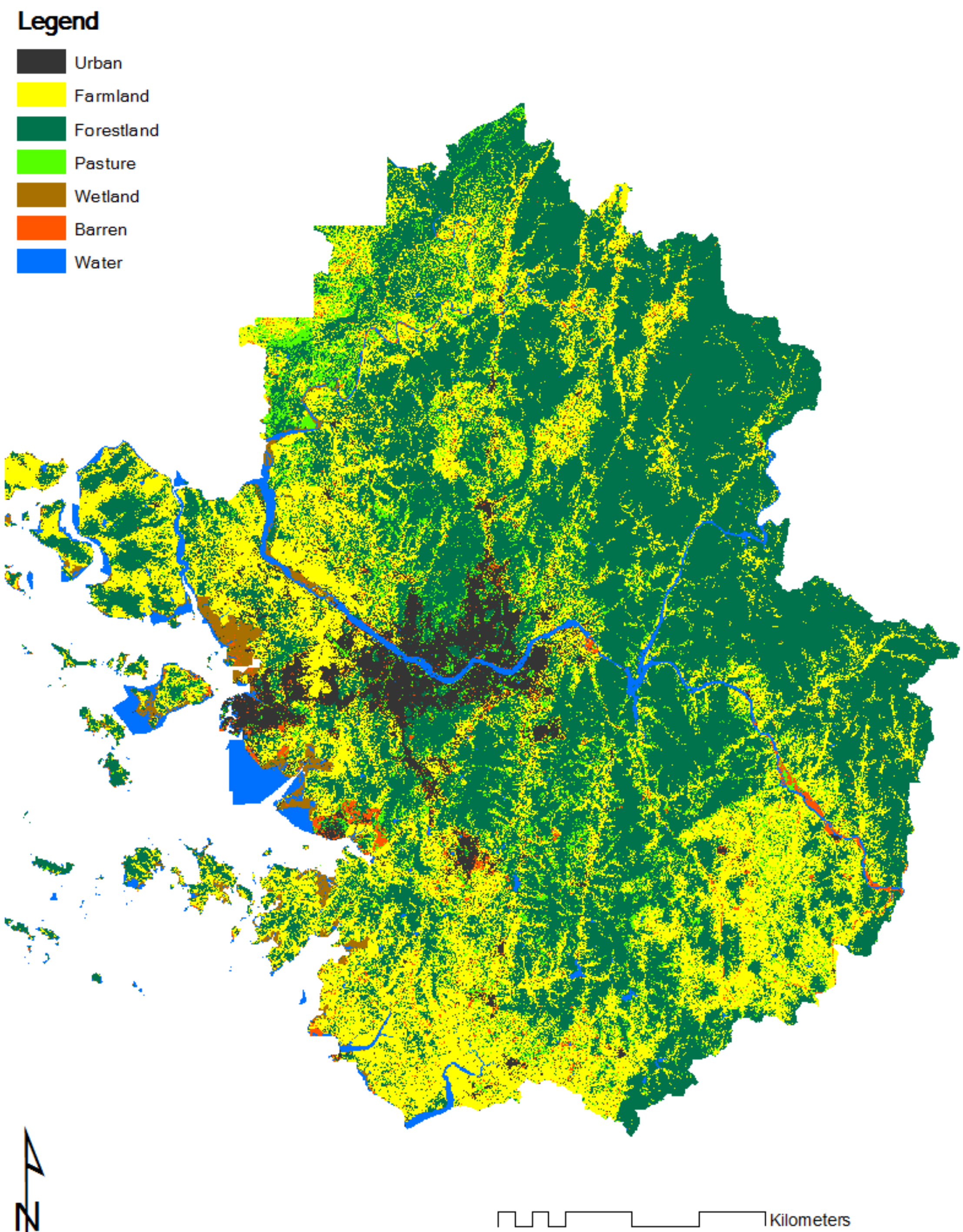


Figure 3-3. Land Cover Map of SMA (1990)

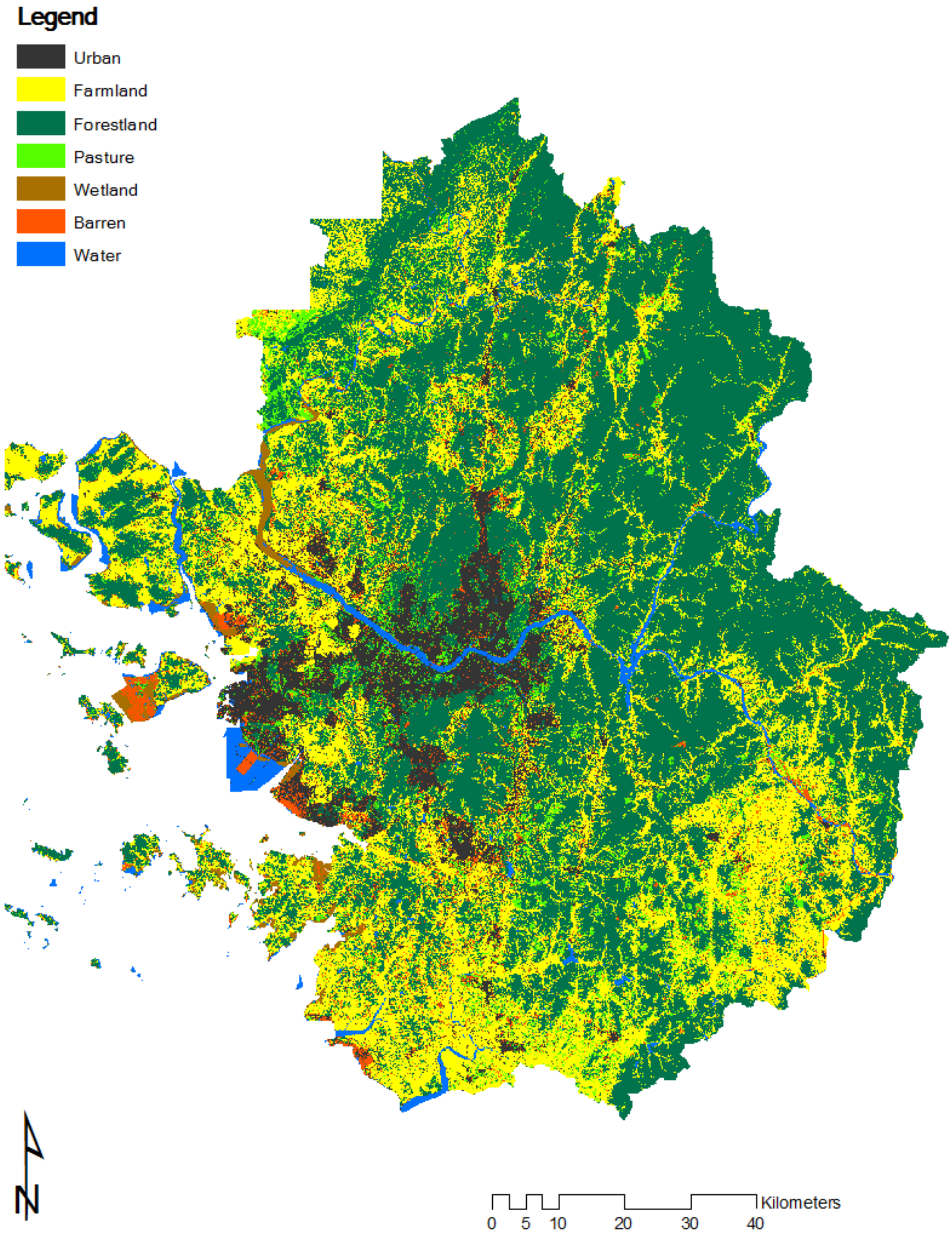


Figure 3-4. Land Cover Map of SMA (2000)

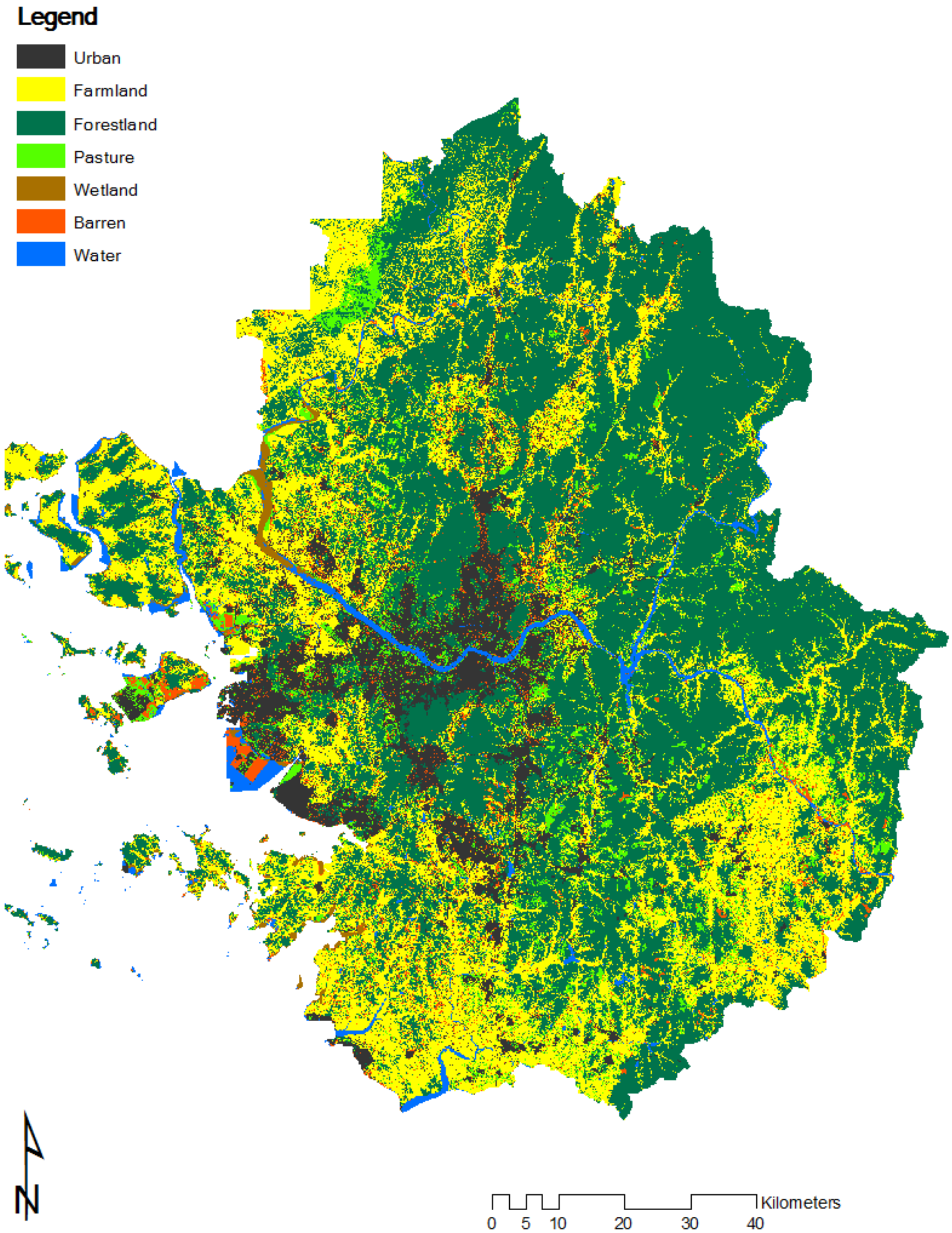
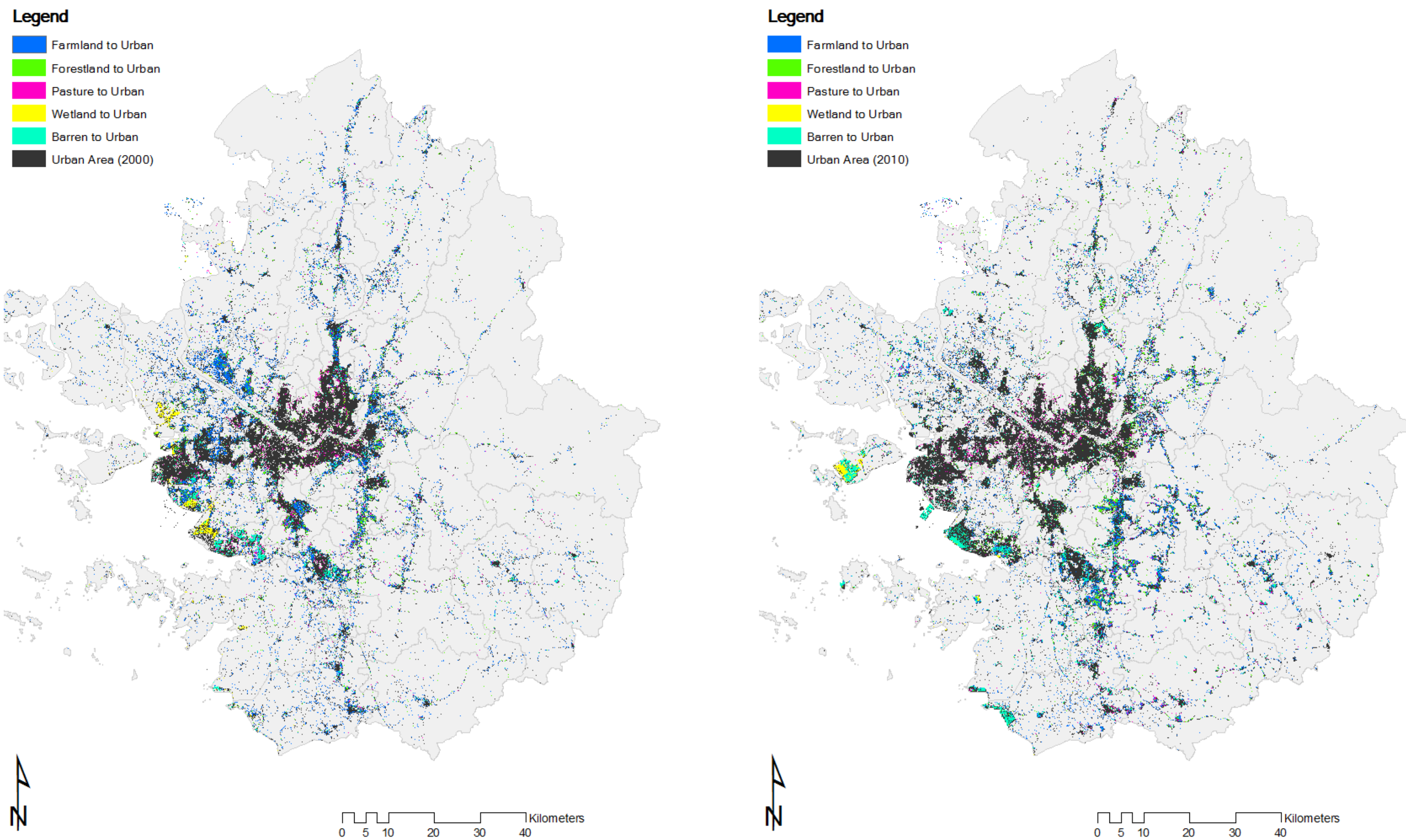


Figure 3-5. Land Cover Map of SMA (2010)



1990-2000 2000-2010

Figure 3-6. Land Conversion to Urban Areas

To further the analysis on the land consumption and conversion, Raster Calculator in ArcGIS software was used to calculate how much of the natural areas, including farmland, forestland, pasture, and wetlands, were converted to urban areas. The calculation was made based on Boolean logic. For example, we calculated the urban areas in 2010 that were not urban areas in 2000 by applying the following logic to the Raster Calculator: "Urban Areas 2010 == 1 & Urban Areas 2000 == 0". To calculate the farmlands that have been converted to urban areas between 2000 and 2010, we used: "Urban Areas 2010 == 1 & Farmland 2000 == 1". The calculated results are summarized in tables below.

Table 3-4. Calculated Land Conversion to Urban Areas based on Boolean Logic

Category	1990-2000			2000-2010		
	No. of Cells	Area (km^2)	Percentage	No. of Cells	Area (km^2)	Percentage
Forestland to Urban	90,149	81.1	15.7%	89,315	80.4	16.3%
Farmland to Urban	326,868	294.2	56.9%	243,728	219.4	44.5%
Pastureland to Urban	48,643	43.8	8.5%	64,072	57.7	11.7%
Wetland to Urban	26,416	23.8	4.6%	12,462	11.2	2.3%
Barren land to Urban	59,102	53.2	10.3%	130,828	117.7	23.9%
Water Area to Urban	23,222	20.9	4.0%	7,682	6.9	1.4%
Total Urban Change	574,400	517.0	100.0%	548,087	493.3	100.0%

Source: Processed by author based on the spatial data retrieved from the Ministry of Environment

Table 3-5. Percentage of Urbanized Areas by Land Cover Type

Category	1990-2000			2000-2010		
	Land Area (1990)	Urbanized Area (km^2)	Percentage	Land Area (1990)	Urbanized Area (km^2)	Percentage
Forestland	3,606.2	294.2	8.2%	3,272.7	219.4	6.7%
Farmland	6,416.5	81.1	1.3%	6,267.4	80.4	1.3%
Pastureland	667.1	43.8	6.6%	706.1	57.7	8.2%
Wetland	153.3	23.8	15.5%	139.0	11.2	8.1%
Barren land	197.0	53.2	27.0%	432.0	117.7	27.3%
Water Area	395.1	20.9	5.3%	299.9	6.9	2.3%

Source: Processed by author based on the spatial data retrieved from the Ministry of Environment

Farmlands converted to urban areas accounted for 56.9% of total urban changes between 1990 and 2000 and 44.5% between 2000 and 2010. The farmland lost between 1990 and 2000 accounted for 8.2% of farmland in 1990, and the farmland lost during 2000 to 2010 accounted for 6.7% of farmland in 2000. Urbanized forestlands accounted for 15.7% of total urban changes between 1990 and 2000 and 16.3% between 2000 and 2010. About 1.3% of total forestland was converted to urban areas between 1990 and 2000, and about the same percentage of forestland was converted in the following period. Considering that the majority of the greenbelt lands are forestlands in mountains surrounding the region, it seems that the forestland was relatively better protected from urbanization than the farmland. Also, farmland is much easier to develop for urban uses than forestland. However, the amount of urbanized forestland during the both periods is quite substantial – 8,110 ha (20,040 acres) between 1990 and 2000, and 8,040 ha (19,867 acres) between 2000 and 2010. The percentages of urban conversions for each land cover type are illustrated in Figure 3-7 below.

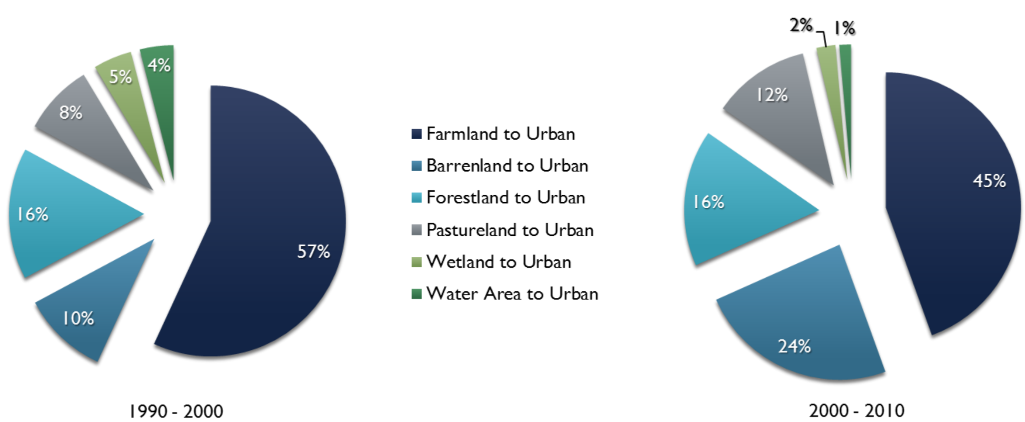


Figure 3-7. Percentage of Urban Conversion by Land Cover Type

What is strikingly interesting is that about 15.5% of the entire wetlands in the region were converted to urban areas between 1990 and 2000 and 8.1% were urbanized between 2000 and 2010. Although wetlands to urban areas only accounted for 4.60% and 2.27% of the total urbanized areas during the two periods, it seems that substantial amounts of wetlands have been urbanized. This is the result of reclamation projects that were conducted over the two decades to secure more lands for developments. Pastureland to urban areas was 6.6% and 8.2% respectively for the two periods in total urban changes. And about 8.5% of the 1990 pastureland was urbanized by 2000 and 11.7% of the 2000 pastureland were urbanized by 2010. About 27.0% of barren land in 1990 was urbanized by 2000, and 27.3% was urbanized by 2010. The share of barren land to urban areas in total urban change was 10.3% in the first decade and 23.9% in the following decade. The increase in the barren land area and its share in urban changes indicate that much more land was made available for development during both periods. Overall, the SMA has experienced considerable conversion of natural areas to urban areas over the 1990-2010 era.

