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Chapter 1
Introduction

The rapid accumulation of people in a mega-city has caused major problems in the fields of housing, basic service, and transportation (Hall, 1984). Moreover, from the environmental point of view, increased impervious surfaces from the urbanization have threatened natural environments by reducing the amount of forest lands, wet lands, and other forms of open space that absorb and clean stormwater in the natural system (Brabec 2002). As one of the mega-cities in Asia, Seoul, the capital of South Korea, has faced these problems whenever new development plans within the city boundary were proposed.

Seoul has experienced unprecedented changes in the population as well as in urban structure. According to the Seoul Metropolitan Government, by 1963 the population grew to about 3 million and the jurisdictional territory accordingly expanded to the current area of about 600 km\(^2\), 2.3 times larger than before. The population of the city has more grown with the south development programs from the late 1960s to 1970s, which showed high-rise apartment buildings along the Han River. As a result, the south districts of Han River expanded rapidly, becoming a similar size of population as the north districts. In present, the population in Seoul is over 10 million inhabitants which occupy 25% of the total population of South Korea.

However, the intense concentration of population in Seoul caused various urban problems such as skyrocketing housing price particularly in south districts, lack of
transportation systems, and environmental disruption. The National Comprehensive Physical Plan in July, 1970 established 1,567 km$^2$ of urban growth boundary along the circumference of Seoul called Greenbelt, mostly composed of forest and woodland (Yokohari, 2000). The primary purposes were to prevent sprawl, protect the surrounding natural environment, reduce air and water pollution, and provide for recreational areas. The Seoul Greenbelt has been evaluated as a successful plan in achieving the goals due to strong legal control.

Furthermore, in an effort to disperse dense population of Seoul, Korean government has established several new satellite cities including Seongnam, Bucheon, Gwacheon, Bundang and Ilsan areas. Despite of these efforts, Seoul has been experiencing rapid population concentration, and the demand for housing in Seoul still exceeds the supply. The government is planning to partially lift the Green Belt and build a new town called Songpa new town, accommodating 50,000 housing units with over 100,000 in about 7 km$^2$ in a south district of Seoul. The primary purpose is to increase insufficient supply for housing and stabilize high priced housing value of south district of Han River.

As for whether the new town should be developed or not, the plan for the new town has been meeting with strong opposition from the Seoul government and several citizen groups representing economics and environment and so on. The construction of Songpa new town has been under debate on the appropriateness for the location of a new town, traffic congestion, environmental problems, and unbalanced development between north and south districts of Han River that would be generated by the development of the new town. Seoul Council and citizen groups have been asserting that development of the new town would
bring excessive speculation in real estate rather than stability of housing value as well as would cause destroyed natural landscape from forest destruction.

Moreover, it is expected that the new development will aggravate current severe air pollution from traffic congestion. The primary reason is that the developments surrounding the proposed new town have already been progressed and almost completed. In addition, the new town would abet more automobile trips within Seoul because it was designed to accommodate residents who are expected to commute to work places in Seoul. In this regard, the environmental civic group supports retention of urban growth boundary and considers the current proposed new town development to be premature.

For the current proposed new town plan, this paper focuses on environmental effects of the development. In particular, the main interests of the study are open space, including forest and agricultural land, and run-off by increased impervious surface on the development area. Based on the background of Seoul and the environmental interests in the development of the new town, this research presents answers to two primary questions. The first question is ‘How the development would change the pre-development open space into built-up land?’ The second question is ‘How the development would affect the change of run-off?’ It is important to deal with the questions because open spaces within Seoul have been getting less and less since the rapid developments so that there are insufficient green spaces that Seoul citizens can use for the purpose of recreation. What is more, it is worth analyzing the changes of run-off coefficient in that the increased impervious surface from the development
increases possibility of flooding in the areas adjacent to Han River and exacerbates water quality by reduction of open space.

The importance of the study is in ensuring that decision-makers consider environmental impacts before deciding whether to proceed with new projects. To do so, the study includes the process of identifying, predicting, and evaluating environmental effects of development proposals prior to major decisions being taken, focusing on the environmental problems Seoul has been experiencing.
Chapter 2

Literature Review

In order to find the best model to apply to Songpa new town case, this chapter examines and evaluates models to forecast future urban growth and assess the environmental effect of development. In terms of how the development of Songpa new town would have an influence on the environment, it is important to start with prediction of urban growth because a specific plan of the new town is not released yet and this study addresses two alternative scenarios in different locations to compare with Songpa new town case. In addition, the paper also reviews preceding studies examining the relationship between urbanization or new development and the physical and potential environmental impacts.