It is noteworthy that urban changes also took place within the greenbelt perimeters. About 10.9% of the total urban change between 1990 and 2000 (65.1 km^2), and 13.2% between 2000 and 2010 (56.3 km^2) took place inside the greenbelt areas. Considering that the raster calculation was done using the post-relaxed greenbelt GIS shapefile as the base perimeter, these numbers are quite alarming.

The South Korean government has claimed that they released greenbelt areas that were environmentally damaged, based on their environmental assessment research. The government has conducted a series of nationwide environmental assessments since 2005 from which they graded lands into five classes depending on their environmental values. When local governments find the need to release the greenbelt areas in their jurisdictions, they have to establish both regional and local comprehensive plans based on the environmental assessments to justify the release. The planning processes include two public hearings and two reviews by both local and central (national) planning commissions. Once the plans are approved, then the local governments can release the greenbelt lands for development.

Table 3-6. Environmental Assessment Land Classification

Land Class	Description
Class 1	High-priority preservation area where developments are strictly prohibited Requires permanent preservation for ecosystem protection
Class 2	High-priority preservation areas where small scale developments are allowed under certain condition
Class 3	Conditional developments are allowed acting as buffers between preserved and developed areas. Developments should not impose negative effects on the surrounding environment.
Class 4	Areas that are already being developed. Certain areas may be subjected for preservation.
Class 5	Areas where developments are completely allowed. Planned developments are strongly recommended.

Korea National Environmental Information Network System (2015)

To analyze whether The South Korean governments released the greenbelt areas according to this protocol, we used the Environmental Assessment maps for 2005 and 2010. If the local governments had followed the protocol, the urbanized areas between 2000 and 2010 should be located in the areas that were graded as Class 3, 4, or 5 in the

2005 environmental assessment. Few developments should have occurred in Class 1 and 2 areas. We also used the 2010 environmental assessment data to see whether notable changes have been made to the land assessment and urbanization pattern. The results are summarized in Table 3-7, and 3-8.

Table 3-7. Land Conversion and 2005 Environmental Assessment

(Unit: km^2)

Category	Environmental Assessment (2005)	Converted to Urban (2000 – 2010)		% of Urban Conversion by Land Class	Greenbelt to Urban (2000 – 2010)		% of GB-to-Urban Conversion by Land Class
	A	*B (km^2)*	*B` (%)*	*B/A*	*C (km^2)*	*C` (%)*	*C/B*
Class 1	4,361.4	82.5	16.8%	1.9%	20.1	35.7%	24.4%
Class 2	2,389.3	79.3	16.1%	3.3%	22.6	40.1%	28.5%
Class 3	2,077.4	79.6	16.2%	3.8%	0.6	1.1%	0.7%
Class 4	898.5	48.8	9.9%	5.4%	0.6	1.1%	1.3%
Class 5	1,859.0	188.7	38.4%	10.2%	12.3	21.8%	6.5%
Unclassified	490.3	12.6	2.6%	2.6%	0.1	0.2%	0.6%
TOTAL	12,075.9	491.6	100.0%	4.1%	56.3	100.0%	11.5%

When the 2005 Environmental Assessment map was overlaid onto the 2000-to-2010 urban change map, we discovered some interesting findings. Of the 491.6 km^2 of total urban change that occurred between 2000 and 2010, 16.8% (82.5 km^2) of urbanization took place in Class 1 areas, and 16.1% (79.3 km^2) in Class 2 areas. Urbanization in Class 3, 4, and 5 areas accounted for 16.2%, 9.9%, and 38.4% respectively. Urbanized areas in Class 1 accounted for 1.9% of the total Class 1 area, and those in Class 2 accounted for 3.3% of the total Class 2 area. Although this percentage may look minimal, the absolute amount of Class 1 and 2 lands converted to urban areas are quite substantial at 82.5 km^2 and 79.3 km^2, respectively.

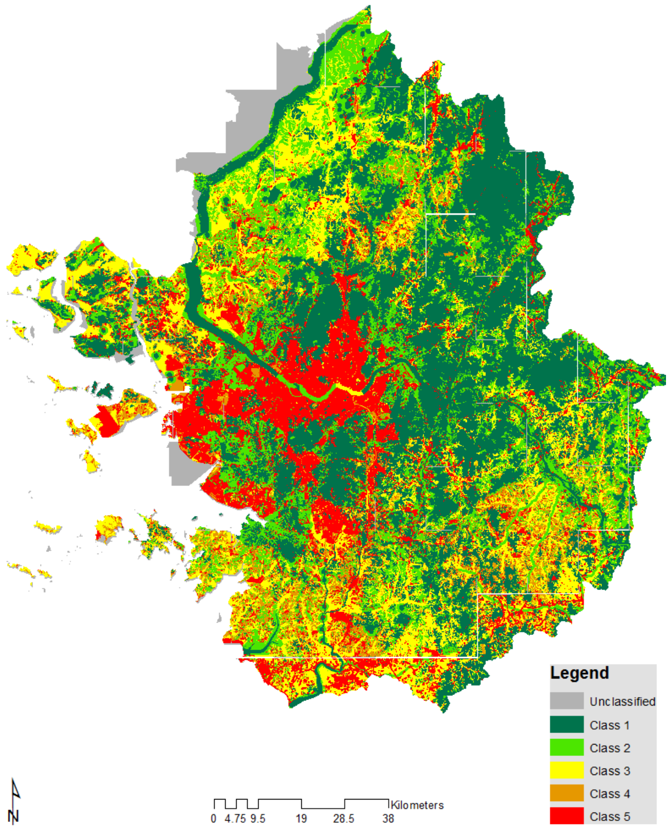
Table 3-8. Land Conversion and 2010 Environmental Assessment

(Unit: km^2)

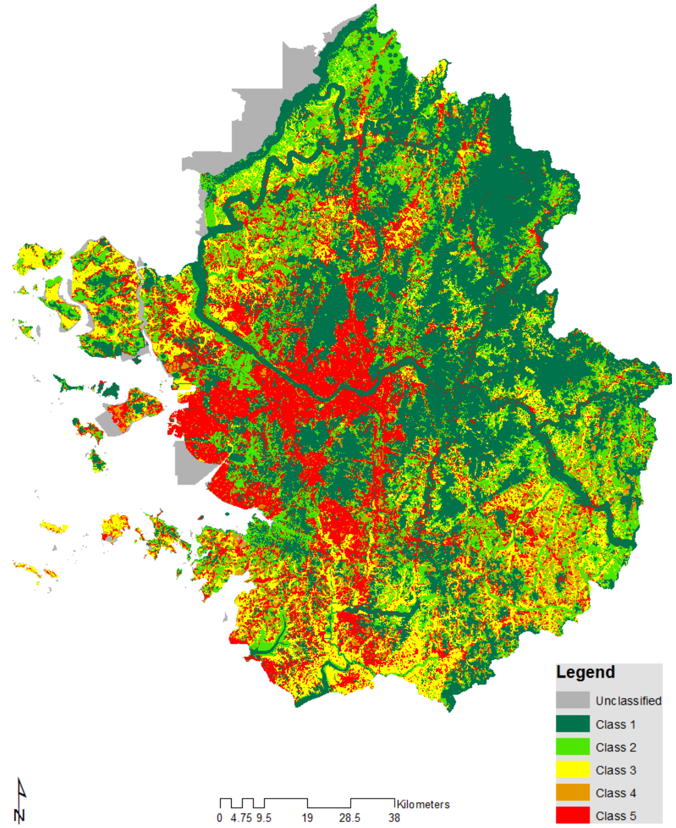
Category	Environmental Assessment (2010)	Converted to Urban (2000 – 2010)		% of Urban Conversion by Land Class	Greenbelt to Urban (2000 – 2010)		% of GB-to-Urban Conversion by Land Class
	A	*B (km^2)*	*B` (%)*	*B/A*	*C (km^2)*	*C` (%)*	*C/B*
Class 1	4,518.3	43.7	9.2%	1.0%	10.3	18.3%	23.6%
Class 2	2,517.5	61.1	12.9%	2.4%	18.7	33.2%	30.5%
Class 3	1,598.5	46.2	9.8%	2.9%	1.2	2.1%	2.6%
Class 4	692.5	22.6	4.8%	3.3%	1.0	1.8%	4.3%
Class 5	2,337.0	298.8	63.2%	12.8%	25.1	44.6%	8.4%
Unclassified	444.8	20.6	4.4%	4.6%	0.0	0.0%	0.1%
TOTAL	12,108.6	472.5	100.0%	3.9%	56.3	100.0%	11.9%

In order to analyze how the environmental assessment areas changed along with the urban changes, we overlaid the 2010 environmental assessment map onto the same urban change map. Theoretically, urban changes between 2000 and 2010 should have occurred in Class 3, 4, and 5 areas – lands where developments are permitted – represented by an increase in the percentage of converted areas (B`) in Table 3-7. The percentage of Class 3 and 4 areas, in fact, decreased when the 2010 data was compared to the 2005 data. The percentage of urbanized areas in Class 3 areas decreased from 16.2% to 9.8% and the percentage in Class 4 areas decreased from 9.9% to 4.8%. Meanwhile, the percentage of urbanized areas in the Class 5 areas where developments are fully permitted increased substantially from 38.4% to 63.2%. Of the 472.5 km^2 of total urbanization that happened between 2000 and 2010, Class 1 areas accounted for 9.2% and Class 2 areas accounted for 12.9%. This is a slight decrease from the 2005 environmental assessment data. The decrease in the percentage is owing to the increase in total Class 1 and 2 areas. Total Class 1 area increased by 3.6% from 4,361.4 km^2 in 2005 to 4,518.3 km^2 in 2010. Total Class 2 area increased by 5.4% from 2,389.3 km^2 to 2,517.5 km^2. With the increase in the total areas, the proportion of urbanized areas for Class 1 and 2, decreased from 1.9% and 3.3% in 2005 to 1.0% and 2.4% in 2010. These changes show that the South Korean government reclassified much of the urbanized areas in Class 1 and 2 areas to Class 5 areas and added more lands to Class 1 and 2 areas for permanent preservation. Although the government added more lands for preservation, it is worrisome that the substantial amount of lands that were originally designated as Class 1 and 2 for permanent preservation were developed and reclassified to Class 5 land. This indicates that the environmental assessment and land preservation policies were inconsistent and not being properly enforced.

What is even more interesting is the changes in the proportion of urbanized areas of each land class in the greenbelt area. Of the 56.3 km^2 of urbanized areas that took place within the greenbelt area, 35.7% of urbanization took place in Class 1 areas and 40.1% of urbanization in Class 2 areas according to the 2005 environmental assessment data. These percentages decreased to 23.6% and 30.5% respectively in 2010. The percentage of urbanized areas in Class 5 areas in the greenbelt increased from 21.8% in 2005 to 44.6% in 2010 meaning that more lands including lands that were originally classified as Class 1 and 2 within the greenbelt were reclassified to be Class 5 land for development. Because these conversions were examined using the greenbelt map after the relaxation, we can suspect that the more greenbelt lands that are re-graded as Class 5, the more greenbelt land is likely to be released. In short, the greenbelt in the SMA has lost its primary function of land preservation.

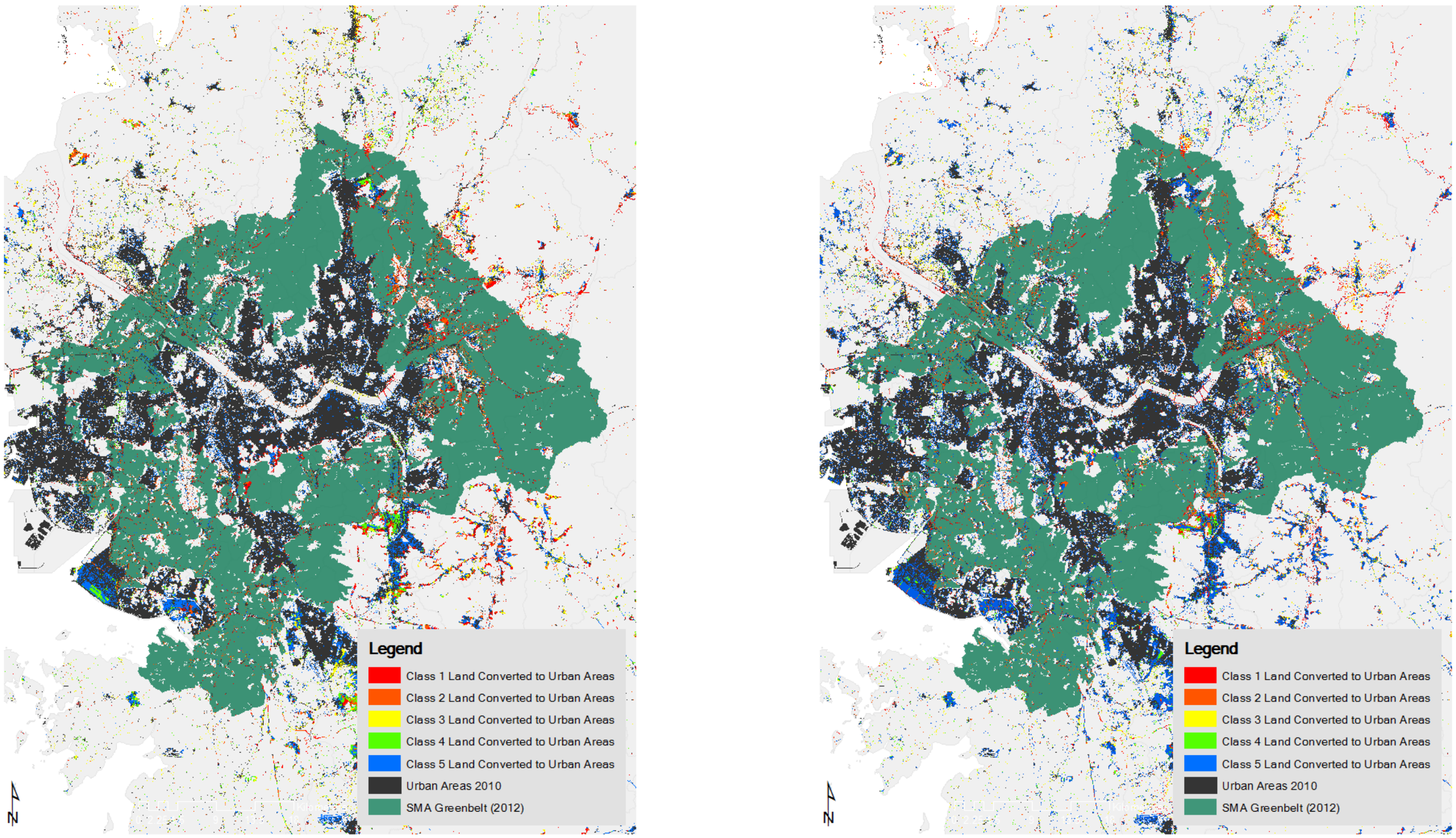


Environmetnal Assessment in 2005



Environmetnal Assessment in 2010

Figure 3-8. Environmental Assessment Maps (2005, 2010)



Based on 2005 Environmetnal Assessment Map   Based on 2010 Environmetnal Assessment Map

Figure 3-9. Land Conversion to Urban Areas between 2000 and 2010 by Environmental Assessment Class Type

2. Land Conversion Analysis using Logit Model

The binomial logistic regression models (Logit Model) using urban changes between 1990 and 2000 and between 2000 and 2010 produced some interesting results. In order to compare the effect sizes of variables, all continuous variables were standard normalized. The modeling results presented in Table 3-8 include the coefficients (B) as well as the odds ratios.

Table 3-9. Logit Modeling Analysis Result

Y		Urban Change (1990-2000)			Urban Change (2000 – 2010)		
Variables		Coef.	Std. err	Odds Ratio	Coef.	Std. err	Odds Ratio
(Intercept)		-5.730***	0.007	0.003	-4.760***	0.004	0.009
Farmland	(1 = farmland)	2.100***	0.007	8.166	1.743***	0.004	5.714
Pastureland	(1 = pasture)	1.462***	0.011	4.315	1.865***	0.005	6.457
Wetland	(1 = wetland)	1.948***	0.022	7.018	2.014***	0.010	7.496
Barren land	(1 = barren)	2.814***	0.014	16.673	3.049***	0.005	21.087
Distance to Railroad		-0.076***	0.004	0.927	-0.066***	0.002	0.936
Distance to Major Roads		0.187***	0.005	1.206	-0.365***	0.004	0.694
Rail/Subway Station 1mile buffer	(1= within the buffer)	0.855***	0.007	2.350	0.418***	0.004	1.519
Distance to Major Employment Centers		-0.424***	0.007	0.655	-0.260***	0.004	0.771
Distance to Major Retail Centers		-0.663***	0.005	0.515	-0.620***	0.003	0.538
Distance to Waterways		-0.228***	0.005	0.796	0.236***	0.002	1.266
Slope greater than 15º	(1 = steep slope)	-1.449***	0.019	0.235	-1.063***	0.010	0.345
Inside Greenbelt	(1 = inside GB)	-0.857***	0.009	0.425	-0.703***	0.005	0.495
Inside Seoul	(1 = Seoul)	0.080***	0.011	1.084	-0.240***	0.006	0.787
Distance to Greenbelt		-0.234***	0.005	0.791	-0.312***	0.003	0.732
Distance to New Towns		0.104***	0.004	1.110	-0.048***	0.003	0.953
N		9,535,561			13,155,063		
AIC		1,311,239			3,530,136		

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

The Logit Models confirmed the outcomes discovered from the land conversion analysis using ArcGIS. During the both periods before and after the greenbelt relaxation, the chances of urbanization were found to be higher in farmland, pastureland, wetland, and barren land. Before the relaxation, barren land had the highest chance of urbanization among the land cover variables followed by farmland, wetland, and pastureland. Forestland was eliminated during the modeling process because it caused multicollinearity problem in both models. After the greenbelt relaxation, the barren land had the highest chance of urbanization followed by wetland, pastureland, and farmland. Both models capture the substantial amount of wetland converted urban areas owing to the land reclamation and development projects.

Distance to railroad was found to be negatively associated with the dependent variable in both periods, meaning that closer it gets to the railroad, higher the chances of urbanization. Distance to major roads including highways and major arterial roads were found to be positively associated with the urban change before the relaxation, but it became negatively associated with the urban change after the relaxation. This finding aligns with the finding from the Difference-in-Difference regression model using percent change in total road length from which we discovered that the road length increased substantially before the greenbelt relaxation. This indicates that the developments along the major roads happened after the greenbelt relaxation. We found that there is higher chance of urbanization within a 1mile radius from train and subway stations in the SMA in both periods. However, note that the standard normalized coefficient is smaller after the relaxation, meaning that despite the positive coefficient, the effect size decreased compared to the period before the greenbelt relaxation.

Distance to major employment centers was found to be negatively associated with the urban changes in both periods, which means that there are higher chances of urbanization near the employment centers. However, the effect size decreased after the relaxation, which may be indicative to jobs-housing mismatch. This is further investigated in the following Difference-in-Differences regression analysis using commuting data. Distances to major retail centers were also found to be negatively associated with the dependent variables with similar effect sizes in both periods.

Urban changes were found to be negatively associated with the steep slope (slope greater than 15 degrees) during both periods. Areas inside the greenbelt were found to have lower chances of urbanization in both periods showing the development restriction function of the greenbelt in the region. Distances to the greenbelt variable were found to be negatively related to the urban changes in both periods, meaning that there were higher chances of urbanization near the greenbelt perimeter. This captures the growth of New Towns and satellite cities located just beyond the greenbelt. Interestingly, inside Seoul dummy variable was positively associated with the urban change before the greenbelt relaxation, but became negatively associated after the relaxation. This means that there was higher chance of urban growth inside Seoul between 1990 and 2000, but the relationship became reversed after the greenbelt relaxation. This may indicate that more developments took place outside Seoul after the greenbelt relaxation. In regards to the New Town variable, we found that the distance to New Towns was positively related to the urban changes before the greenbelt relaxation, but the relationship became reversed after the relaxation. This indicates the growth of New Towns after the greenbelt relaxation.

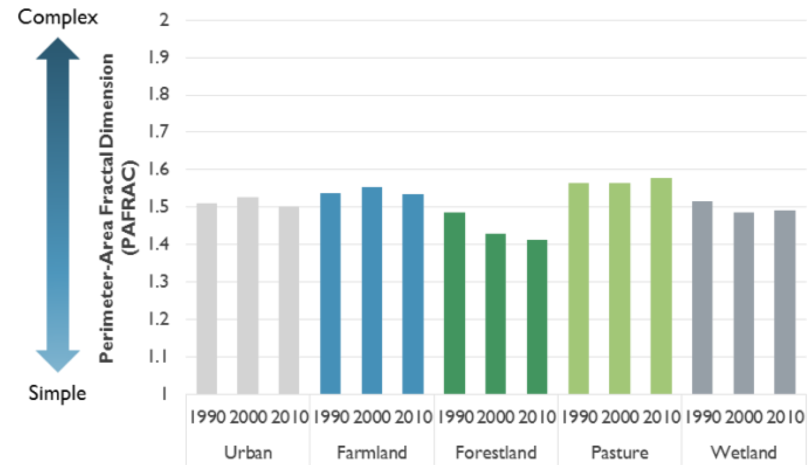
In summary, we found that farmland, wetland, and barren land were vulnerable to urban conversion during both periods before and after the greenbelt relaxation. Substantial amount of developments occurred near greenbelt perimeters after the relaxation, especially outside Seoul. The growth of New Towns after the greenbelt relaxation was also confirmed. Overall, the findings from the modeling analysis verified the physical signs of urban sprawl.

3. Land Continuity and Fragmentation Analysis using FRAGSTATS

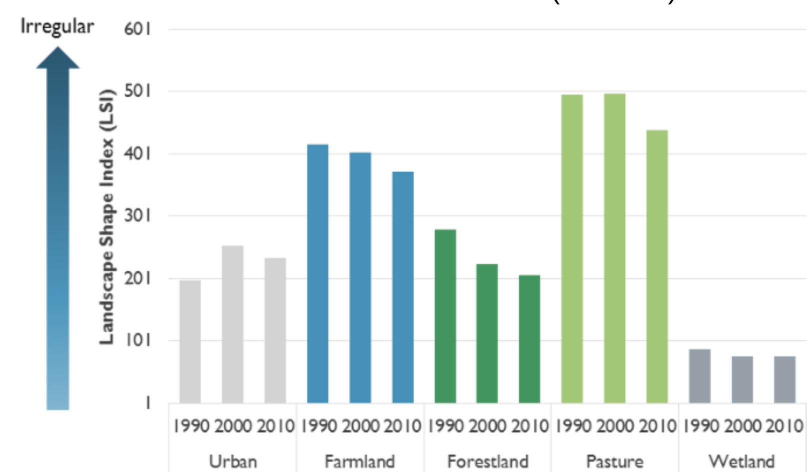
A spatial pattern analysis program called FRAGSTATS was employed to analyze the land continuity and fragmentation of developed and natural land areas (McGarigal and Marks 1995; McGarigal and Marks 2014). There are number of studies that have used this program to analyze land fragmentation and urbanization patterns. Notably, Bereitschaft and Debbage (2014) analyzed the urban fragmentation among US Metropolitan and Megapolitan areas as the measurement criterion for urban sprawl (Bereitschaft and Debbage 2014). This part of the analysis employs the same spatial metrics used in their research to analyze the continuity and fragmentation of five land cover types: urban areas, farmland, forestland, pastureland, and wetlands.

Table 3-10. FRAGSTATS Analysis Summary

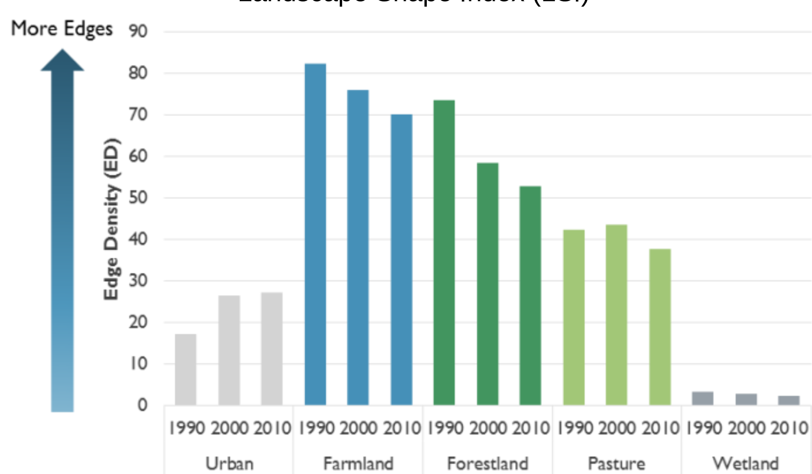
Land Cover	Year	PAFRAC	LSI	ED	CLUMPY	PLADJ	CONTIG	LPI
Urban	1990	1.509	198.029	17.153	0.761	77.400	0.763	3.309
	2000	1.526	253.604	26.518	0.740	76.052	0.747	4.009
	2010	1.501	234.212	27.055	0.778	79.983	0.787	4.627
Farmland	1990	1.538	415.730	82.210	0.705	79.229	0.781	7.249
	2000	1.553	402.610	75.821	0.711	78.886	0.776	5.296
	2010	1.536	372.104	69.943	0.733	80.459	0.792	4.859
Forestland	1990	1.485	279.693	73.514	0.778	89.523	0.889	16.444
	2000	1.429	224.798	58.288	0.824	91.481	0.908	12.049
	2010	1.413	205.816	52.852	0.841	92.124	0.915	10.079
Pasture	1990	1.565	495.239	42.165	0.392	42.473	0.403	0.156
	2000	1.564	496.766	43.515	0.405	43.900	0.417	0.144
	2010	1.578	439.405	37.741	0.465	49.433	0.476	0.314
Wetlands	1990	1.517	87.289	3.358	0.788	78.834	0.778	0.295
	2000	1.486	76.954	2.675	0.804	80.397	0.792	0.263
	2010	1.491	75.917	2.199	0.772	77.152	0.757	0.264



Perimeter-Area Fractal Dimension (PAFRAC)

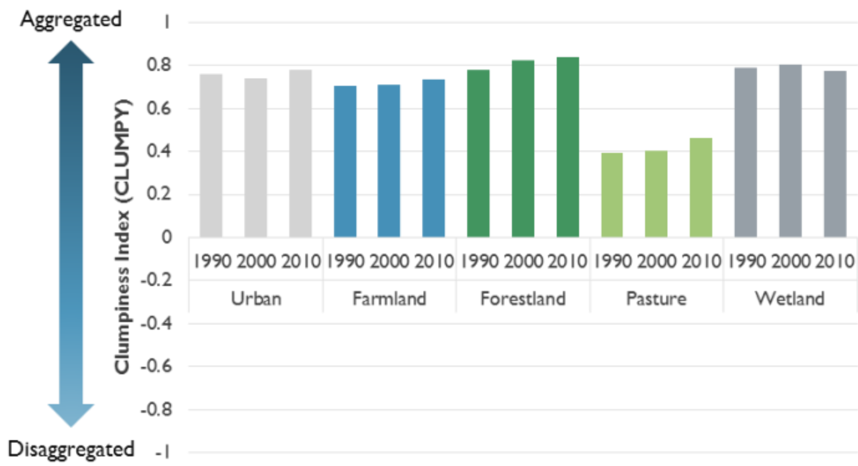


Landscape Shape Index (LSI)

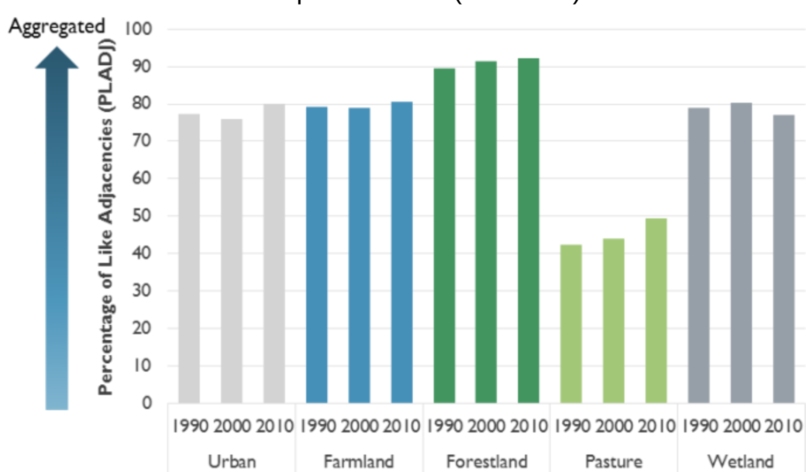


Edge Density (ED)

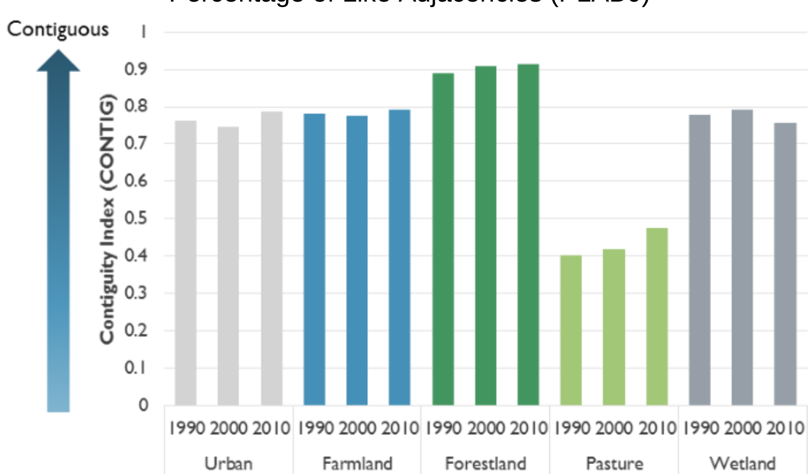
Figure 3-10. FRAGSTATS Analysis Result I: PAFRAC, LSI, and ED



Clumpiness Index (CLUMPY)

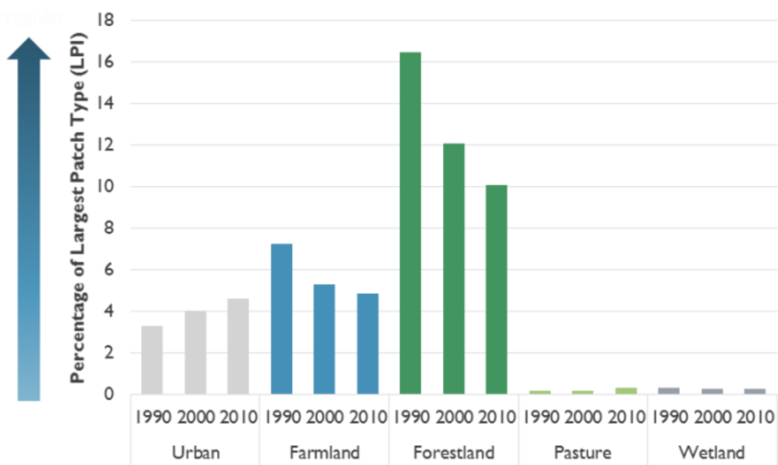


Percentage of Like Adjacencies (PLADJ)



Contiguity Index (CONTIG)

Figure 3-11. FRAGSTATS Analysis Result II: CLUMPY, PLADJ, and CONTIG



Percentage of Largest Patch Type (LPI)

Figure 3-12. FRAGSTATS Analysis Result III: LPI

Urban Areas

Several FRAGSTATS metrics indicate that the shape of the urban areas has become more complex and irregular especially between 1990 and 2000. The PAFRAC values maintained a range of around 1.5 indicating moderate convoluted form. There was substantial increase in the LSI between 1990 and 2000 meaning that the shape of urban areas became more irregular. The value slightly decreased between 2000 and 2010. The ED values confirm that the urban areas have become more complex in shape. The ED increased considerably between 1990 and 2000 and then slightly increased between 2000 and 2010.

CLUMPY and PLADJ show that the urban areas became more aggregated between 1990 and 2010 although both values slightly decreased in 2000. The CLUMPY values maintaining positive values and closer to 1 is an indication of aggregation. In all three years, urban areas maintained a high percentage of like adjacencies (PLADJ). The CONTIG value showing the connectivity was closer to 1 in all three years meaning that the urban areas are fairly well connected to one another. Lastly, percentage of largest patch type (LPI) has steadily increased between 1990 and 2010 showing that the largest patch area of urban land became bigger every year.

Overall, urban areas in the SMA showed moderately complex and irregular forms between 1990 and 2000 and began to show more regular form in the 2000s. This might be explained by the fact that the greenbelt relaxation and the new developments filled in the gaps in the urban areas that used to be divided by the greenbelt. Aggregation of urban areas between 2000 and 2010 indicates that urban fragmentation – one of many proxies for measuring sprawl – did not occur in the SMA. This suggests that urban expansion relied on central sewer and water systems and created phased growth rather than leapfrog development.

Farmland & Forestland

Farmland showed a considerable decrease in LSI and ED values in all three years indicating that the shape of farmland became less complex and simpler. The absolute values of these two metrics are much higher than those of urban areas meaning that the farmland showed higher complexity and irregularity than the urban areas. CLUMPY maintained the values above 0.6 showing a fairly good level of aggregation. PLADJ values were all above 80 in all three years confirming the aggregation. The CONTIG value was similar to that of urban areas meaning that farmlands are also fairly well connected to one another. Unlike the urban areas, the percentage of largest patch type significantly decreased between 1990 and 2010 meaning that the largest patch of farmland has decreased substantially during this period.

Forestland shows a similar pattern to the farmland. PAFRAC values are slightly lower than those of farmland meaning that the forestland has a simpler shape. Both the LSI and ED are lower than those of farmland and the degree to which their values decreased is substantial. This means that forestland showed a simpler shape than the farmland, and the shape got even simpler over the 20 years. All of the CLUMPY, PLADJ, and CONTIG values show that the forestland had maintained its continuous and connected form for 20 years, even better than the farmland. Similar to farmland, there was drastic decrease in the LPI indicating that the largest patch area of forestland decreased significantly.

In the case of both farmland and forestland, no major fragmentation was found in all three time periods. And both land types remained well-connected and became simpler in forms. Considering that there were large decreases in the number of cells representing both land cover types, it seems that both the forestland and farmland were converted near existing urban areas, and perhaps on the edge of the existing urban areas.

Pastureland & Wetlands

Pastureland shows the highest LSI value among the five land cover types, but shows a low edge density. This means that the pastureland shows irregular form owing to small and simple patches of pastureland scattered around the region. Although the patches of pastureland are scattered, the CLUMPY and PLADJ values show that they are still fairly aggregated. Pastureland also shows the lowest degree of connectedness as it can be seen from the CONTIG value. All the CLUMPY, PLADJ, and CONTIG values increased between 1990 and 2010 meaning that the land became more aggregated. Wetlands show the lowest LSI and ED values among the comparison groups, while wetlands had high CLUMPY, PLADJ, and CONTIG values. The reason for these results is that the region has the lowest amount of wetlands relative to other land types because they are only found in lands adjacent to water bodies. In the case of both pastureland and wetlands, not much fragmentation could be found. The concerning matter about these two land cover types is that the SMA has lost a considerable portion of pastureland and wetlands to development.

3.4. Summary of the Land Cover Analysis

Although it is hard to isolate the effect of greenbelt relaxation on land consumption, the land cover analysis showed that a large amount of farmland, forestland, and pastureland has been converted to urban areas, thus supporting Hypothesis 1. The land classification based on the nationwide environmental assessment seems to have been ineffective for protecting the prime environmental areas (Class 1 and 2) from development. The analysis revealed that the South Korean government simply reclassified the environmental areas to developed areas, thus failing to preserve important natural areas.

Table 3-11. Summary of the Modeling Results

	Hypotheses	Result
1	Greenbelt relaxation has urbanized more farmland, forestland, and pastureland that used to be strongly protected under the original greenbelt policy	Supported
2	Greenbelt relaxation has made the urban landscape more continuous since the relaxation happened in areas near the existing urban areas filling in the gaps.	Supported

The land fragmentation analysis results supported Hypothesis 2. It appears that most of the new urban development took place where the gaps used to exist, perhaps caused by the greenbelts restricting the developments. The urban areas became more continuous and connected after the greenbelt relaxation occurred. Not much fragmentation occurred in both the urban and natural landscapes.

CHAPTER 4. MODELING ANALYSIS II – STATISTICAL ANALYSIS

4.1. Hypotheses

Several Difference-in-Differences regression models were constructed to test hypotheses 3, 4, 5, and 6, representing the four evaluation criteria – "Physical Containment", "Housing Affordability", "Community Service Provision Costs", and "Commuting Costs". Hypothesis 3 is: **"Greenbelt relaxation promoted new developments inside the greenbelt rather than the outside"**. As noted in the literature review, some scholars have argued that the rigidness of the previous greenbelt policy has resulted in leapfrogging developments (Kim and Kim 2012; South Korea Ministry of Land, Transport and Maritime Affairs 2011; Bae, Jun, and Richardson 2011). As the greenbelt relaxation occurred near existing urban areas, especially near Seoul, it may be possible that the relaxation has guided new developments to areas inside the greenbelt rather than the outside.

Hypothesis 4 on the housing affordability criterion is: **"Greenbelt relaxation has eased the development pressure near Seoul; therefore, slowing down the rate of increase in land and property values"**. One of the arguments against the greenbelt policy is that it constrained land supply in the SMA, thus increasing land prices and housing prices (South Korea Ministry of Land, Transport and Maritime Affairs 2011). If this argument is true, increasing the land supply through the greenbelt relaxation should have produced lower the land and housing prices in the region.

Hypothesis 5 on the community service provision criterion is: **"The greenbelt relaxation has guided new developments to areas inside the greenbelt, therefore, intensifying**

the fiscal impacts associated with the community service provisions at a greater degree inside than the outside the greenbelt after the relaxation". New developments usually bring additional fiscal costs resulting from providing new community services. If we see more developments taking place inside the greenbelt rather than the outside after the relaxation, the fiscal impacts would be greater inside than the outside. In such case, we can determine that the policy change has contributed to guiding new developments to areas inside the greenbelt, thus preventing further leapfrogging development. On the contrary, more infrastructure being added to the areas outside than the inside the greenbelt may indicate continuous sprawling development which may financially burden local governments located outside the greenbelt.

The last hypothesis related to the commuting costs criterion is: **"Greenbelt relaxation and the new housing developments that followed have provided homes closer to the jobs in Seoul; therefore, mitigating the jobs-housing mismatch and lowering the transportation/commuting costs"**. Several studies have revealed that the original greenbelt policy increased the overall commuting costs in the SMA region (Jun and Bae 2000; Jun and Hur 2001). One of the expected outcomes of the greenbelt relaxation is mitigating the jobs-housing mismatch by providing homes closer to Seoul where major job centers are located. Testing this hypothesis allows us to determine whether the relaxation is justifiable on the ground of mitigating overall transportation costs.

4.2. Methodology

As illustrated in the figure below, Difference-in-Differences regression models were run using the group classification variable as the main predictor variable, and various outcome variables representing the four criteria to test the four hypotheses. The following part will describe the dependent variables and the expected outcomes, and the independent variables which account for the temporal and spatial effects of the greenbelt policy.

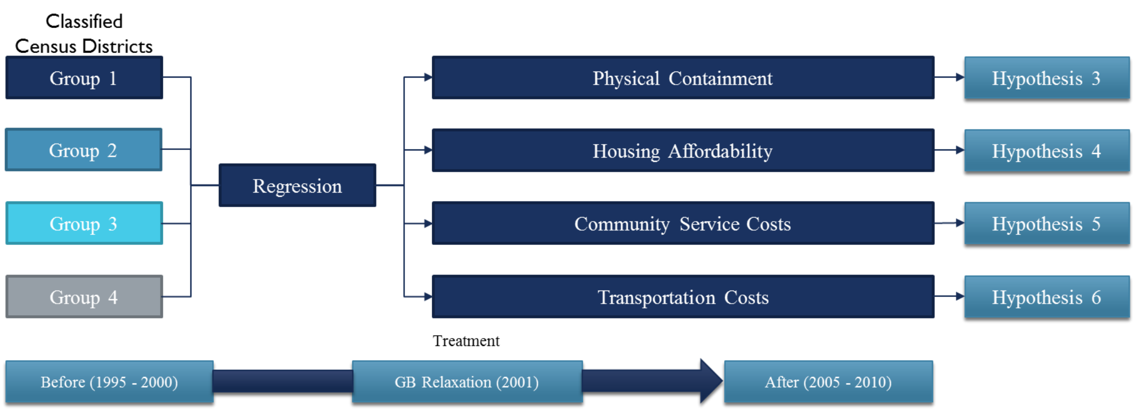


Figure 4-1. Conceptual Model for Statistical Analysis

1. Dependent Variables

For each of the four criteria, several outcome (dependent) variables were selected to test the four hypotheses. Because the South Korean government gradually released the greenbelt lands in the early 2000s, it makes sense to compare the changes of the dependent variables between the periods before and after the relaxation. Percent changes were calculated for selected outcome variables between 1995 and 2000 to represent the "before effect" and between 2005 and 2010 to represent the "after effect".