2.1 Urban growth model

2.1.1 SLEUTH model

SLEUTH model is a land-cover change transition model developed by the USGS and researchers at the University of California, Santa Barbara. The model simulates urban growth through urban patterns defined as four types of urban land use change: spontaneous growth, new spreading center growth, edge growth, and road-influenced growth (Hakan Oguz, 2008). Each growth type is controlled and affected by five coefficients consisting of diffusion, breed, spread, road gravity, and slope. The model is calibrated reflecting historical trends of land use change. The SLEUTH model has been applied to urbanization of metropolitan areas around the United States including Santa Barbara, San Francisco and later the Baltimore-Washington metropolitan area. Although the model was successful in simulating urban
change for these study areas, SLEUTH model has a limitation for a scale. As Clarke et al (1997) stressed that the model fits to simulate historic change and predict future urban growth trends at a regional scale, SLEUTH model is not proper to predict urbanization at the local level.

2.1.2 UrbanSim model

UrbanSim model, designed by Paul Wadell, projects urban development incorporating land use, transportation, and public policy. UrbanSim’s modeling process consists of several phases: goal setting, establishing objectives and policies, formulating scenarios, examining the effects of the scenarios on outcomes, developing indicators, and evaluating the effectiveness of the policy scenarios. The UrbanSim model consists of a set of several sub-models including demographic transition, economic transition, household relocation, employment relocation, household location choice, employment location choice, real estate development, and land price. A variety of data, such as parcel data about land and real estate, business establishments, and GIS overlays about environmental and planning characteristics, are integrated into a database for the application of UrbanSim. The strength of the model is that it enables users to create more realistic urban simulation results with socio-economic input data and a variety of user-specified scenarios. However, UrbanSim is designed for use at the metropolitan scale and requires extensive data.

2.1.3 Dynamic Urban Evolutionary Model (DUEM) model

DUEM model, introduced by Xie and evolved to several versions by Batty, simulates the evolution of cities based on cells and/or agents. DUEM differs from standard urban CA
models because it deals with a comprehensive series of land uses. The model divides land use into five types: residential, manufacturing, services and commerce, streets, and vacant land. Through three separate phases of land use change, which are initiation, maturity, and decline, land use can be changed to some other land use class. The probability converting one land use type into other types is determined by a series of if-then rule. Although the model has strength designed to consider different land use types, the model requires setting complex and arbitrary rules. In addition, the richness of the data required makes calibration and estimation difficult and predictive accuracy hard to assess in terms of past simulations (Batty 2005).

2.1.4 California Urban Future (CUF) model

John Landis developed two GIS-based urban models called CUF-1 and CUF-2. CUF-1 model projects the location, pattern, and density of residential population growth. CUF-2 model supplemented CUF-1 model limited to residential development without projecting and/or allocating future industrial, commercial, and public activities (Landis, 1998). CUF-2 model added the process of calibration omitted from CUF-1. The model creates calibration equations from the past urbanization patterns and projects future development using the development pattern, assuming that the past development patterns will continue into the future. Calibration of the model uses the multinomial logistical regression with variables including land use / land cover, topography, transportation network, hydrography, jurisdictional bounds, wetlands, population and employment levels. The estimated coefficients are used to calculate future probabilities of grid cells converted to each of 10 different density categories. Based on environmental, locational, or other policy
characteristics such as urban growth boundary, flood zone, and wetland, particular grid cells are precluded from development regardless of their development probability. Projected population or housing growth is allocated to non excluded cells.

2.2 The study on environmental effects of development

2.2.1 Extension of urban growth boundary and its impacts

Conservation Council of South Australia (CCSA) strongly opposed the proposal to extend the Urban Growth Boundary and release 2,000 hectares of land for residential development over the 20 years in Submission on Urban Growth Boundary Extension Proposal worked out by CCSA on September, 2007. This is because extending development will bring about overwhelmingly negative outcomes environmentally, economically and socially. CCSA assessed the impacts of urban growth boundary extension on greenhouse gas emissions, water resources, sewage disposal and urban storm water management, urban layout, parks and coast, metropolitan open space system in terms of environmental sustainability. Furthermore, CCSA also considered impacts of the extension for the development on mobility, housing affordability, social services and amenity, population growth concentration, off-site financial impacts, and community consultation. However, CCSA did not show the consequences proving scientifically specific impacts through prediction of future growth.