Physical Containment Criterion (Hypothesis 3)

Two outcome variables were used for the "Physical Containment Criterion" to test Hypothesis 3. The land fragmentation analysis can give us a general idea of how the greenbelt policy has affected the land use pattern. But it does not explain how the development pattern varies among the census districts that are affected differently by the greenbelt policy. Therefore, we included percent changes of urbanized areas and population density to analyze how these two outcomes were affected by the greenbelt relaxation.

Changes in the urban areas were calculated from the land cover datasets. Because we have the land cover datasets for 1990, 2000, and 2010, we first used Raster Calculator in the ArcGIS function to calculate the changes of urban areas between 1990 and 2000 for the "before effect", and between 2000 and 2010 for the "after effect" and joined them to each of the 66 census districts. After the joining process, we divided the urban change by the previous year's total urban areas to calculate the percent change in urban areas.

Another major variable that is commonly used in urban sprawl studies is population density. Several scholars such as Fulton et al. (2001) and Lopez and Haynes (2003) used population density as one of the primary proxies for measuring sprawl. Fulton el al. (2001) specifically calculated the population density by dividing the population of studied cities in the US by the actual urbanized areas represented in the land cover datasets (Fulton et al. 2001; Lopez and Hynes 2003). More specific to our study area, Eom and Woo (2015) used a sprawl index based on population density to measure urban sprawl in the SMA (Eom and Woo 2015).

Similar to these previous studies, the second modeling analysis uses population densities change as the dependent variable in the regression analysis. The population density for 1990, 2000, and 2010 were first calculated by dividing the populations by the actual urbanized areas of each year. The 1990 population data required additional processing because the geographic boundaries of some census districts were different from year 2000 and 2010. The 1990 census districts that were different from other two years were identified by spatially joining the 1990 administrative boundary shapefile to the standardized 2000 and 2010 boundary shapefiles. Then the 1990 population in census districts that were found to be inconsistent with the standardized census districts were redistributed to match the other years. Population data for smaller geographic units, “Eub”, “Myeon”, and “Dong”, were manually redistributed to the standardized census districts after checking the incorporation and annexation status of each municipality. Using the Zonal Statistics as Table function in ArcGIS, the number of cells representing each year’s urban areas were calculated for each of the 66 census districts. Then the calculated urban areas were joined to the population data using the census district name as the unique identifier. After the joining process, numeric and percent changes of the population density were calculated for periods between 1990 and 2000 and between 2000 and 2010. This way we can compare how the population densities in each census district have changed over time accounting for the effects of the greenbelt relaxation.

Housing Affordability Criterion (Hypothesis 4)

Criticism against urban containment policies such as the greenbelt and Urban Growth Boundaries have centered around housing unaffordability (Montgomery 2011). Theoretically, urban containment policies may constrain the number of developable land parcels resulting in reduced quantity of new housing units; hence raising the price of new housing relative to existing housing. In situations where the housing demand is inelastic, the effects of constrained housing supply on the housing price would be even more substantial. If the housing demand is elastic meaning that people can afford housing in different markets or neighboring communities, the price impact of a housing shortage would be minimal (Dawkins and Nelson 2002). By analyzing how the land and property values have changed along with the changes made to the SMA greenbelt policy, we can test Hypothesis 4.

There are several studies that analyzed the effects of the conventional rigid greenbelt on the regional housing market in the SMA. Lee and Linneman (1998) found that there were no significant differences in the land markets or marginal value of accessibility between the land markets inside and outside the greenbelt in 1989. However, they estimated that the future growth of the city would likely result in increasing housing costs, diminishing green spaces, and intensifying traffic congestion (C.-M. Lee and Linneman 1998). During the *1992 Public Forum on Improving Greenbelt Policy*, urban economist, Dr. Kyung-Hwan Kim stated that the conventional greenbelt policy had restricted the land supply for development, thereby increasing land and housing prices. The Greenbelt Reform Council added that the greenbelt directed new developments to areas beyond the greenbelt where lands were relatively cheaper which in turn increased commuting costs (South Korea Ministry of Land, Transport and Maritime Affairs 2011). Although the early discussions on the rigid greenbelt policy have addressed the greenbelt's impacts on land and housing prices, there are few recent studies that followed up on the relationship between the housing price and the greenbelt policy. Moreover, currently there are no studies that have analyzed how the greenbelt relaxation has affected the housing and land markets.

To fill this gap, we used "land price index (LPI)" and "local property tax" as the dependent variable for analyzing the effects of greenbelt relaxation on the housing affordability. Unfortunately, the actual property assessment data was not available for the entire study area and study period. The Korea Appraisal Board did not start collecting property assessment data for the entire census districts until 2006. Prior to 2006, the South Korean government only sampled certain census districts. Because the percentage change in the LPI and the local property tax data covered all time periods and study areas, they were chosen as dependent variables to test the effects of greenbelt relaxation on housing affordability. The LPI is calculated based on the Laspeyres Price Index method. The land prices for years 1995, 2000, 2005, and 2010 were all weighted by the land price in 2014 (Korea Appraisal Board 2015). To compare the "before effect" and the "after effect" of greenbelt relaxation, percent change in the LPI was calculated. Considering that the LPI represents the relative price of lands, it made sense to use the degree of price changes rather than the absolute changes. Because the LPI does not account for other factors that might affect the housing price such as construction costs, we also used local property tax data to run additional regression analyses.

Community Service Provision Cost Criterion (Hypothesis 5)

One of the major arguments regarding the cost of sprawl is the increase in fiscal costs resulting from constructing extensive infrastructure such as roads, sewers, and waterlines, and providing additional public services such as schools, police, and fire stations. Several scholars have argued that urban/suburban sprawl wastes natural and human resources compared to compact development form (Daniels 2010; R. Burchell et al. 1998; Newman and Jennings 2008). Carruthers and Ulfarsson (2003) also confirmed these arguments in their study and stated the importance of justifying growth management programs from the standpoint of public finance (Carruthers and Ulfarsson 2003).

This part of the modeling analysis uses the community service provision cost as the indicator to test the fifth hypothesis. Theoretically, if the greenbelt has contributed to densifying the urban core and discouraging sprawling development, the fiscal costs for providing community services in areas with a greenbelt should be lower than those areas without one. However, some studies have argued that the conventional rigid greenbelt has caused leapfrog development outside the greenbelt along with the New Towns and satellite cities developments, increasing community service provision costs (South Korea Ministry of Land, Transport and Maritime Affairs 2011). If this argument holds true, the greenbelt relaxation should have guided more developments to areas inside the greenbelt areas rather than outside which can be examined by temporal and spatial changes in the community service provisions. Depending on the outcome of the modeling analysis, we can determine whether the greenbelt relaxation has burdened the region in providing community service provisions compared to the pre-relaxation period.

A number of variables were chosen as the dependent variables for testing the fifth hypothesis. First, we calculated the percent change of the local public utility tax for the 66 census districts. The public utility tax is a local tax budgeted for sewer service, waste management, water service, and other public facilities. It is imposed on property owners who benefit from the community service provisions. Although the collected local taxes go to local governments, the tax rate is set by the central government usually at a fixed rate across the country (South Korea National Tax Services 1982). We also used percent changes in the total amount of collected local tax, and total amount of local tax expenditure that represent the fiscal impacts associated with providing community services. Percent changes in total road length was also included to examine the effects of greenbelt relaxation on the physical infrastructure. We assumed that the change in the road length was an indication of new developments being connected to the existing road network.

Commuting Costs Criterion (Hypothesis 6)

Ingram and Hong (2009) used mode choice and traffic congestion as performance indicators for evaluating smart growth policies (Ingram and Hong 2009). Jun and Bae (2000) used commuting costs as an indicator for assessing the impacts of the greenbelt in the SMA (Jun and Bae 2000). And as noted in the previous section, increasing commuting costs was one of the major justifications for the South Korean government to release and develop greenbelt lands (South Korea Ministry of Land, Transport and Maritime Affairs 2011).

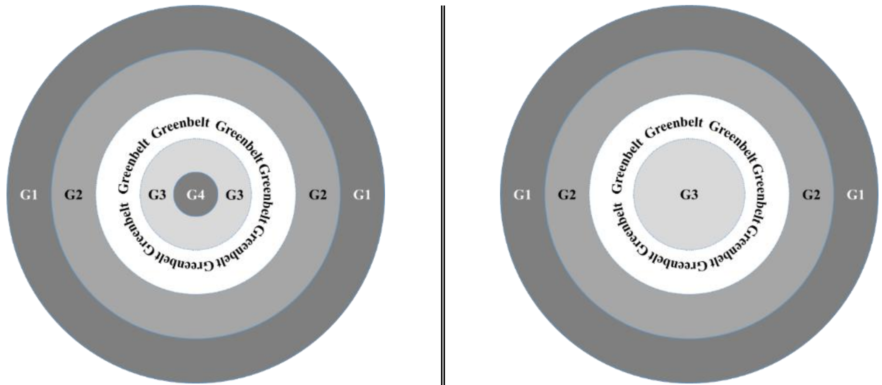
Building on these previous studies, this part of the modeling analysis examines how the greenbelt relaxation has affected transportation/commuting costs. First, we used the origin-destination commuting survey dataset to analyze how the commuting pattern has changed between the times before and after the greenbelt relaxation. The variables selected from the dataset include population commuting within the census districts of their residency and population commuting to other census districts. These variables were chosen because they could be a good indicator for analyzing the jobs-housing mismatch that could have been caused or exacerbated by the greenbelt policy. Similar to the other dependent variables, both numeric and percent changes were calculated for both variables to compare the before and after effects of the greenbelt relaxation.

Other key dependent variable was the commuting time data. Commuting time survey datasets covering all 66 census districts were available for years 1995 and 2010 which fortunately cover the times before and after the greenbelt relaxation. Because the datasets were available for only two years, we could not calculate the numeric and percent changes. Instead, we calculated the percentages of population spending less or more than 60 minutes on commuting and used them as the outcome variables for the regression analysis.

Unfortunately, other transportation data such as commuting mode share were only available at a larger geographic scale (Seoul, Incheon, and Gyeonggi) making it impossible to use them in the regression analysis. These statistics were used instead to further the discussion on the commuting cost associated with the development pattern.

2. Key Predictor (Independent) Variables

To analyze how the dependent variables are affected by the locational factors and by the greenbelt policy, all of the 66 census districts were classified into 4 groups (or 3 groups) depending on their proximity to the greenbelt and locations. The census districts located solely within the greenbelt boundary were classified as Group 4, which was later used as the base case for group comparison. Census districts located within the boundary and encompassing the greenbelt areas on the urban fringe area of Seoul were classified as Group 3. Both census districts in Group 3 and 4 are the ones in Seoul Metro City. Census districts located outside the greenbelt boundary and partially encompassing the greenbelt were classified as Group 2. Lastly, the census districts that are located on the edge of the metropolitan area and not overlapping with the greenbelt were classified as Group 1. Census districts of Group 1 and 2 are located in Incheon Metro City and Gyeonggi Province. Three binary variables were created to represent the 3 groups (Group 1 = X_1; Group 2 = X_2; Group 3 = X_3) which were compared to the base case, Group 4 coded as 0 and 0. For the three group classification, two binary variables were created with Group 3 being the base case. The group classification used in this analysis module is illustrated in the figure below. For the sake of clarity, Group 1 will be referred to as the Metro Edge Group, Group 2 as the Outer Rim Group, Group 3 as the Inner-Rim Group, and Group 4 as the Urban Core Group. For three group classification, Group 1 is the Metro Edge Group, Group 2 is the Outer Rim Group, and Group 3 is the Urban Core Group.



4 Group Classification

Classification	X_1	X_2	X_3
Group 1 (G1) Metro Edge Group	1	0	0
Group 2 (G2) Outer Rim Group	0	1	0
Group 3 (G3) Inner Rim Group	0	0	1
Group 4 (G4) Urban Core Group	0	0	0

*G4 is the base case

3 Group Classification

Classification	X_1	X_2
Group 1 (G1) Metro Edge Group	1	0
Group 2 (G2) Outer Rim Group	0	1
Group 3 (G3) Inside Group	0	0
-		

*G3 is the base case

Figure 4-2. Group Classification

As described in the dependent variable section, the percent changes of variables between 1995 and 2000 were calculated to represent the "before effect" and the same calculations were made for period between 2005 and 2010 to represent the "after effect". These calculations were applied to one continuous predictor variable – percent change in population (POPCHG%). A binary variable was created to differentiate the "before" and "after" – "after effect" being 1 (RELAXATION). In addition to the variable indicating the temporal changes, we also included a binary variable indicating the census districts where the actual greenbelt relaxation took place. This is to examine whether the greenbelt relaxation had regional or local effects. A binary variable indicating census tracts where New Towns were built in the 1990s and 2000s was added to control for the effects of New Town developments on the selected outcome variables (NEW_TOWN). Interaction terms between the RELAXATION dummy variable and the group classification variables were introduced to analyze the Difference-in-Differences.

$$Y = \beta_0 + \beta_1 RELAXATION + \beta_2 GROUP1 + \beta_3 GROUP2 + \beta_4 GROUP3 + \beta_5\, RELAXATION * GROUP1 + \beta_6\, RELAXATION * GROUP2 + \beta_7\, RELAXATION * GROUP3 + \beta_8 GB\_RELAXED\_CD + \beta_9\, POPCHG\% + \beta_{10} NEW\_TOWN + \varepsilon \quad (1)$$

The key predictors listed above and the interaction terms between the group variables and the relaxation variable summed up 11 variables. As shown in the equation above, all of these independent variables together with the dependent variables form Difference-in-Differences regression models that are used to analyze the temporal difference in spatial differences. In other words, we can determine the effectiveness of the policy by comparing the before and after effects, as well as examine how the effectiveness differs by groups representing census districts that are differently affected by the greenbelt policy. A series of statistical diagnostics were run to check for statistical errors such as multicollinearity and heteroscedasticity.

4.2. Statistical Analysis Results

A Difference-in-Differences study design was employed to analyze the policy effects of greenbelt relaxation on various urban sprawl criteria. This particular model allows us to analyze the temporal difference in spatial differences. In other words, we can determine the effectiveness of the policy by comparing the before and after effects, as well as examine how the effectiveness differs by groups representing census districts that are differently affected by the greenbelt policy. A total of 13 dependent variables were selected to test the four hypotheses in the four evaluation criteria. These variables were chosen based on availability of the data, quality of the data, and most importantly the relationship of the variables with the hypotheses. A total of seven common independent variables were used in all of the 13 regression models to test Hypotheses 3, 4, 5, and 6. Descriptive statistics of both dependent and independent variables are summarized in Table 4-1 below.

Table 4-1. Descriptive Statistics of the Variables used in the Models

Variables	Mean	SD	Min.	Max.	N
Continuous Variable					
% Change in Urban Areas	0.82	1.02	0.01	5.49	132
% Change in Population Density	0.11	1.05	-0.90	7.03	132
% Change in Land Price Index	0.02	0.13	-0.15	0.3	112
% Change in Property Tax	0.17	0.85	-1.00	2.77	132
% Change in Collected Local Tax	0.09	0.67	-1.00	1.46	132
% Change in Collected Local Tax for Public Utility	0.07	0.18	-0.27	1.28	132
% Change in Local Tax Expenditure	0.44	0.51	-1.00	1.79	132
% Change in Total Road Length	0.11	0.24	-0.42	1.19	112
% Change in Population Commuting within the CD of their Residency	0.25	0.24	-0.12	1.61	110
% Change in Population Commuting to other CDs	0.09	0.43	-0.58	3.89	110
% of Population Spending less than 30 mins on Commuting	0.50	0.13	0.34	0.93	132
% of Population Spending more than 60 mins on Commuting	0.20	0.07	0.01	0.33	132
% of Population Spending more than 90 mins on Commuting	0.07	0.02	0.00	0.13	132
% Change of Total Population	0.07	0.18	-0.27	1.28	132
Binary Variable					
Greenbelt Relaxation Dummy (RELAXATION)	0.500	0.502	0	1	66
CDs outside the GB not intersecting with the GB (GROUP 1)	0.227	0.421	0	1	30
CDs outside the GB intersecting with the GB (GROUP 2)	0.394	0.490	0	1	52
CDs inside the GB intersecting with the GB (GROUP 3)	0.273	0.447	0	1	36
CDs inside the GB not intersecting with the GB (GROUP 4 (Baseline))	0.106	-	0	0	14
Location of Census Districts where GBs were Released (GB_RELAXED_CD)	0.152	0.360	0	1	20
Location of New Towns (NEW_TOWN)	0.227	0.421	0	1	30

1. Physical Containment Criterion (Hypothesis 3)

Two dependent variables were used in the Difference-in-Differences regression analysis to test the third hypothesis – “Greenbelt relaxation promoted new developments inside the greenbelt rather than the outside”. The first dependent variable is the percentage change in urban areas calculated using the land cover dataset. The second dependent variable is the percentage change in the population density. The population density was calculated by dividing each year’s population by the actual urbanized areas represented in the land cover dataset. The population density variable is chosen as the dependent variable because one of the general growth containment effects is the densification of urban areas. Theoretically, if the greenbelt relaxation promoted new developments inside the greenbelt, the change in the population density of the inner areas should be higher than that of the outer areas. The regression analysis and Chi-square test results using the two variables are summarized in Table 4-2 and 4-3 below.

Table 4-2. Physical Containment Criterion Regression Results[5]

Y		%Change in Urban Areas			Change in Population Density (persons / km^2)		
Variables		**Coef.**	**Std. err**	***p*-value**	**Coef.**	**Std. err**	***p*-value**
(Intercept)	β_0	0.234	0.316	0.462	-1,987.45	3,804.34	0.602
RELAXATION	β_1	-0.008	0.445	0.987	-1,745.51	5,386.57	0.746
GROUP 1	β_2	0.996*	0.386	0.011	-3,250.01	4,623.63	0.483
GROUP 2	β_3	0.971*	0.390	0.014	-5,548.15	4,421.75	0.212
GROUP 3	β_4	0.034	0.372	0.928	-4,816.45	4,493.57	0.286
RELAXATION * GROUP 1	β_5	-0.448	0.539	0.408	5,726.63	6,622.14	0.389
RELAXATION * GROUP 2	β_6	-0.494	0.532	0.356	6,230.09	6,327.65	0.327
RELAXATION * GROUP 3	β_7	0.606	0.528	0.253	6,985.33	6,396.15	0.277
GB_RELAXED_CD	β_8	-0.416	0.271	0.128	-1,262.58	3,192.94	0.693
POPCHG%	β_9	2.360***	0.491	0.000	0.030***	0.00	0.000
NEW_TOWN	β_{10}	-0.234	0.196	0.234	2,699.86	2,375.60	0.258
N			132			132	
R-Squared			0.335			0.299	

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Table 4-3. Physical Containment Criterion Chi-Square Test Results

Groups	Hypothesis	%Change in Urban Areas			Change in Population Density (persons / km^2)		
		Chi-square	**DF**	***p*-value**	**Chi-Square**	**DF**	***p*-value**
Significance of Greenbelt Relaxation for Each Group							
GROUP 1	$H_0: \beta_1 + \beta_5 = 0$	2.237	1	0.135	1.105	1	0.293
GROUP 2	$H_0: \beta_1 + \beta_6 = 0$	3.004	1	0.083	1.745	1	0.187
GROUP 3	$H_0: \beta_1 + \beta_7 = 0$	4.454*	1	0.035	2.330	1	0.127
GROUP 4	$H_0: \beta_1 = 0$	0.000	1	0.987	0.105	1	0.746
Group Comparison of the Greenbelt Relaxation Effects							
GROUP 1 vs GROUP 2	$H_0: \beta_5 - \beta_6 = 0$	0.012	1	0.914	0.009	1	0.924
GROUP 1 vs GROUP 3	$H_0: \beta_5 - \beta_7 = 0$	6.409*	1	0.011	0.062	1	0.804
GROUP 1 vs GROUP 4	$H_0: \beta_5 = 0$	0.689	1	0.406	0.748	1	0.387
GROUP 2 vs GROUP 3	$H_0: \beta_6 - \beta_7 = 0$	8.255**	1	0.004	0.027	1	0.870
GROUP 2 vs GROUP 4	$H_0: \beta_6 = 0$	0.859	1	0.354	0.969	1	0.325
GROUP 3 vs GROUP 4	$H_0: \beta_7 = 0$	1.318	1	0.251	1.193	1	0.275

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

[5] Variance Inflation Factor (VIF) tests were conducted to prevent multicollinearity problem. Any independent variable that had VIF value greater than 10 was eliminated from the model. VIF test were performed for every model presented in this chapter.

As shown in Table 4-2, the model using the percentage change in urban areas (log-transformed) showed R-squared value of 0.335 meaning that about 33.5% of variation in the observations can be explained by this model. The second model using the percentage change in population density explained about 29.9% of variation in the observations. The Difference-in-Differences modeling framework was specifically designed to analyze whether the greenbelt relaxation has significant effects on a dependent variable in each of the four groups and compare the significance of the policy intervention among them. The Chi-Square test results summarized in Table 4-3 tested the hypotheses that allowed us to examine the significance of the differences. For example, the significance of the greenbelt relaxation on Group 1 (Metro Edge) can be analyzed by testing the null hypothesis "coefficient $\beta_1 + \beta_5 = 0$". Note that this hypothesis was derived from the regression formula after substituting *X*s with the binary numbers representing the conditions of each group.

The Chi-Square test revealed that the greenbelt relaxation only showed significant association with the percent change of urban areas in Group 3 (Inner Rim of Greenbelt). The coefficient β_7 had a value of 0.606 which means that the percent change in urban areas in Group 3 increased relative to the baseline, Group 4 (Urban Core). In other words, the greenbelt relaxation only caused significant effect on percent change in urban areas in Group 3 compared to Group 4. This implies that the urbanization in the census districts in Group 3, the ones inside the greenbelt overlapping with the greenbelt perimeter, was found to be accelerating after the greenbelt relaxation. Considering that the new greenbelt developments have taken place inside the greenbelt rather than the outside, the model seemed to have correctly estimated the current development pattern. Group 1 and Group 2 variables controlling for the effects of the relaxation showed statistical significance at the 0.05 level. This means that urbanization in Group 1 (Metro Edge) and 2 (Outer Rim of Greenbelt) happened regardless of the greenbelt relaxation. Another independent variable that was included to control for the effects from population change was found to have significant association with the dependent variable. With all other factors being equal, the percentage change in total population was significantly related to the percentage change in urban areas at the 0.001 level.

When the effects of greenbelt relaxation were compared by groups, we found that the policy intervention had significantly different effects on each group. When Group 1 and Group 3 were compared, the policy intervention was found to have greater effects on Group 3 than Group 1 at the 0.05 level ($\beta_5 - \beta_7 < 0$). When Group 2 (Outer Rim) and Group 3 (Inner Rim) were compared, the greenbelt relaxation had greater effects on Group 3 than Group 2 at the 0.01 significance level ($\beta_6 - \beta_7 < 0$). Other group comparisons did not yield significant results. These group comparisons indicate that in regards to percentage change in urbanization, the greenbelt relaxation had the most effect on Group 3, the census districts encompassing the inner side of the SMA greenbelt. From the both sets of Chi-Square testing, we can verify that the greenbelt relaxation effects on urbanization was substantial in Group 3 (Inner Rim) where new developments have been planned and implemented and the impacts of the policy intervention was the higher than Group 1 – the edge of the SMA, and Group 2 – the outer-rim of the SMA greenbelt.

In regards to the change in population density, the greenbelt relaxation did not have any effect on the population density in all groups. None of the Chi-square tests yielded statistically significant results. The only independent variable that showed a significant relationship with the dependent variable was the percent change in total population. The greenbelt relaxation did not affect the population density distribution in the SMA region.

In sum, the findings make it possible to accept Hypothesis 3 since the relaxation policy alone guided new developments to Group 3 (Inner Rim) with greater impacts compared to the other groups. However, it is important to note that significant percent change in urbanization could be found in Group 1(Metro Edge) and 2 (Outer Rim) without the effects of the relaxation indicating the sign of sprawl. Meanwhile, no significant relationship between the population density and the relaxation policy could be found. Despite the interesting findings, this model only explains just under half of the variance in the observations. This limitation might have to do with the small sample size – perhaps increasing the number of observations could have resulted in a different outcome.

Table 4-4. Inverse Marginal Density

Category	Inverse Marginal Density 1990-2000 (A)	Inverse Marginal Density 2000 – 2010 (B)	Differences (A-B)
Group 1 (Metro Edge)	0.141	-0.055	-0.196
Group 2 (Outer-Rim)	1.200	0.062	-1.138
Group 3 (Inner-Rime)	0.037	-1.812	-1.849
Group 4 (Urban Core)	0.150	0.020	-0.130
New Towns	-0.664	0.059	0.724

When we ran the regression model using the inverse marginal density – the change in land cover divided by the change in population, we got the same insignificant result as the one using the regular population density. When the overall changes in the inverse marginal density by the four groups were examined, however, we discovered some interesting findings. As shown in Table 4-4, the overall changes in the inverse marginal density were found to be negative in all four groups when the densities before and after the relaxation were compared. Interestingly, the aggregated change in the density of the New Town was found to be positive . This means that the New Towns sprawled after the greenbelt relaxation prior to reaching their appropriate densities.

2. Housing Affordability Criterion (Hypothesis 4)

Percent change in land price index (LPI) and local property tax were used to test the fourth hypothesis – "Greenbelt relaxation has eased the development pressure near Seoul; therefore, slowing down the rate of increase in land prices and property values". The LPI is an index of historic land prices standardized for the 2014 land value (2014 value being 100). This means that no locational comparison can be made using the absolute values of the data. In this regard, the percentage change of the LPI was used as the dependent variable so that we can compare the degree of changes. Since the LPI was the only available historic data related to housing value, it was assumed that the housing value was directly associated with the land price. It is also important to note that this regression model does not account for other factors that might affect housing prices such as construction costs. Therefore, property tax data was used to run an additional regression analysis.

The Difference-in-Differences regression model using percentage change in LPI yielded an R-squared value of 0.930 meaning that 93% of the variation in observations could be explained by the model. As shown in the Chi-Square test result table, the greenbelt relaxation was found to have significant effects on the percent change in LPI for each of the four groups at the 0.001 level. The coefficients β_5, β_6, and β_7 representing the relaxation effects on Group 1 (Metro Edge), 2 (Outer Rim), and 3 (Inner Rim) were all negative meaning that the percent change in LPI decreased in these groups compared to Group 4 (Urban Core). In other words, the greenbelt relaxations in fact decreased the percent change in the LPI in all three groups compared to the urban core where the percent change in the LPI was found to have increased after the relaxation. This indicates that the relaxation has contributed to easing some level of development pressure in the region relative to the urban core.

Table 4-5. Housing Affordability Criterion Regression Results

Y		%Change in Land Price Index			%Change in Property Tax		
Variables		Coef.	Std. err	*p*-value	Coef.	Std. err	*p*-value
(Intercept)	β_0	-0.130***	0.013	0.000	0.420·	0.237	0.079
RELAXATION	β_1	0.332***	0.019	0.000	-0.445	0.334	0.185
GROUP 1	β_2	0.057**	0.018	0.001	0.259	0.290	0.372
GROUP 2	β_3	0.037*	0.017	0.032	0.381	0.292	0.195
GROUP 3	β_4	0.000	0.016	0.984	-0.027	0.279	0.924
RELAXATION * GROUP 1	β_5	-0.129***	0.025	0.000	-0.521	0.404	0.200
RELAXATION * GROUP 2	β_6	-0.120***	0.023	0.000	-0.939*	0.399	0.020
RELAXATION * GROUP 3	β_7	-0.051*	0.022	0.025	-0.084	0.396	0.832
GB_RELAXED_CD	β_8	0.018	0.012	0.143	-0.081	0.203	0.691
POPCHG%	β_9	-0.004	0.024	0.875	1.225**	0.368	0.001
NEW_TOWN	β_{10}	0.005	0.010	0.613	-0.195	0.147	0.188
N			112			132	
R-Squared			0.930			0.460	

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

The subsequent Chi-Square tests comparing the relative impacts of the relaxation on the LPI among the four groups produced some interesting findings. We found that the relaxation had the most significant impacts on the LPI in Group 4 (Urban Core) compared to Group 1 (Metro Edge), Group 2 (Outer Rim), and Group 3 (Inner Rim). The degree of the impacts was followed by Group 3 and Group 2. All of the group comparisons were significant at the 0.001 level except for comparing Group 3 and 4 (0.05 level) and comparing Group 1 and 2 (insignificant).

Table 4-6. Housing Affordability Criterion Chi-Square Test Results

Groups	Hypothesis	%Change in Land Price Index			%Change in Property Tax		
		Chi-square	DF	*p*-value	Chi-Square	DF	*p*-value
Significance of Greenbelt Relaxation in Each Group							
GROUP 1	$H_0: \beta_1 + \beta_5 = 0$	163.150***	1	0.000	17.912***	1	0.000
GROUP 2	$H_0: \beta_1 + \beta_6 = 0$	255.380***	1	0.000	40.746***	1	0.000
GROUP 3	$H_0: \beta_1 + \beta_7 = 0$	541.710***	1	0.000	6.179*	1	0.013
GROUP 4	$H_0: \beta_1 = 0$	308.310***	1	0.000	1.774	1	0.183
Group Comparison of the Greenbelt Relaxation Effects							
GROUP 1 vs GROUP 2	$H_0: \beta_5 - \beta_6 = 0$	0.221	1	0.639	1.732	1	0.188
GROUP 1 vs GROUP 3	$H_0: \beta_5 - \beta_7 = 0$	15.500***	1	0.000	1.963	1	0.161
GROUP 1 vs GROUP 4	$H_0: \beta_5 = 0$	27.572***	1	0.000	1.663	1	0.197
GROUP 2 vs GROUP 3	$H_0: \beta_6 - \beta_7 = 0$	16.268***	1	0.000	8.870**	1	0.003
GROUP 2 vs GROUP 4	$H_0: \beta_6 = 0$	26.616***	1	0.000	5.532*	1	0.019
GROUP 3 vs GROUP 4	$H_0: \beta_7 = 0$	5.154*	1	0.023	0.045	1	0.832

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

The model using the percent change in local property tax as the dependent variable had R-squared value of 0.460 meaning about 46% of the variation in observations could be explained by the regression model. Aside from the group classification and the relaxation variables, the dependent variable was positively related to the percentage change in total population. The Chi-Square test showed that the effects of the greenbelt relaxation on the percent change in property tax are significant in Group 1 and 2 at the 0.001 level and in Group 3 at the 0.05 level compared to the urban core. The policy effect on Group 4 (Urban Core) itself was found to be insignificant. The negative coefficients of the Group variables indicate that the percent change in property tax decreased after the greenbelt relaxation in Group 1 (Metro Edge), 2 (Outer Rim), and 3 (Inner Rim) compared to the baseline. This also confirms that the greenbelt relaxation has contributed to lowering the rate of property tax change. However, it is important to note that the percent change of property tax in the urban core actually increased after the relaxation and the decreasing percent change of other groups are relative to the change of Group 4. The group comparison Chi-square test showed that the greenbelt relaxation had a greater degree of impact on the percentage change in property tax in Group 3 compared to Group 2 at the 0.01 level. When Group 4 and Group 2 were compared, the relaxation had greater effects on Group 4 than Group2 at the 0.05 level. Other group comparison tests yielded insignificant results.

Both modeling analyses using the percent changes in LPI and property tax have confirmed that the greenbelt relaxation has contributed to alleviating the development pressure in the region compared to the urban core area. While we found some indication of drastic LPI increase in the urban core area of Seoul, the greenbelt relaxation did little to effect the changes in the property tax inside the greenbelt. All of these test results support Hypothesis 4. However, it goes without saying that both the land price and the property tax data do not fully represent the housing affordability. Property taxes tend to lay the land market prices, so they are not as accurate as change in real estate value. Due to the lack of data on housing price data, current findings are very limited to examining the effects of greenbelt relaxation on real estate markets represented by land price and local property tax.

3. Community Service Cost Criterion (Hypothesis 5)

One of the key hypotheses is whether the greenbelt relaxation has guided new developments closer to Seoul, especially to inner areas of the city; therefore, intensifying the fiscal impacts associated with the community service provisions at a greater degree inside the greenbelt than the outside after the relaxation. If new developments happened further away from the existing urban areas, it is likely that there would be higher costs for providing infrastructure and higher fiscal burden on local governments. This hypothesis was tested by analyzing the percent changes in the amount collected local tax, local public utility tax, and local tax expenditure, and the percent change in the total road length. If we see more sprawling development, quantified infrastructure change (i.e. road length) and infrastructure costs represented by the tax features would be significantly greater in Group 1 (the edge of SMA) than other groups. If the greenbelt relaxation has guided new developments inside the greenbelt, the changes will be significant for Group 3.

The Difference-in-Differences model using the percentage change in collected local tax had an R-Squared value of 0.622 meaning that 62.2% of the variation in the observations can be explained by the model. From the Chi-Square testing, we found that the greenbelt relaxation caused significant effects on the local tax collection in Group 1 (Metro Edge) and 2 (Outer Rim) at the 0.001 significance level and on Group 3 (Inner Rim) and 4 (Urban Core) at the 0.1 significance level. In both Group 1 and 2, the greenbelt relaxation variable was found to be negatively related to the dependent variable meaning that the relaxation decreased the percent change in local tax collection in Group 1 and 2 compared to Group 4. This means that in Group 1 and 2 – both outside the greenbelt – the total amount of local tax collection somehow decreased after the greenbelt relaxation compared to the urban core.

The group comparison Chi-Square Test shows that the greenbelt relaxation had greater effect on the local tax collection in Group 3 (Inner Rim) compared to Group 1 (Metro

Edge) and 2 (Outer Rim) at the 0.001 level. The effect was greater in Group 4 (Urban Core) compared to 1 and 2 at the 0.01 significance level. This means that although the individual effect of greenbelt relaxation on tax collection was more significant in Group 1 and 2, it had stronger effects inside the greenbelt than the outside. In other words, Seoul City, which consists of census districts in both Group 3 and 4, is more fiscally affected by the relaxation policy than Gyeonggi Province and Incheon City.

Percent change in the local tax allocated for public utilities was also used as the dependent variable to test the fiscal effect of the greenbelt relaxation on the provision of public utilities. Because local governments generally allocate taxes based on capital improvement programs and planning, we assumed that the percent change in local public utility taxes reflects the planned developments in each census district. The regression model had an R-squared value of 0.460 meaning that the model explained 46% of the variation in the observations. The Chi-Square Test showed that the greenbelt relaxation had significant effects on the dependent variable in Group 1 (Metro Edge) and 2 (Outer Rim) at the 0.001 significance level and in Group 3 (Inner Rim) at the 0.05 level. The coefficients suggest that the percent change of the public utility taxes decreased in Group 1, 2, and 3 after the greenbelt relaxation compared to Group 4 (Urban Core). The group comparison Chi-Square test showed that the policy effects were greater in Group 3 and 4 compared to Group 2.

Another variable used for the community service cost criterion was the percent change in local tax expenditures. Because the subcategories for local tax expenditures have changed considerably over time, we could only use the percent change in the total tax expenditures as the dependent variable. The model using this variable explained about 30.5% of the variation in the observations. Although the overall goodness-of-fit was not as good as the other models, the two Chi-Square tests yielded significant results. The first Chi-Square tests showed that the greenbelt relaxation had significant effects on the percent change of local tax expenditures in Group 1 (Metro Edge) and 2 (Outer Rim) at the 0.001 significance level. The negative coefficients tell us that the relaxation decreased the percent changes of tax expenditures in Group 1 and 2 compared to Group 4 (Urban Core). The group comparison Chi-Square test tells us that the relaxation had greater effects on Group 3 (Inner Rim) than Group 1 and 2 at the 0.001 significance level. The relaxation had greater effects on Group 4 than Group 1 at the 0.001 level and greater than Group 2 at the 0.01 level. These findings are consistent with the outcome from the model using the percent change in tax revenue – the census districts in urban core were more fiscally affected by the relaxation than the census districts outside the greenbelt.

Percent change in total road length was also used as one of the dependent variables for measuring community service costs. The R-squared value of 0.41 indicates that this model explained 41% of the variation in the observations. The Chi-Square Tests showed that the relaxation had significant effects on Group 1 (Metro Edge) and 2 (Outer Rim) compared to Group 4 (Urban Core) at the 0.05 level and 0.001 level, respectively. Coefficients for both groups were negative, meaning that the percent change in total road length decreased after the greenbelt relaxation compared to the baseline, Group 4. Relatively speaking, the changes in the total road length outside the greenbelt did not change as much as inside the urban core. However, when the effect of the greenbelt relaxation is controlled, the percent change in road length is found to be significantly greater in Group 2 at the 0.01 significance level. In other words, the road length increased substantially outside the greenbelt, but most of the increase happened prior to the greenbelt relaxation.

In summary, the greenbelt relaxation decreased the percent changes in all of the tested variables – collected local tax, collected tax allocated for public utility, total tax expenditures, and total road length – in Group 1(Metro Edge) and 2 (Outer Rim) compared to the urban core in Seoul. The group comparison Chi-Square tests showed that the effect of the greenbelt relaxation was greater inside the greenbelt than the outside. Percent change in total road length was found to be significant in Group 2 and the greenbelt relaxation had no effects on the change, meaning that the increase happened prior to the relaxation. More specific to Group 3 (Inner Rim) where new greenbelt developments are happening, the greenbelt relaxation increased the percent change in total local tax at the 0.1 level, but decreased the percent change in the tax allocated for public utilities at the 0.05 level. While we are seeing decreases in both tax collection and expenditure outside the greenbelt as the result of the relaxation, the collected tax in Group 3 seems to have increased due to the post-relaxation developments. All of these results lead to accepting Hypothesis 5 – the greenbelt relaxation guided new developments to Group 3 thereby decreasing the fiscal burdens of the census districts outside the greenbelt.