2.2.2 Ecological indicators as effects of urbanization

The article by Whitford (2001) showed deleterious effects of urbanization through four indicators for the ecological performance of urban area: climate, hydrology, carbon
storage and sequestration, biodiversity indicators. She applied the indicators to four residential areas of Merseyside, UK and found out the correlation between each indicator and the proportion of green space in each site. The article has the strength to use simplified method and quantify the environmental effects of urbanization on surface temperature, hydrology, carbon storage, and biodiversity. However, the study ended up with application to the existing development areas in order to test the indicators, not to future development area for predicting the effects of urbanization.

2.2.3 Environmental effects of the change of land use and land cover

In Stephan Pauleit’s study (2005), ‘Modeling the environmental impacts of urban land use and land cover change’, he investigated the change of land use and land cover of 11 residential areas in UK, using aerial photographs from 1975 to 2000. His model showed how these changes would alter three important environmental parameters: surface temperature, run-off of rainfall, and green space diversity. The environmental impact model draw the outcomes presenting characteristics of environmental effects according to density, socio-economic status, and development type. Using surface temperature model, hydrology model, biodiversity indicators, the study found out the relationship between socio-economic status and each submodel. The model could make certain of the importance of green space planning and management based on the results of land use and land cover characteristics of the residential areas. On the other hand, the model only showed how the development has affected each environmental parameter, not considering prediction of the change of natural environment by a new development.
2.2.4 Urban ecological model

Urban ecological model was created to develop a dynamic and integrated understanding of the environmental and human systems by researchers at the University of Washington. The integrated urban development and ecological simulation model predicts the environmental effects according to urban development, land use changes under the condition of various demographic, economic, environmental, and policy scenarios. In this model, the objects used in UrbanSim model, which are households, businesses, developers, governments, were extended to land use conversion, resource use, and emission in order to reflect human induced environmental effects (Alberti, 2000). The output of the urban ecological model serves as the input to several biophysical models for hydrology, hill slope stability, water quality, atmosphere, and ecosystems. Ecological changes will feed back on the choices of both households and business locations, and availability of land and resources. Most of all, the strengths of this urban ecological model are to predict the impact of urban development and to well reflect human response to environmental change through the feedback process. However, the model has too complex process from collecting data to simulation and is designed for simulating a metropolitan area.
Chapter 3
Methodology

Major methodology of this paper consists of urban growth model and environmental effect analysis. Through the two processes, the paper examines how urbanization will occur by new development and how the change will affect natural environment.

3.1 Binomial logistic regression

Urban growth simulation of this research is based on California Urban Future Model (CUF) created by John Landis. CUF, which is one of the urban growth models, draws equations to project future development from past urbanization patterns. However, this research utilizes simplified binomial logistic regression approach to model future residential growth by detecting a historic urban change, in place of multinomial logistic regression used in CUF model to consider the conversion among other land use types and redevelopment. The main reasons to use binomial logistic regression are that new town plan is mostly designed to develop residential units and the surrounding open space for the recreational purpose. Redevelopment and other land uses are beyond the interest of the paper.

Moreover, the project uses the limited variables available to calculate urban growth probability of each cell to be developed. Explanatory variables to account for future residential development include distance from existing cells and distance from major roads as accessibility indicators, and elevation and slope as nature and physical constraint indicators. Coefficients of explanatory variables are calculated by using binomial logistical regression
where a dependent variable can take one of two values, 0 or 1, for undeveloped cells and developed cells. Using this equation, future urbanization probability of each cell within proposed development areas is calculated for determining which cells will be developed.

Binomial logistic regression used when a dependent variable is a dichotomy is described by the general equation as follows:

\[ y = a + b_1 x_1 + b_2 x_2 + b_3 x_3 + \ldots + b_n x_n \]  

(1)

\[ y = \ln \left( \frac{P_1}{P_2} \right) = \ln \left( \frac{P_1}{1 - P_1} \right) \]  

(2)

\[ P_1 = 1 - \frac{1}{1 + \exp(y)} \]  

(3)

where \( x_1, x_2, x_3, \ldots, x_n \) are explanatory variables, \( b_1, b_2, b_3, \ldots, b_n \) are regression coefficients to be estimated, and \( y \) is a linear combination function of the explanatory variables. In this case, \( P_1 \) means the probability that transition from rural to urban occurs. A positive sign of an explanatory variable indicates that the variable increase the probability of cells to change into urban, on the other hand, a negative sign is opposite. In addition, as a way to assess the goodness-of-fit of the regression model, the paper uses the way to calculate the percentage of observations correctly predicted.

In this paper, urban growth probability map is generated by the results of binomial logistic regression model reflecting development pattern at two points in the past. The total number of cells to be developed is controlled on a basis of the desired developed land area calculated from the planned number of people to be accommodated and the proposed density
in a new town plan. Based on the urban growth probability map, transition from rural to urban occurs, starting with the highest probabilities until the number of developed cells is equal to the desired future area. Finally, this study analyzes and compares the change of land cover through examining what kinds of open space will be altered to developed cells.

3.2 Hydrologic analysis

As an environmental indicator to affect water quality and flooding, the paper quantifies run-off volume based on curve number for soil types and land use types, which is the approach first proposed by Soil Conservation Service (SCS) and further developed by Pandit and Goppalakrishnan (Whitford, 2001). The equation of run-off derived from the results of empirical studies on many small watersheds is as follows:

\[
P_e = \frac{(P - 0.2S)^2}{P + 0.8S}
\]

where \( P_e \) is run-off; \( P \) is the precipitation; and \( S \) is the maximum potential retention of the catchment. \( S \) is also described by the following expression:

\[
S = \frac{2540}{CN} - 25.4
\]

where CN is the curve number of the particular type of watershed.

The curve number is a function of land use, soil type, and soil moisture, used to describe the storm water runoff potential for drainage area. For an area with many land covers a weighted curve number can be calculated if the soil type and percentage cover of each land use are known (Chow, 1988; Whitford, 2001). SCS defined 13 land use categories and classified over 8,500 soil series into 4 soil groups according to their infiltration
characteristics for hydrologic analysis. 13 land use categories include 3 residential land uses with high density, medium density, and low density; commercial; industrial; disturbed or transitional; agricultural; open space; meadow; woods with thick cover; woods with thin cover; impervious; and water. The hydrologic groups are designated as A, B, C, and D: Group A with a low run-off potential and high infiltration rate, such as sands and gravels; Group B with moderate infiltration rate; Group C with slow infiltration rate; and Group D with a high run-off potential and very slow infiltration rate.

The study areas used in this paper consist of a variety of soil types and land uses so that the weighted curve number is used for hydrologic analysis. The weighted curve number is described by the following equation:

\[
CN_w = \frac{\sum_{i=1}^{n} (CN_i \times A_i)}{\sum_{i=1}^{n} A_i}
\]  

(6)

where \( CN_w \) is the weighted curve number; \( CN_i \) is the curve number for each combination of land use and soil group; and \( A_i \) is the area for each combination of land use and soil group. Based on the run-off calculated by above equations, (4), (5), and (6), the paper compares run-off between pre-development and post-development and analyzes how the development affects the change in run-off volume by increased impervious surface.
Chapter 4
Study Materials

4.1 Study area

Reflecting the previous research asserting that urbanization can have different effects depending on where and how land use change has occurred (Jantz, 2003), this paper chooses three study areas: Songpa district, where the Songpa new town will be built, and two alternative areas, Enpyung and Bundang districts (Fig. 1). Urban growth in alternative districts is simulated, assuming that the development will occur at the same size as the Songpa new town plan.

Figure 1 The study area
4.1.1 Songpa district

Songpa district is one of the 25 districts which make up the city of Seoul and has about 650,000 people, the most people among the districts in Seoul. The district is located about 15 km far from central business district of Seoul and bordered by the Han River to the north, Tancheon stream to the west, and Greenbelt to the south. In 2005, the Seoul city government determined to build a new town called ‘Songpa New Town’ to accommodate over 100,000. The new town plan centers on two neighborhoods in Songpa district, Geoyeong-dong and Jangji-dong, and a neighborhood in Sungnam district, Bukjung-dong. Some areas in the new town plan belong to the urban growth boundary. Therefore, the proposed new town project is based on removal of green space including the existing military service area and urban growth boundary.