Table 4-7. Community Service Cost Criterion Regression Results

Y		%Change in Local Tax Collection		%Change in Local Tax Collection for Public Utility		%Change in Local Tax Expenditure		%Change in Total Road Length	
Variables		Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
(Intercept)	β_0	0.715***	0.157	0.420·	0.237	0.386*	0.160	0.062	0.069
RELAXATION	β_1	-0.387·	0.222	-0.445	0.334	0.132	0.225	-0.036	0.098
GROUP 1	β_2	-0.139	0.192	0.259	0.290	0.340·	0.195	0.153	0.093
GROUP 2	β_3	-0.255	0.194	0.381	0.292	0.083	0.197	0.265**	0.090
GROUP 3	β_4	-0.279	0.185	-0.027	0.279	-0.006	0.188	-0.021	0.082
RELAXATION * GROUP 1	β_5	-0.729**	0.268	-0.521	0.404	-0.979***	0.273	-0.166	0.127
RELAXATION * GROUP 2	β_6	-0.750**	0.265	-0.939*	0.399	-0.617*	0.269	-0.288*	0.121
RELAXATION * GROUP 3	β_7	0.154	0.263	-0.084	0.396	0.033	0.267	0.023	0.116
GB_RELAXED_CD	β_8	-0.092	0.135	-0.081	0.203	0.166	0.137	-0.041	0.064
POPCHG%	β_9	0.678**	0.244	1.225**	0.368	0.733**	0.249	0.356**	0.114
NEW_TOWN	β_{10}	-0.186·	0.097	-0.195	0.147	0.157	0.099	-0.034	0.046
N		132		132		132		112	
R-Squared		0.622		0.460		0.305		0.410	

*p < 0.05; **p < 0.01; ***p < 0.001

Table 4-8. Community Service Criterion Chi-Square Test Results

Groups	Hypothesis	%Change in Local Tax Collection			%Change in Local Tax Collection for Public Utility			%Change in Local Tax Expenditure			%Change in Total Road Length		
		Chi-square	DF	*p*-value	Chi-square	DF	*p*-value	Chi-square	DF	*p*-value	Chi-square	DF	*p*-value
Significance of Greenbelt Relaxation in Each Group													
GROUP 1	$H_0: \beta_1 + \beta_5 = 0$	54.240***	1	0.000	17.912***	1	0.000	30.176***	1	0.000	6.121*	1	0.013
GROUP 2	$H_0: \beta_1 + \beta_6 = 0$	10.729***	1	0.000	40.746***	1	0.000	10.980***	1	0.000	20.755***	1	0.000
GROUP 3	$H_0: \beta_1 + \beta_7 = 0$	2.736·	1	0.981	6.179*	1	0.012	1.322	1	0.250	0.046	1	0.830
GROUP 4	$H_0: \beta_1 = 0$	3.050·	1	0.081	1.774	1	0.183	0.344	1	0.557	0.139	1	0.710
Group Comparison of the Greenbelt Relaxation Effects													
GROUP 1 vs GROUP 2	$H_0: \beta_5 - \beta_6 = 0$	0.010	1	0.921	1.732	1	0.188	2.855·	1	0.091	1.276	1	0.259
GROUP 1 vs GROUP 3	$H_0: \beta_5 - \beta_7 = 0$	18.134***	1	0.000	1.963	1	0.161	23.044***	1	0.000	3.371·	1	0.066
GROUP 1 vs GROUP 4	$H_0: \beta_5 = 0$	7.374**	1	0.007	1.663	1	0.197	12.857***	1	0.000	1.694	1	0.193
GROUP 2 vs GROUP 3	$H_0: \beta_6 - \beta_7 = 0$	22.482***	1	0.000	8.870**	1	0.003	11.253***	1	0.000	12.193***	1	0.000
GROUP 2 vs GROUP 4	$H_0: \beta_6 = 0$	8.008**	1	0.005	8.532*	1	0.019	5.245*	1	0.022	5.644*	1	0.018
GROUP 3 vs GROUP 4	$H_0: \beta_7 = 0$	0.341	1	0.559	0.045	1	0.832	0.015	1	0.902	0.039	1	0.843

*p < 0.05; **p < 0.01; ***p < 0.001

Because we did not have detailed information on the actual tax expenditures, we examined descriptive statistics that were available at the larger geographic scale. The following figure shows the total amount of produced clean water in Seoul, Incheon, and Gyeonggi area. Annually produced clean water for Seoul has been decreasing since 1994 while that of Gyeonggi Province increased steadily between 1991 and 2012. Between 1991 and 2000, the amount water in Gyeonggi Province increased by 77.8% from 566,263 m^3 to 1,061,638 m^3 while that of Seoul decreased by 11.5 % from 1,799,190 m^3 to 1,526,721 m^3. This trend continued in the following decade. Between 2001 and 2010, the annually produced clean water of Gyeonggi increased by 18.9 % from 1,122,768 m^3 to 1,335,284 m^3 while that of Seoul decreased by 19.3 % from 1,479,693 m^3 to 1,194,678 m^3. Compared to the drastic changes in the clean water production of Gyeonggi and Seoul, the clean water production in Incheon maintained at a relatively steady level between 1991 and 2012.

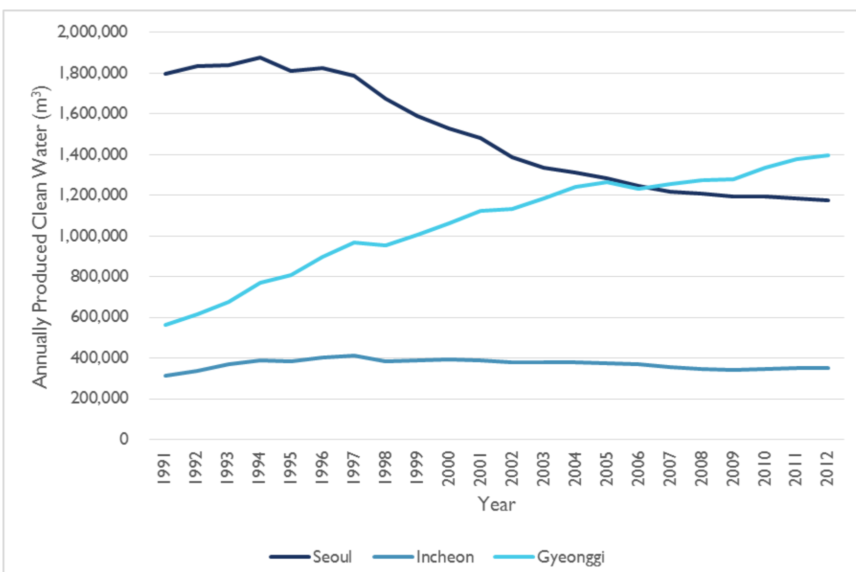


Figure 4-3. Annually Produced Clean Water (1991 - 2012)

The considerable increase in the annually produced clean water in Gyeonggi Province is proportional to the exponential population growth of the province. As noted in Chapter 2, between 1990 and 2000, the population of Gyeonggi province increased by 45.2% from 6.15 million to 8.94 million, while the population of Seoul decreased by 7.1% from 10.6 million to 9.85 million. During the same period the population of Incheon increased by 35.8% from 1.82 million to 2.47 million. The population of Seoul continued to decline in the following decade. It decreased by 2.3% to 9.63 million people in 2010. The continuous decrease in population coincides with the continuous decrease in the clean water production in Seoul. During the same period, the population of Gyeonggi increased by 25.3% reaching 11.2 million in 2010. The population of Incheon increased by 6.7% reaching 2.63 million in 2010. The population and the water statistics indicate that Gyeonggi Province produced more clean water to support the growing population. In order to meet the growing demand, the province might have to increase its expenditures on water infrastructure which could be fiscally burdensome for some municipalities.

This contradicts our findings from the Difference-in-Differences model. However, without knowing the exact breakdown of the tax expenditures including those spent on producing clean water, it is impossible to identify the relationship between the greenbelt relaxation and clean water production. While the challenges such as the one with the clean water production exist, our modeling analysis alone still supports Hypothesis 5.

4. Commuting Costs Criterion (Hypothesis 6)

One of the major criteria for measuring the performance of the greenbelt policy is transportation costs related to commuting. This analysis used point-to-point commuting destination and commuting time data as the dependent variables to measure how the greenbelt relaxation has changed the commuting pattern in the region. We hypothesized that the greenbelt relaxation and the developments that followed have provided housing closer to the major job centers, especially near Seoul; therefore, mitigating the commuting costs resulting from the jobs-housing mismatch. One of the South Korean government's justifications for releasing greenbelt lands and developing them was to achieve this very outcome. This part of the modeling analysis uses two commuting destination variables and three commuting time variables to analyze the effects of greenbelt relaxation on commuting costs. Unlike the previous models, the regression models for the commuting cost criterion use three group classifications instead of four because the geographic boundary of Seoul (inside the greenbelt) is small enough for people to live and commute within the city limits using a variety of transportation modes.

Commuting Destination

The Different-in-Differences regression model using percent change in population commuting within the census districts of their residency had an R-Squared value of 0.594 meaning that about 59.4% of the variation in the observation could be explained by this model. From the Chi-Square Test, we found that the greenbelt relaxation had significant effects on Group 1(Metro Edge) at the 0.05 significance level, on Group 2 (Outer Rim) at the 0.1 significance level, and on Group 3 (Inside) at the 0.001 significance level. The coefficients for Group 1 and 2 were both negative, meaning that the relaxation decreased the percent change of population commuting within their census districts of their residency in Group 1 and 2 compared to Group 3 – inside the greenbelt. The coefficient for Group 3 was positive meaning that the percent change of people commuting to areas of their residency increased inside the greenbelt. In other words, fewer people are commuting to areas where they live indicating the exacerbation of jobs-housing mismatch outside the greenbelt after the relaxation, but more people were found to commuting to areas where they live inside the greenbelt.

The model using the percent change in population commuting to other census districts had a better predictive power than the previous model. The model could explain about 73.3% of the variation in the observations. The Chi-Square Test revealed that the relaxation caused significant effects on Group 1 (Metro Edge) and 2 (Outer Rim) at the 0.01 significance level and on Group 3 (Inside) at the 0.001 level. According to the coefficients, as the result of the greenbelt relaxation, the population commuting to other areas increased in Group1 and slightly decreased in Group 2 compared to the census districts inside the greenbelt. The relaxation was found to increase the percent change in Group 3 after the relaxation. This implies that the greenbelt relaxation intensified the jobs-housing mismatch in Group 1 and 3, but not so much in Group 2.

The modeling analyses using the commuting destination data verified the jobs-housing mismatch in census districts outside the greenbelt especially on the edge of the metropolitan area – Group 1 where the second set of New Towns are being constructed. Both percent changes of population commuting to census districts of their residency and to other census districts were found to significantly increase in Group 3 – inside the greenbelt, Seoul – after the greenbelt relaxation. The increase in the former percent change could have been caused by the new housing developments on the released greenbelt areas in Seoul. In short, the greenbelt relaxation did not contribute to mitigating the jobs-housing mismatch in the region as a whole.

Table 4-9. Commuting Costs Criterion Regression Results

Y		% Change in Population Commuting within CDs of their Residency		% Change in Population Commuting to other Census Districts		% of Population Spending less than 30 Minutes on Commuting		% of Population Spending More than 60 Minutes on Commuting		% of Population Spending More than 90 Minutes on Commuting	
Variables		Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
(Intercept)	β_0	0.126***	0.031	-0.098***	0.024	0.410***	0.017	0.225***	0.011	0.059***	0.004
RELAXATION	β_1	0.195***	0.044	0.153***	0.034	0.004	0.025	0.009	0.015	0.004	0.006
Group 1	β_2	-0.014	0.057	0.072	0.046	0.271***	0.028	-0.117***	0.018	-0.011	0.007
Group 2	β_3	0.057	0.053	0.090*	0.041	0.066*	0.028	-0.006	0.018	0.013·	0.007
RELAXATION * Group 1	β_4	-0.052	0.081	0.011	0.065	-0.013	0.04	-0.004	0.025	-0.001	0.010
RELAXATION * Group 2	β_5	-0.091	0.069	-0.037	0.053	-0.002	0.037	0.013	0.023	0.013	0.009
GB_RELAXED_CD	β_6	-0.023	0.052	-0.023	0.040	-0.007	0.028	-0.001	0.017	-0.001	0.007
POP_PCHG	β_7	1.048***	0.104	1.032***	0.080	0.072	0.050	0.009	0.013	0.004	0.012
NEW_TOWN	β_8	-0.064	0.042	-0.004	0.032	-0.009	0.020	-0.028	0.032	0.003	0.005
N		110		110		132		132		132	
R-Squared		0.594		0.733		0.589		0.463		0.285	

*p < 0.05; **p < 0.01; ***p < 0.001

Table 4-10. Commuting Costs Chi-Square Test Results

Groups	Hypothesis	% Change in Population Commuting within CDs of their Residency			% Change in Population Commuting to other Census Districts			% of Population Spending less than 30 Minutes on Commuting			% of Population Spending More than 60 Minutes on Commuting			% of Population Spending More than 90 Minutes on Commuting		
		X^2	DF	p-value	X^2	DF	p-value	X^2	DF	p-value	X^2	DF	p-value	X^2	DF	p-value
Significance of Greenbelt Relaxation in Each Group																
GROUP 1	$H_0: \beta_1 + \beta_4 = 0$	4.552*	1	0.033	8.924**	1	0.003	0.085	1	0.771	0.061	1	0.805	0.103	1	0.749
GROUP 2	$H_0: \beta_1 + \beta_5 = 0$	3.293·	1	0.070	7.045**	1	0.008	0.003	1	0.956	1.430	1	0.232	5.123**	1	0.024
GROUP 3	$H_0: \beta_1 = 0$	19.717***	1	0.000	20.896***	1	0.000	0.022	1	0.881	0.327	1	0.567	0.379	1	0.538
Group Comparison of the Greenbelt Relaxation Effects																
GROUP 1 vs GROUP 2	$H_0: \beta_4 - \beta_5 = 0$	0.288	1	0.592	0.467	1	0.495	0.061	1	0.805	0.408	1	0.523	1.726	1	0.189
GROUP 1 vs GROUP 3	$H_0: \beta_4 = 0$	0.238	1	0.625	0.030	1	0.863	0.103	1	0.748	0.025	1	0.874	0.016	1	0.898
GROUP 2 vs GROUP 3	$H_0: \beta_5 = 0$	1.727	1	0.188	0.499	1	0.480	0.003	1	0.956	0.337	1	0.562	1.989	1	0.158

*p < 0.05; **p < 0.01; ***p < 0.001

Commuting Time

Commuting time is an important factor that determines commuting costs. From the South Korean census database, we collected two sets of commuting time data for years 1995 and 2010 covering all 66 census districts. The two datasets cover the times before and after the greenbelt relaxation. The datasets contained population statistics categorized by the amount of time people spent on commuting. From the datasets, we computed the percentages of population spending less than 30 minutes on commuting, population spending more than 60 minutes on commuting, and population spending more than 90 minutes on commuting. We tested these four variables for statistical significance. We assumed that people spending more than 60 or 90 minutes on commuting had burdensome commuting costs.

The regression model using the percent of population spending less than 30 minutes on commuting explained about 58.9% of variance in the observations. None of the group variables showed statistical significance in the Chi-Square Test, indicating that the greenbelt relaxation did not cause any measurable effects on the percentage of population spending less than 30 minutes on commuting on the groups. Without the group specific effects, the Group 1 (Metro Edge) showed positive association with the dependent variable at the 0.001 level and Group 2 (Outer Rim) showed the same association at the 0.05 level. This means that regardless of the greenbelt relaxation, more people are spending less than 30 minutes on commuting in Group 1 and 2 compared to Group 3 – inside the greenbelt.

The model using the percentage of population spending more than 60 minutes on commuting could explain about 46.3% of the variance in the observation, but none of the group variables were found to be statistically significant from the Chi-Square Test. The Group 1 variable was found to be negatively associated with the dependent variable at the 0.001 significance level; this means that the percentage of population spending more than 60 minutes on commuting decreased in Group 1 (Metro Edge), regardless of the greenbelt relaxation, compared to Group 3 (Inside). The increase in the percentage of population spending less than 30 minutes and the decrease in the percentage of population spending more than 60 minutes on commuting could be explained by the following three reasons: 1) there are more diversified commuters in Group 1 because of the recent population increase caused by the second New Town developments that also provided jobs nearby, 2) there are many census districts that remain rural where people generally commute within their own census districts, and 3) people living inside the greenbelt in Seoul (Group 3), generally spends more time on commuting than people living outside the greenbelt .

The model using the percentage of population spending more than 90 minutes on commuting could only explain about 28.5% of the variation and none of the variables from the regression model showed statistical significance. Group 2 (Outer Rim) specific effects of the greenbelt relaxation were found to be significant at the 0.01 significance from the Chi-Square test. We found that the greenbelt relaxation slightly increased the percentage of population spending more than 90 minutes on commuting compared to the census districts inside the greenbelt. This seems to capture the effects from the people living in the first New Towns and satellites cities just outside the greenbelt commuting to Seoul. Some level of jobs-housing mismatch and burdensome commuting time were identified from this model. However, this model only explains a little over quarter of the variation in the observations.

Based on the commuting time analysis, we could not find direct causal relationships between the greenbelt relaxation and the percent of population spending different amounts of time on commuting with the exception of the percentage of population spending more than 90 minutes on commuting. However, the percentage of population spending less than 30 minutes on commuting increased outside the greenbelt area and that of population spending more than 60 minutes on commuting decreased on the edge of the SMA. This requires some further investigation to identify what caused shorter commuting time in these areas although the commuting destination data showed significant jobs-housing mismatch in the area.

Commuting Mode Share

Another indicator of the effects of greenbelt relaxation on commuting costs is the commuting mode share. Along with the jobs-housing mismatch that we discovered from the previous analyses, heavy reliance on automobiles can elevate the overall transportation costs spent on commuting. Commuting mode data were available for years 1995, 2000, 2005, and 2010 only at a larger geographic scale of metropolitan city and province. Although it was impossible to run a similar regression analysis using the mode share data, comparing the changes in the mode share statistics yielded some interesting findings.

As summarized in Table 4-10, the population commuting by private automobile in Seoul increased by 0.8% between 1995 and 2000, 1.4% between 2000 and 2005, and 12.6% between 2005 and 2010. The number of commuters by private automobile actually increased at a greater degree in Seoul after the greenbelt relaxation. The number of commuters using private motor vehicles in Gyeonggi Province and Incheon Metro City also increased steadily during the same period, but at diminishing rates. The number of private motor vehicles in Gyeonggi Province covering the areas outside the greenbelt increased by 50.7% between 1995 and 2000, 33.0% between 2000 and 2005, and 22.9% between 2005 and 2010. Although the rates of change might be different, these statistics verified major automobile dependency in the region.

The population commuting using private vehicles continued to increase and the number of public transit users in Seoul and Incheon decreased between 1995 and 2000, and between 2000 and 2005. Seoul's public transit users decreased by 3.5% from 2.39 million to 2.31 million between 1995 and 2000 and then decreased again by 5.3% during the following five years. Incheon's public transit users decreased by 7.5% from 503,242 to 465,484 and then decreased again by 6.7%. All of these decreases in the number of public transit users happened prior to the greenbelt relaxation. Then, the number of public transit commuters increased substantially between 2005 and 2010 in both Seoul and Incheon.

The public transit users in Seoul increased by 7.4% reaching 2.35 million in 2010 and transit users in Incheon increased by 18.5% reaching a record high of 514,759. Interestingly, the public transit users in Gyeonggi, where all the leapfrogging and sprawling developments happened, increased steadily over the years. The public transit users increased from 1.44 million in 1995 to 2.04 million in 2010. The mode share of public transit increased by 23.9% between 2005 and 2010.