The plan could not proceed not only due to a problem to remove the existing green belt but also due to worry to make worse the current state of unbalanced development between the north and the south of Han River. Furthermore, environmental groups have presented problems related to air quality, water quality, and flooding in adjacent Kangdong district. It is inevitable to cause severe traffic congestion because the new town is adjacent to the existing large residential town. Furthermore, it is possible to additionally expand the boundary of Seoul due to excessive influx to the new town and additional development around the new town.
4.1.2 Eunpyung district

As an alternative to the Songpa new town, the paper chooses Eunpyung district which is located at the north of Han River and on the north-west border of the city of Seoul. About 50% of total area of Eunpyung district fell under urban growth boundary and a lot of green space has been preserved compared to other districts until Korean government revised the urban growth boundary in 2004. After the revision of the urban growth boundary, Eunpyung new town plan was proposed to accommodate about 40,000 residents in Jinkwan-dong, and the first phase to accommodate 10,000 people is now under way. Eunpyung district is also expected to be under additional development pressure after completion of the Eunpyung new town plan.

The reasons why this paper considers Eunpyung district as an alternative to Songpa new town are threefold. First, Eunpyung district is located about 10 km away from Seoul central business district, Jongno district, and on the border connecting the city of Seoul with Goyang in Gyeonggi Province. These geographical conditions give good access to Seoul CBD, where the politics, economics, culture, and history concentrate, as well as enable Eunpyung district to play an important role as the entrance to the city of Seoul. Second, Korean government and Seoul metropolitan government have been encouraging development and redevelopment in northern areas of Han River in order to achieve balanced development between the south and north of Seoul. New town development and redevelopment within Eunpyung district are expected to increase tax revenue of Eunpyung district, provide better residential environments, attract excessive demand for living in the southern area of Han River, and finally solve disparity of housing prices and residential conditions between the
north and south of Han River. At last, Eunpyung new town has fallen far more out of development during 30 years due to restriction of development by urban growth boundary than other districts in northern area of Han River. Natural environment that has reserved for 30 years can accomplish sustainable development in Eunpyung district by developing lands available for residential and commercial uses and at the same time preserving vulnerable and sensitive natural environment to the utmost.

4.1.3 Bundang district

Bundang district, the second alternative to Songpa new town, has been evaluated as a successful satellite city about 22 km far from central business district (CBD) of Seoul. At present, Pankyo new town development was planned to make a self-sufficient neighborhood in Bundang district and will be completed in December 2009 not only by providing residential dwelling units to accommodate about 80,000 residents but also by creating jobs such as high-tech jobs and research institutes.

The first reason to choose Bundang district as the alternative to Songpa new town is that Bundang district has been considered more pleasant place to live than other districts in Seoul in terms of environmental, economical, educational, and recreational conditions. Second, new infill development in Bundang district would also obtain the desired results to prevent inadequate accumulation of people in Seoul. Third, it can avoid the current problems related to the extension of urban growth boundary, which is a prerequisite for Songpa new town development. Finally, improved rapid mass transit systems which are in progress by
Bundang district office would reduce car dependence and provide the prospective commuters to Seoul with easier access to their workplace.

On the other hand, new infill development in Bundang district as an alternative to Songpa new town would increase vehicle miles traveled because it is intended to accommodate commuters to the Seoul. It is possible to cause severe traffic congestion and deteriorate current levels of air pollution in both Seoul and Bundang district. However, the traffic problems would be mitigated after completion of mass transit systems like subway that is under construction. In addition to improved transit systems, attracting high quality jobs into Bundang district can contribute effectually toward making Bundang district self-sufficient and reducing car dependence.

4.2 Data sources

Geographic data layers prepared for input to urban growth model and run-off estimation are listed in Table 1. Data used in this paper include Landsat TM of 1990, Landsat ETM+ of 2000, 1:25,000 topography map of 1998, soil map of 1998 and land cover map of 2001. Remote sensing data are classified by using unsupervised classification through Erdas Imagine 9.1 package. Erdas Imagine provides unsupervised classification algorithm named Iterative Self-Organizing Data Analysis Technique (ISODATA). ISODATA clustering technique is the way to create clusters through the process to begin with arbitrary cluster means, calculate a new mean for each cluster by each iteration, use the new mean to define clusters for the next iteration, and finally complete the process when the number of pixels changing clusters are fewer than a certain threshold specified in initial setting. Although unsupervised classification provides users with simpler method to classify a remotely sensed image, it is inevitable that it is less accurate than supervised classification that users
define the training data. The paper reclassified 16 classes, created from unsupervised classification method, into three land cover types: water, urban, and rural. In order to reduce classification errors resulting from unsupervised method, the research revises classified images based on the original image data of 1990 and 2000 and a land cover map which was produced by Ministry of Environment in 2001. All data sets are created through ArcGIS based on spatial resolution of 10m.