Table 4-11. Commuting Population Change by Commuting Mode (1995 – 2010)

Category	Location	1995	% Change (`95 – `00)	2000	% Change (`00 – `05)	2005	% Change (`05 – `10)	2010
Private Motor	Seoul	1,042,580	0.8%	1,050,612	1.4%	1,065,225	12.6%	1,199,554
	Incheon	276,115	44.5%	398,910	11.2%	443,414	19.3%	528,890
	Gyeonggi	954,645	50.7%	1,438,384	33.0%	1,913,017	22.9%	2,351,047
Public Transit	Seoul	2,394,237	-3.5%	2,311,195	-5.3%	2,189,791	7.4%	2,352,398
	Incheon	503,242	-7.5%	465,484	-6.7%	434,295	18.5%	514,759
	Gyeonggi	1,439,867	9.3%	1,574,144	4.4%	1,643,931	23.9%	2,037,006
Walking	Seoul	1,280,624	-9.8%	1,154,794	21.7%	1,405,343	0.3%	1,410,144
	Incheon	220,788	14.4%	252,505	27.6%	322,182	8.7%	350,191
	Gyeonggi	898,904	14.9%	1,032,493	33.9%	1,382,223	5.6%	1,459,408
Others	Seoul	656,962	-0.1%	656,033	-33.1%	438,824	88.9%	829,136
	Incheon	119,120	-14.8%	101,482	-26.2%	74,944	104.4%	153,159
	Gyeonggi	385,689	2.5%	395,224	-20.9%	312,595	123.4%	698,467
Biking	Seoul	31,227	8.9%	33,996	30.4%	44,345	103.9%	90,420
	Incheon	11,267	-3.9%	10,828	-10.1%	9,735	77.5%	17,279
	Gyeonggi	40,442	-11.6%	35,739	4.3%	37,281	91.0%	71,196

Source: Korea Statistics Information System (2015)

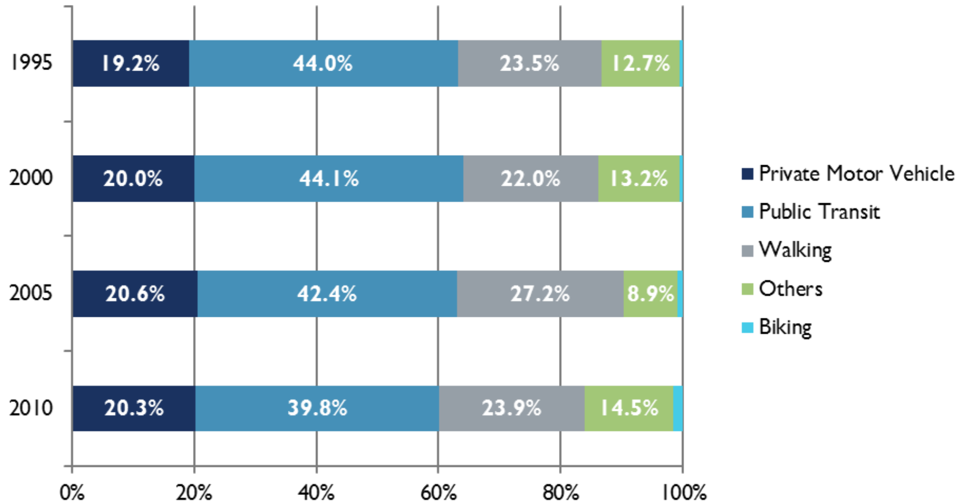


Figure 4-4. Changes in the Commuting Mode Share of Seoul (1995 – 2010)

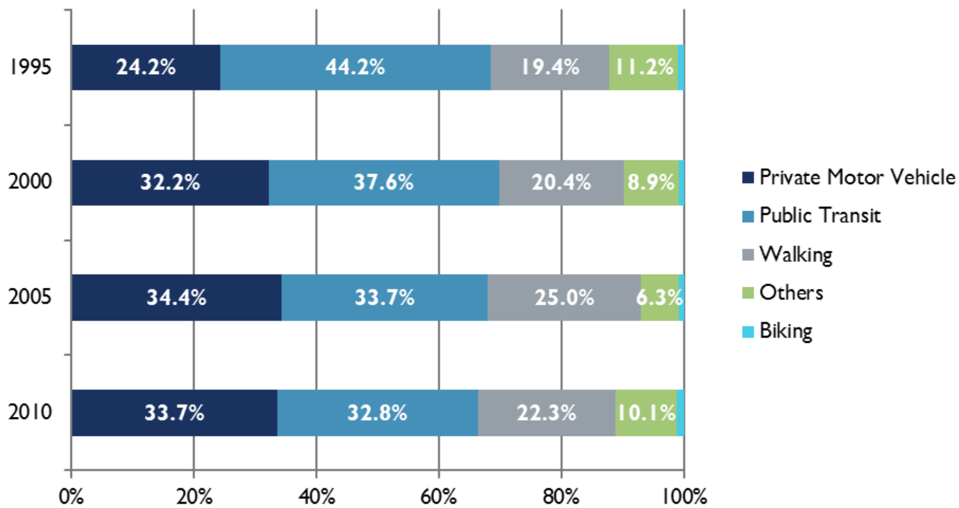


Figure 4-5. Changes in the Commuting Mode Share of Incheon (1995 – 2010)

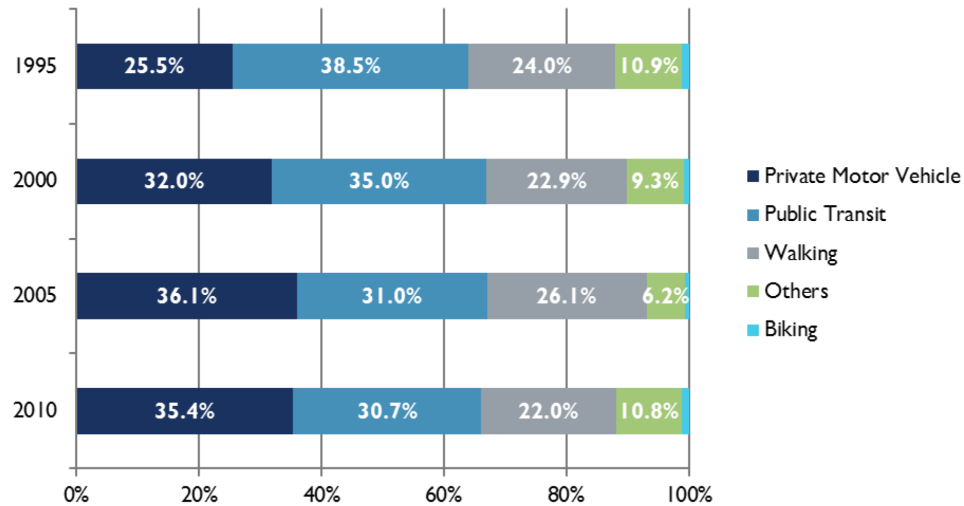


Figure 4-6. Changes in the Commuting Mode Share of Gyeonggi (1995 – 2010)

Although the absolute number of public transit users increased in all three areas, the mode share percentages tell quite a different story. As illustrated in Figures 4-4, 4-5, and 4-6, Seoul maintained the highest percentage of public transit mode share among the three areas, but the share has been decreasing since 2000. The share of public transit in Seoul decreased from 44.1% in 2000 to 39.8% in 2010 while that of private motor vehicles maintained steady at around 20%. What is noteworthy about the mode share is the substantial increase of automobile share in Incheon and Gyeonggi. The automobile mode share of Incheon increased from 24.2% in 1995 to 33.7% in 2010 as more areas in the region become urbanized and developed. The automobile share of Gyeonggi also increased considerably. The mode share increased from 25.5% in 1995 to 35.4% in 2010. While both areas saw a substantial increase in the automobile mode share, the share of public transit dropped sharply. The public transit share in Incheon decreased from 44.2%

in 1995 to 32.8% in 2010, and decreased in Gyeonggi from 38.5% in 1995 to 30.7% in 2010. Considering that both areas experienced rapid population growth and urbanization, the steep increase in automobile share and the decrease in public transit share are quite concerning. People in Incheon and Gyeonggi are relying more and more on automobiles for commuting than public transit. It is difficult to analyze the temporal and spatial variations of commuting mode shares accounting for the effects of the greenbelt relaxation. But, these statistics may indicate rising commuting costs in the region, especially in areas outside the greenbelt.

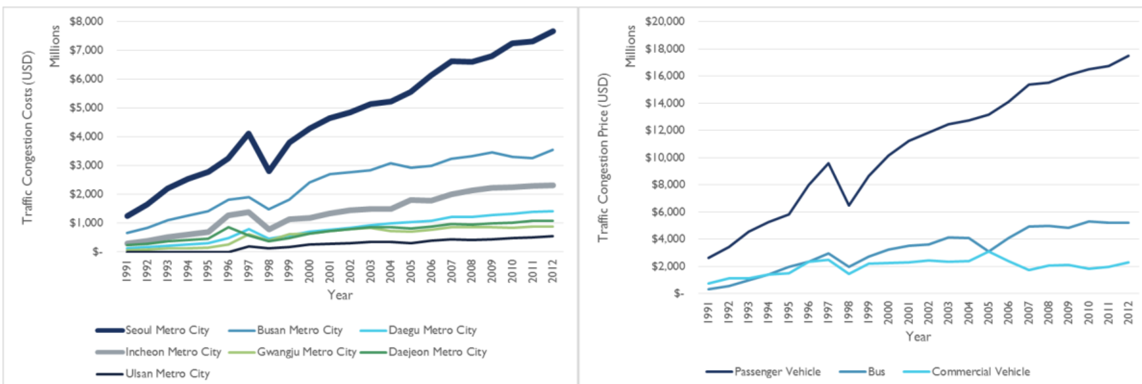


Figure 4-7. Traffic Congestion Costs

According to a study conducted by the South Korea National Transportation Institute, costs imposed by traffic congestion have increased sharply in both Seoul Metro City and Incheon Metro City compared to any other metro cities in South Korea. The institute calculated the costs using the amount of time people spent on transportation modes, amount of money people spent on gas and other vehicle related expenses, and the amount of money people spent on public transit. Although the statistics illustrated in Figure 4-7 below do not capture the costs for Gyeonggi Province, we can at least say that the jobs-housing mismatch has increased on the edge of the metropolitan area regardless of the greenbelt relaxation and has imposed greater transportation cost burdens on people in Seoul and Incheon.

4.3. Summary of the Statistical Analysis

The statistical analyses revealed some interesting findings as summarized in Table 4-11. When we examined where the new developments took place during the study period, we found that the greenbelt relaxation served its purpose of guiding new developments to inside the greenbelt area. However, a considerable amount of urbanization took place outside the greenbelt prior to the greenbelt relaxation. This seems to have been caused by the satellite cities located just outside Seoul (Outer Rim Group) that have grown substantially to accommodate additional population during the early 2000s. Meanwhile, the greenbelt relaxation seems to have eased development pressures and slowed down the rate of increase in land prices and property values in census districts outside the greenbelt (Outer Rim) and inside the greenbelt (Inner Rim) where new developments are happening, compared to the urban core.

Table 4-12. Summary of the Modeling Results

	Hypotheses	Result
3	Greenbelt relaxation promoted new developments inside the greenbelt rather than the outside.	Supported
4	Greenbelt relaxation has eased the development pressure near Seoul; therefore, slowing down the increase rates of land and property values in the region.	Supported
5	If the greenbelt relaxation has guided new developments inside the greenbelt, the fiscal impacts associated with the community service provisions should have intensified at a greater degree inside than the outside after the relaxation.	Supported
6	Greenbelt relaxation and the new housing developments that followed have provided homes closer to the jobs in Seoul; therefore, mitigating the jobs-housing mismatch	Rejected

When we looked at the fiscal impacts of the greenbelt relaxation on the provision of community services, we found that the percent changes of collected local tax, collected tax allocated for public utilities, total tax expenditures, and total road length all decreased outside the greenbelt compared to the urban core in Seoul. In other words, the greenbelt relaxation decreased the fiscal burdens of the census districts outside the greenbelt (Outer Rim and Metro Edge). Meanwhile we found that the collected tax increased inside the greenbelt (Inner Rim) where new greenbelt developments are happening. However, local government spending on community service such as producing clean water has increased substantially in Gyeonggi Province.

The commuting destination analysis verified the jobs-housing mismatch in census districts outside the greenbelt (Metro Edge, Outer Rim), especially on the edge of the metropolitan area where the second set of New Towns were built. Both percent changes of population commuting to census districts of their residency and to other census districts were found to significantly increase inside the greenbelt (Inner Rim) after the greenbelt relaxation. The increase in the former percent change could have been caused by the new housing developments on the released greenbelt areas in Seoul. We could not find direct causal relationships between the greenbelt relaxation and the percent of population spending different amounts of time on commuting with the exception of the percentage of population spending more than 90 minutes on commuting.

While no substantial effects of greenbelt relaxation on commuting time could be found, the changes in the commuting mode share in Seoul, Incheon, and the Gyeonggi area over the past 20 years are quite alarming. As Gyeonggi Province grew, the percentage of people commuting by private motor vehicle increased considerably. Although the public transit ridership increased as well, the number of automobile commuters increased more drastically, meaning that the SMA has more cars on roads compared to 20 years ago. Although Seoul has maintained a high percentage of public transit mode share over the past two decades, the share of automobile commuters has increased considerably. It is difficult to connect these phenomena to the greenbelt relaxation; however, it seems that the region is facing a substantial traffic congestion and growth management challenge.

In summary, the greenbelt relaxation did contribute to mitigating the land price and property value increases throughout the SMA compared to the urban core in Seoul. Although the relaxation guided new developments inside the greenbelt and lowered the tax collection and expenditures outside the greenbelt, the community service costs are expected to be higher outside the greenbelt since more developments continued to happen outside the greenbelt regardless of the relaxation policy. Lastly, although the regression analyses on commuting time data produced some mixed outcomes, the commuting destination analysis and the mode share statistics showed that the SMA as a whole is facing substantial transportation challenges.

CHAPTER 5. POLICY IMPLICATIONS AND RECOMMENDATIONS

5.1. Policy Effect Assessment

In the 1990s, the South Korean government assessed the original greenbelt policy and identified problems that they expected to resolve by relaxing the greenbelt policy. As mentioned in Chapter 2, the problems included: 1) increasing land and housing prices due to insufficient land supply; 2) increasing commuting costs due to residential developments beyond the greenbelt perimeter where lands are affordable; 3) burdensome investment in public infrastructure due to the leapfrogging developments; and 4) rising property disputes (South Korea Ministry of Land, Transport and Maritime Affairs 2011). We analyzed whether relaxing the greenbelt has resolved the first three problems through the quantitative analyses in Chapter 3 and 4. The fourth problem is difficult to quantify requiring additional qualitative studies based on surveys and interviews.

Box 5-1. Policy Objectives of the Greenbelt Relaxation

7. Release of greenbelts should only happen in areas that are assessed to have low environmental values.
8. Developments in released areas should be based on thorough land use planning to prevent reckless and sprawling developments.
9. Capital appreciation from the greenbelt developments should be invested in providing community services by means of impact fees and taxes.
10. Unreleased greenbelt areas should be strongly protected.
11. People who have owned the greenbelt lands prior to the establishment of the policy should be properly compensated. Governments may purchase the lands via impact fees, development fees, or issuing bonds.
12. Excessive speculation and rent-seeking activities accompanying the greenbelt developments should be monitored by the governments. An additional land transaction tax may be applied.

Source: South Korea Ministry of Land, Transport and Maritime Affairs (2011)

In addition to the problems the South Korean government had hoped to resolve, they established the six policy objectives of greenbelt relaxation to minimize the negative effects of the greenbelt relaxation while achieving the expected outcomes. Our study discovered that the South Korean government has failed to achieve some of these objectives.

The modeling analysis using the Land Price Index (LPI) and local property tax data showed that the greenbelt relaxation did contribute to alleviating development pressure and slowing down the rates of land value and property tax increase in the region. Notably, the alleviation effect was significant on the edge of Seoul (Group 3 in the analysis) where greenbelt developments have taken place. However, because the datasets did not fully represent the "housing price", it is difficult to conclude whether the greenbelt relaxation has made the housing more affordable. Since the property assessment data does not capture the time before the relaxation, perhaps conducting additional analysis with more years of data in the future might explain the effects of the greenbelt relaxation on the housing affordability. Collecting data on a household spending more than 30% of its income on housing can be a way to measure the housing affordability problem in the SMA. Currently, the South Korean Census Bureau does not have data on household expenditure on housing.

In regards to the second problem on the commuting costs, we found that the greenbelt relaxation did not decrease the commuting costs outside the greenbelt, especially on the edge of the SMA. The modeling analysis using the point-to-point commuting destination data revealed that the jobs-housing mismatch is increasingly happening outside the greenbelt especially on the edge of the SMA. This seems to have been caused by the on-going New Town developments, overshadowing the effects of the greenbelt relaxation. Although the housing supply increased inside the greenbelt, the average housing price is still unaffordable to many people, forcing people to relocate beyond the greenbelt. Housing affordability problems received media attention in 2015. A recent article published in October 2015 addressed the recent outmigration of people from Seoul to other areas beyond the greenbelt in search of housing they can afford, calling the phenomenon a "Seoul Exodus." According to this article, between January and August of 2015, the net migration of population from Seoul to Gyeonggi Province exceeded 70,000 which was a 14% increase from two years ago. Real estate experts stated that the gentrification caused by urban redevelopment projects in Seoul increased the housing stock but also increased the overall housing price forcing people to relocate to areas that are more affordable (Park 2015). Even after recovering from the Global Recession, the housing became more unaffordable due to the distorted housing market affected by the unique tenure system called Jeonse[6] (Yoo 2015). It seems that increasing the land supply via greenbelt relaxation did little to resolve the housing affordability problem, indicating the complexity of the problem in the SMA.

[6] Jeonse is a unique lease system found only in South Korea. Instead of paying monthly rent, renters make lump-sum deposit to a landlord which ranges from 50% to 100% of the market price to live in housing for two to three years. The landlord makes profits out of interest income or alternative investments during the lease period. At the end of the lease term, the landlord returns the same amount of money originally paid by the tenant.

While the jobs-housing mismatch is increasingly happening on the edge of the metropolitan area, the commuting mode share statistics indicate that the percentage of people commuting by private motor vehicle has increased exponentially over the past 20 years in Gyeonggi Province where most of the former Seoul residents are relocating to. The share of commuters using private motor vehicles also increased considerably in Seoul – inside the greenbelt. Although it was difficult to identify the direct causal relationship between the greenbelt relaxation and the mode share, it is evident that the commuting costs in the region have increased regardless of the greenbelt relaxation.

The third problem related to the fiscal costs of community service provision seems to have been mitigated after the relaxation. Because the greenbelt relaxation guided new developments to the edge of Seoul (Group 3), the fiscal impacts measured by various tax data were found to be greater inside the greenbelt than the outside. However, the modeling analysis was limited in examining how much of the local tax dollars were spend on public utilities due to the limitation of data; this requires further investigation. Even so, the rapid increase in the amount of clean water production in Gyeonggi Province is quite worrisome in that the region as a whole might have to bear a substantial fiscal burden in the future. According to the South Korean Census Bureau, the regional population is expected to increase by 2 million over the next two decades. If the region continues to sprawl to accommodate the population growth, the new developments beyond the greenbelt will require new infrastructure to provide additional community services such as clean water, sewer service, and road construction. This will be fiscally more burdensome than utilizing existing infrastructure to promote infill developments.

One of the important findings from our study is that the release of the greenbelt was not consistent with the environmental assessment policy that was designed to ensure the careful release of the greenbelt lands. Environmental areas that were supposed to be protected under the environmental assessment policy were simply reclassified to developable areas. This indicates that there are unforeseen factors influencing the greenbelt release, perhaps the political agendas of the decision makers. Along with the democratization of the country in the 1990s, the South Korean government reenacted the Local Autonomy Act, which empowered the local governments to make their own planning decisions. Releasing and developing greenbelt lands became one of the primary interests of local politicians from which they could gain political support from the local residents and secure sufficient tax base. According to a survey conducted by the South Korean government in 1998 prior to the greenbelt relaxation, about 69.8% of the local residents responded that the greenbelt should be completely or mostly released for developments. Approximately 26.8% responded that the greenbelt should be partially readjusted, and only 2.8% responded that the greenbelt should remain as it is. What is even more interesting is that about 86.1% of the general population who are not affected by the greenbelt responded that the greenbelt land should be released for development (South Korea Ministry of Land, Transport and Maritime Affairs 2011). Without public support or political leadership advocating for maintaining the greenbelt, it is unlikely that the new greenbelt would be effective in protecting important natural areas from development.

The land conversion analysis showed that the region has lost substantial amounts of farmland, forestland, and wetland between 1990 and 2010. A lot of the farmland and forestland that are located within the perimeter of the greenbelt have been converted to urban areas or left as fallow lands awaiting for future development. Meanwhile, the Difference-in-Differences model using percent change in urban areas showed that more development occurred outside the greenbelt regardless of the effects of the greenbelt relaxation. This clearly indicates a sprawling development pattern. The greenbelt lost its primary function of growth containment as the satellite cities and New Towns located beyond the greenbelt started to sprawl. The increase in the inverse marginal density of New Towns verified the sprawling. Saturated developments inside the greenbelt and the planned developments beyond the greenbelt to accommodate the population growth during the 1980s and 1990s together have drastically changed the metropolitan geography. New Towns and satellite cities built prior to the greenbelt relaxation have grown dramatically, voraciously consuming farmland, forestland, and wetland. Relaxing the greenbelt has guided new development inside the greenbelt only to provide additional housing units to resolve the housing affordability problem while more natural areas were being urbanized.

5.2. Recommendations

This dissertation revealed that relaxing the greenbelt is not a panacea for resolving growth management, transportation, and housing problems in the Seoul Metropolitan Area. Problems such as housing affordability are too complex to be resolved by merely increasing the land supply. The greenbelt relaxation happened too abruptly without considering the consequences of the growth of the New Towns and satellite cities built prior to the relaxation. Although the South Korean government has tried hard to justify the cause of the relaxation with the property disputes and overwhelming development pressures, there are other options that might have contributed to resolving those problems let alone the side effects from relaxing the greenbelt. This part of the chapter provides a list of recommendations to resolve the problems at hand and more importantly help the region move toward sustainable metropolitan growth management.

1. Enhancement of the Regional Planning System

The current decision making system in South Korea allows local governments to release greenbelt lands for development upon the approval of the local planning commission and the national planning commission. The national planning commission may or may not approve the greenbelt release depending on its consistency with the regional comprehensive plan. The 2020 SMA Regional Comprehensive Plan was first adopted in 2007 and last updated in 2009. The current regional planning policy mandates the establishment of local comprehensive plans in accordance with the regional plan. The regional plan was mandated after the greenbelt reform in 1999, after the damage have been done to the environment as the result of urban sprawl. In the plan, the South Korean government addresses the importance of land preservation and environmental protection and states that the growth of the region will be comprehensively managed by promoting polycentric developments (South Korea Ministry of Land, Infrastructure and Transport et al. 2009).

Although a lot of the regional growth problems are addressed in the plan, many of the provisions are either too ambiguous or too general. For example, one of the provisions on future land use states a goal to “promote planned development to control growth of Yongin, Suwon, Hwaseong, Seongnam, and Osan to prevent regional sprawl” (South Korea Ministry of Land, Infrastructure and Transport et al. 2009). These cities are the satellite cities and the New Towns that have grown substantially causing urban sprawl outside the greenbelt. The plan did not specify what constitutes “planned developments” nor how to manage and control the growth of the cities and towns to prevent further sprawl. The beginning of the plan states that the regional plan is a “policy plan” that is designed to provide “guidelines” to the local governments. It also states that the regional plan does not have the power to control the local level land use decisions and developments. The irony is that the South Korean government considers the 2020 SMA Regional Plan as the policy plan that does not have any specific requirements that the local governments have to meet other than establishing a comprehensive plan. The guidelines that are supposed to aid the local level planning are not specific enough to be useful to achieve the goals and objectives at the local level. This means that the plan contains many loopholes that the local governments can take advantage of.

The regional planning under the current planning system is vulnerable to political influences. The 2020 SMA Regional Plan was drafted by the four government-funded research institutes, not by the planners representing each local government. The 2020 SMA Regional Plan was established by the South Korea Research Institute for Human Settlements (KRIHS) – an affiliated organization of the Ministry of Land, Infrastructure, and Transport (MOLIT), the Seoul Institute – an affiliated research institute of Seoul Metropolitan City, Incheon Development Institute – an affiliated research institute of Incheon Metropolitan City, and Gyeonggi Research Institute – an affiliated research institute of Gyeonggi Province. The presidents of these research institutes are appointed by the president and political leaders (e.g., governor and mayors), meaning that the research institutes are vulnerable to political influence. The national planning commission which holds the power to review the regional plan is appointed by the minister of the MOLIT, meaning that the commissioners can also be affected by the political agendas of the central government. Although it might appear in the policy documents and plans that the release of greenbelt lands was based on scientific studies conducted by the research institutes, this loophole in the planning system enabled the South Korean government to release and develop greenbelts to suit their needs. The problems with the environmental assessment and the greenbelt release seem to have been caused by this very loophole. The massive housing development projects on greenbelt lands were one of the primary agendas of the former president Lee Myung-Bak. With the central government having control over the regional planning and the greenbelt release, the reclassification of the land classes appears to have been done to fit the needs of the former administration.

In order to overcome the problem of undue political influence in the current regional planning system, we recommend the establishment of a regional planning authority, named the Seoul Metropolitan Area Council of Governments, which consists of representatives from all local governments in the region as well as the representatives from the two metropolitan cities and the province. Duany et al.(2010) pointed out that one of the challenges for establishing a regional planning authority in the US is that few municipal bodies exist at the regional scale (Duany, Plater-Zyberk, and Speck 2010). The SMA has a total of 66 self-governing bodies, two metropolitan governments, and one provincial government which seem to be sufficient to constitute a regional planning authority. The hierarchy of governance between local, regional, and central governments that already exists could be improved by establishing a new regional planning authority as suggested above. The planning authority should be established to make independent decisions without considerable interference from the politicians. The council of governments should participate in the planning process of the long-term regional plan during which they should address and negotiate their needs and wants. The role of the research institutes that are currently in charge of drafting the entire plan should be limited to providing information and planning expertise so that the council can establish appropriate goals and objectives. Meanwhile, the central government such as the Ministry of Environment and MOLIT should enforce land use and environmental regulations so that current urban problems can be addressed in the regional plan. This way it may be possible to prevent the rent-seeking activities of the local governments while addressing their important housing, transportation, and fiscal needs. The regional council should be a planning apparatus that balances the powers of the local, regional, and central governments. In addition, it should be a planning body that monitors the implementation of the plan to achieve the goals and objectives.

One of the good examples of balancing the planning efforts of various levels of governments can be found in the planning system of the Puget Sound Region in the State of Washington. The regional comprehensive plan of Puget Sound Region, *Vision 2040*, was adopted by the Puget Sound Regional Council in 2009. The Puget Sound Regional Council (PSRC) members include 71 of the region's 82 cities and towns. It also includes statutory members from various government agencies including the port authorities of Bremerton, Everett, Seattle, and Tacoma, the Washington State Department of Transportation, and the Washington Transportation Commission, and other members representing various parts of the communities such as the Port of Edmonds, the University of Washington, Island County, Puyallup Tribe of Indians, Snoqualmie Tribe, Thurston Regional Planning Council, and the Tulalip Tribes. The council's primary decisions are made by the General Assembly consisting of the elected officials from all member jurisdictions — county executives and commissioners, mayors, and city and county council members. The Executive Board comprised of local elected officials oversees the functions of the council based on the recommendations for growth management and transportation made by the Policy boards (Puget Sound Regional Council 2009). More studies will be required to benchmark other successful cases of regional planning bodies that may be tailored to the SMA region's unique social, economic, and political circumstances.

All local plans should be reviewed by the regional planning authority to ensure their consistency with the regional goals and objectives not by the national planning commission. Orfield (2002) states that "the regional authority should have the power to withhold approval from local plans, which prevents the municipality from receiving beneficial services such as regional roads, sewers, or other aid from state and federal governments" (Orfield 2002). In the case of South Korea, rather than the national planning commission making the final call for the central government's support for beneficial services, the regional authority should review the plans and proposals so that the resources provided by the central government can be used according to the regional plan. This way the regional authority will have the "teeth" to implement regional goals and objectives.

2. Regional Share of Resources

One of the benefits of having a regional planning authority is the efficient and effective distribution of regional resources to local governments. The fiscal analysis showed that the greenbelt relaxation actually decreased the fiscal burdens outside the greenbelt compared to the urban core, while seeing a substantial increase in tax bases where the new greenbelt developments are happening. This suggests that fiscal resources have been concentrated inside the greenbelt, more particularly in Seoul compared to other municipalities outside the greenbelt. Even inside the greenbelt, the fiscal capacity varies by census districts. As shown in the graph below, the total amount of collected local tax in Seoul is disproportionately higher in Gangnam, Jung, and Seocho, Yeongdeungpo, and Songpa census districts that are known to have a large concentration of high-income population.

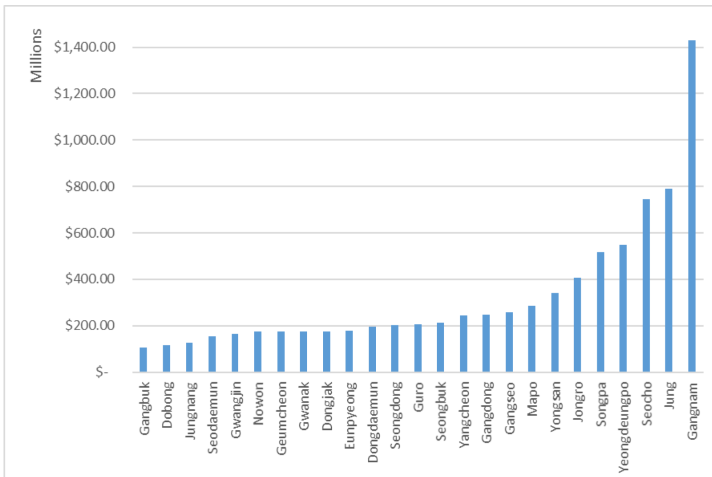


Figure 5-1. Distribution of Collected Local Tax in Seoul

Table 5-1. Comparison of Total Collected Local Tax among Census Districts in Seoul, Incheon, and Gyeonggi

(Unit: US$)

Area	Minimum	Mean	Median	Maximum
Seoul Metro	107,026,118.32	327,032,294.44	206,341,388.00	1,428,688,553.60
Incheon Metro	18,846,823.60	167,431,174.68	179,215,422.76	321,321,146.96
Gyeonggi Province	55,831.60	354,956.71	284,650.96	1,068,904.32

Note: Exchange rate of October 27th, 2015 was applied to convert The South Korean currency to US dollars.

As summarized in Table 5-1, the regional difference in the fiscal capacity represented by total collected local tax is even greater among Seoul Metropolitan City, Incheon

Metropolitan City, and Gyeonggi Province. As Duany, Rusk, and Orfield argue, regional planning has the benefits of regional sharing of tax revenues, regional fair share of low and moderate income housing, and reinvestment in cities and older suburbs (Duany, Plater-Zyberk, and Speck 2010; Rusk 2001; Rusk and Orfield 1998). The housing affordability problem in the SMA may require planning intervention to secure more low and moderate income housing throughout the region. Regional share of fiscal resources can be used to subsidize affordable housing developments.

Some of the older census districts throughout the region have been facing the problems of deteriorating infrastructure and public facilities. Regional share of fiscal resources allows the government to allocate resources to areas that need them the most. Orfield (2002) recommends that the scope of land use planning should be broadened and the regional body should develop an advisory land-use plan for the region that "embodies a vision for coordinating all major forms of developmental infrastructure efficiently" (Orfield 2002). Perhaps, establishing a regional Capital Improvements Program through coordination with the local governments can be a way to invest in declining cities and towns in the region.

3. Preservation of Farmland and Forestland

The greenbelt of Seoul Metropolitan Area has lost its primary functions of land preservation and growth containment. However, it still holds important amenity value in providing recreational areas and open space. National defense remains a very important function of the greenbelt. Considering the important functions of the greenbelt, the remaining greenbelt areas should be protected from future development. This can be done by designating the remaining greenbelt area as a regional park system. Currently, the greenbelt areas consist of mountains that are already designated as national parks. Expanding the perimeter of the parks to a regional scale to include adjacent pastureland and wetlands could be a good way to preserve natural areas in the region. Once designated, a central government agency such as the South Korea National Park Service and the South Korea Forest Service could better protect and manage the forestland, pastureland, and wetland.

An important element that is missing from the regional plan and the government policies is farmland preservation. Farmlands near existing urban areas are generally considered potential developable areas from which many land owners expect to make a great fortune. As we have analyzed from the land conversion analysis, substantial amounts of farmland were urbanized during the past two decades both before and after the greenbelt relaxation. The converted areas included farmlands that were originally designated as prime agricultural lands on the land use maps. Moreover, a lot of these converted areas were originally classified as Class 1 and 2 lands on the 2005 environmental assessment map. In order to prevent the rent-seeking activities of land owners and developers, the South Korean government should consider introducing market-based land preservation programs. Introducing Transferable Development Rights (TDR) has been discussed in the planning literature for many years. Bae et al.(2011) listed the following obstacles that have prevented the application of market-oriented land preservation programs in South

Korea: 1) a political atmosphere reluctant to using market-oriented policy instruments, 2) local governments lack experience with the farmland preservation, 3) the limited powers of local jurisdictions, and 4) local governments lack the fiscal resources to buy up development rights to protect lands from development (Bae, Jun, and Richardson 2011). Many of these obstacles can be overcome by reforming the current planning system to become a regional one. As noted above, establishing a regional planning authority will limit planning intervention from the central government and promote an efficient use of regional fiscal resources. Some of the abundant local taxes collected from census districts in Seoul can be used to buy out valuable agricultural areas and other natural areas for permanent preservation. In addition to the aggressive approach to land preservation, the South Korean government should consider enhancing the agricultural zoning to protect lands that are currently designated as prime agricultural areas in the land use plan. Daniels warned that "a growth boundary and a purchase of development rights program without agricultural zoning make the countryside vulnerable to rural residential sprawl that will fragment the land base, drive up land prices, tempt farmers to sell land for development, and hinder the expansion of farming operations" (Daniels 2010, 260). Conversion of prime agricultural lands to urban areas and the regional and local plans missing a farmland preservation element show that the South Korean government has been indifferent to the value of agriculture. Unless the government and the people recognize the importance of farmland, enhancing the agricultural zoning may continue to be challenging.

4. Establish Regional Urban Growth Boundary

In this dissertation, we discovered that the New Towns and satellite cities located outside the greenbelt have sprawled over the past two decades. Currently, the regional plan does not address the sprawling of these planned cities and towns. New Towns and satellite cities without any growth control measures have set seeds for further sprawling developments to convert adjacent rural areas to urban areas.

To prevent further sprawl, we recommend that Urban Growth Boundaries (UGB) be established around these growing New Towns and satellite cities as well as around Seoul and Incheon metropolitan cities. Unlike the greenbelt, an urban growth boundary (UGB) is not a physical space, but a line drawn to separate areas where urban development may take place and where it may not. Usually, areas outside the boundary are zoned as rural areas and the areas inside the boundary are zoned as urban areas (Bengston and Youn 2006). Another major difference between the UGB and the greenbelt is that the UGB can be periodically reassessed and expanded as needed (Bengston, Fletcher, and Nelson 2004). In general, local governments will not allow rezonings to urban or suburban uses or densities during the current planning period beyond the UGB (Landis and Pendall 2009). The following map shows the location of growing New Towns and satellite cities in the SMA and the hypothetical urban growth boundaries that could surround them.

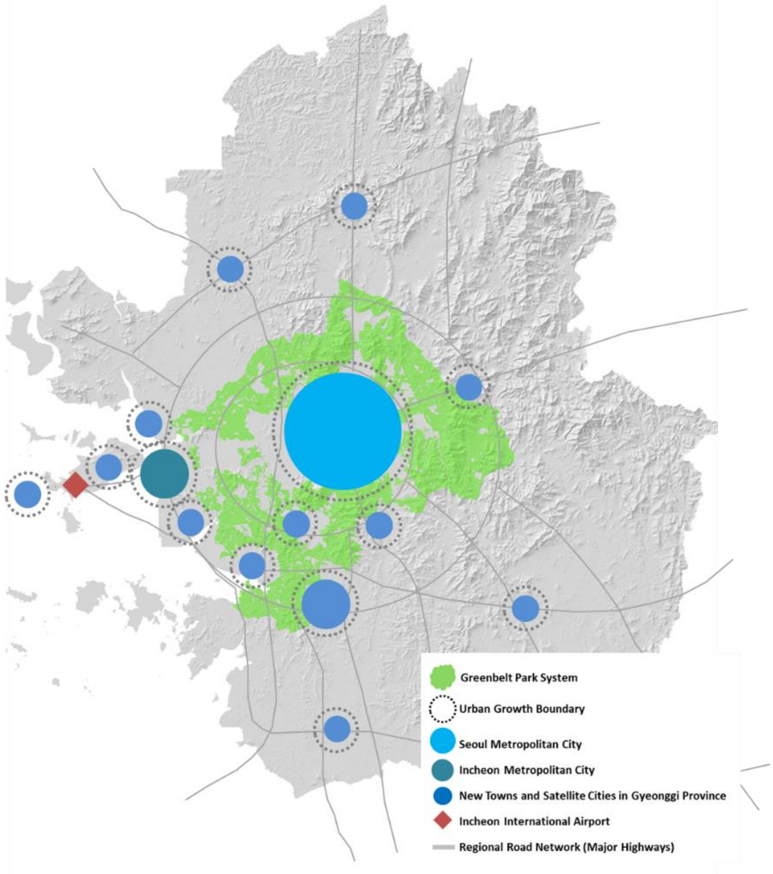


Figure 5-2. New Towns and Satellite Cities and the Regional Urban Growth Boundary

The regional plan should be updated to identify where the future population growth should occur so that UGBs can be established accordingly. As noted above, the regional population is expected to grow by 2 million over the next two decades. This means that the growth will occur somewhere in the region either in the form of sprawl or higher density developments depending on the future planning efforts. The migration data showed that Seoul has been losing population to Gyeonggi Province and Incheon Metropolitan City, meaning that there is a room for future growth accommodation in Seoul if the housing affordability problem is resolved. With the new greenbelt developments providing new affordable housing near Seoul, the UGB around Seoul may not have to cover large areas and further land releases from the greenbelt may not be necessary. The fast growing satellite cities and New Towns, on the other hand, will need to plan for future growth accommodation to prevent reckless sprawling developments. In the local plans as well as the regional plan, the growth profile of the areas should be investigated in-depth to plan for future growth accommodation and to establish UGBs.

5. Enhancement of Public Transit System

As shown in Figure 5-2 above, the New Towns and satellite cities in the SMA are well connected to each other via expressways and public transit systems. All of these towns and cities are accessible via cars, Bus Rapid Transit, subways, and even high-speed rail. The 2020 SMA Regional Plan states that it is their goal to enhance such transportation systems to promote regional economic development (South Korea Ministry of Land, Infrastructure and Transport et al. 2007). Despite such ambitious plans, our analysis found that the number of commuters using private motor vehicles has increased substantially over the past two decades while a significant jobs-housing mismatch was found outside the greenbelt.

In order to promote public transit use and discourage automobile commuting, it is very important that the transportation planning be done at a regional level. Enhancing the accessibility to public transportation systems requires a holistic understanding of transit demand and supply at a regional scale, as well as the transportation and land use planning connections. Regional planning provides a platform where local governments, metro governments, and experts form a transportation authority to discuss ways to enhance the transportation system. The South Korean government is currently planning to construct a regional express rail that will connect Seoul and the satellite cities and New Towns (South Korea Ministry of Land, Infrastructure and Transport 2014). Once placed, the regional rail might contribute to increasing the share of public transit commuters in the region, especially for those commuting from outside the greenbelt to Seoul. Incorporating regional land use planning with regional transportation planning can help establish a good regional plan that can yield effective results.

5.3. Summary

This part of the dissertation discusses the policy implications and the recommendations to resolve the problems discovered from the modeling analysis. The fundamental cause of the problems seems to have been the systemic failure of governance from conflicting interests at different levels of government. The planning culture of South Korea failed to adapt to the changes made to the political, social, and economic circumstances. Under the current system, it is very difficult to reach consensus among central, regional, and local governments, which leads to an inconsistent establishment and implementation of plans and policies. As the prerequisite for solving the current problems, it is important to establish a regional planning authority representing all members of the region in order to draft good plans and have the "teeth" to implement them. The regional planning authority will be the apparatus for all governments to communicate with, which will lead to creating plans that fairly represent the communities' interests and produce tangible outcomes. Consequently, this planning process will promote consistency between the regional plan and local comprehensive plans.

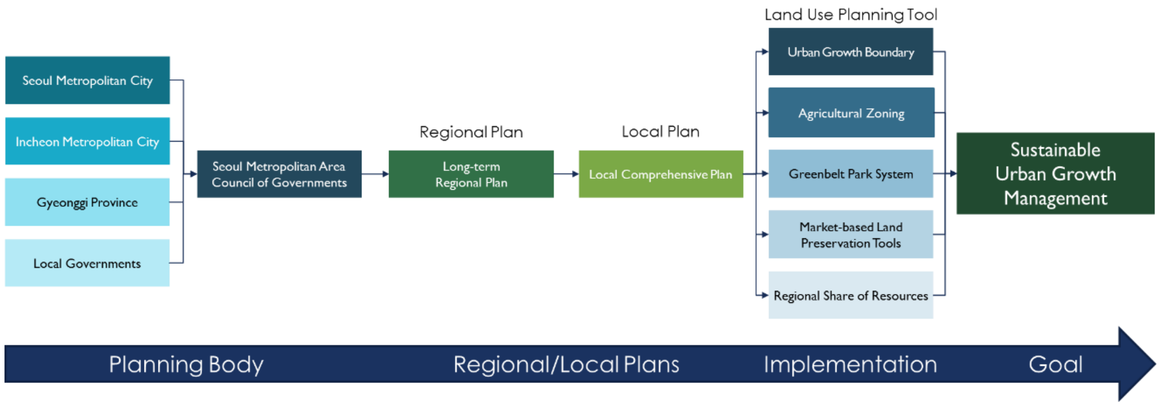


Figure 5-3. Regional Planning Framework for SMA

The greenbelt was instituted under an authoritarian government. Since then, South Korea has transformed itself to become a more democratic country with capitalism driving its economy. The political economy of the country is now similar to that of the US. This means that a lot of innovative growth management measures of the US may be applicable to the South Korean case. A market-based land preservation program, urban growth boundaries, and other regional planning approaches may be useful toward resolving contemporary metropolitan challenges. The land use planning tools could help to implement regional and local plans in ways that will mitigate the property disputes and accomplish the goals of protecting the environment. As illustrated in Figure 5-3, reforming the planning system to a regional one and introducing market-based land use planning tools to implement the regional plan could lead to achieving goals and objectives that would promote sustainable growth management in the SMA. More studies on innovative land use planning tools and growth management policy will be required to develop plans and policies that will work best in South Korea.

It has been over six years since the 2020 SMA Regional Plan was last updated. In revising this plan, South Korean planners have an opportunity to improve the plan to resolve contemporary growth challenges that this dissertation has revealed. The first step to solving a problem is recognizing there is one. It is better later than never.

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INDEX