The classified data from remote sensing images are used to make the observed growth, which is the dependent variable, between the two time periods (1990 and 2000 in this case). Water area is not used in the logistic regression, but used to exclude future development in urban growth model. The classified data from Landsat TM and Landsat ETM+ are also used for independent variables in the urban growth model to represent proximity to developed cells that influences growth. The topographic map (1:25,000) produced in 1998 is used for extracting roads and DEM. The paper ignores influence from new roads after 1998 because there is only one road data available for use in this project. Slope is made based on the elevation through ArcGIS program. Soil types and land use types, which are used to calculate the weighted curve number for run-off, are respectively reclassified into four groups according to the standard of SCS and into eight groups in order to match the land cover map of 2001 to the land use categories of SCS. Since residential land use is not classified by density in the land cover map and single family home occupies only less than 10% of the total housing units in the study areas, the paper assumes that residential land use in the study areas is based on high density.
Table 1. GIS data layers in the study

<table>
<thead>
<tr>
<th>Subject</th>
<th>Data layer</th>
<th>Data Source</th>
<th>Cell Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Urban/Rural Area of 2000</td>
<td>Landsat ETM+ of 2000</td>
<td></td>
</tr>
<tr>
<td>Accessibility Indicators</td>
<td>Proximity to developed cells in 1990</td>
<td>Landsat TM of 1990</td>
<td>Distance from the developed cell</td>
</tr>
<tr>
<td></td>
<td>Proximity to developed cells in 2000</td>
<td>Landsat ETM+ of 2000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Proximity to Major Road (highways and local roads)</td>
<td>1:25,000 topography map of 1998</td>
<td>Distance from the road</td>
</tr>
<tr>
<td>Physical Constraint Indicators</td>
<td>DEM (m)</td>
<td>1:25,000 topography map of 1998</td>
<td>Elevation (m)</td>
</tr>
<tr>
<td></td>
<td>Slope (degree)</td>
<td>1:25,000 topography map of 1998</td>
<td>Slope (degree)</td>
</tr>
<tr>
<td>Soil type</td>
<td>Soil group by SCS</td>
<td>Soil map of 1998</td>
<td>A / B / C / D</td>
</tr>
<tr>
<td>Land use</td>
<td>Land use by 8 land use types</td>
<td>Land cover map of 2001 (Level 2 Classification)</td>
<td>Residential / Industrial / Commercial / Open Space / Agriculture / Woods / Meadow / Water</td>
</tr>
<tr>
<td>Excluded</td>
<td>Water</td>
<td>Land cover map of 2001 (Level 2 Classification)</td>
<td></td>
</tr>
</tbody>
</table>

4.3 Variables

This paper uses limited data due to difficulty to get some of the useful data to apply to this model. Simulating more realistic future urban growth may require more variables: public transportation facilities such as bus stops and subways, amenity including parks and public libraries, information on infrastructure such as water lines and sewer lines, and other factors that can be selected based on residents’ preference, such as location of notable schools for parents with interest in the education of their sons and daughters.
In binomial logistic regression to simulate urban growth, the paper uses the observed growth between the two time periods as the dependent variable and distance from the existing developed area, distance from the road, elevation, and slope as the independent variables (Fig. 2). Therefore, the binomial logistic regression used in this model can be described as follows:

\[
\ln \left( \frac{P_1}{1 - P_1} \right) = b_0 + b_{\text{urbdist}} + b_{\text{roadist}} + b_{\text{dem}} + b_{\text{slope}}
\]

where \( P_1 \) is the probability of occurrence of transition from rural to urban, \( \text{urbdist} \) is the shortest distance from the existing area, \( \text{urbroad} \) is the shortest distance from the existing road, \( \text{dem} \) is elevation, and \( \text{slope} \) is degree of slope.

4.3.1 Accessibility factor

As accessibility factors, different values of distance from developed area and road are assigned to rural cells (Fig. 2). These layers are used to simulate the influence of the existing developed area and roads on future development.
4.3.2 Physical constraint factor

Although cells around rural areas are fairly developed and the rural areas are proximate to roads, rural areas should meet natural conditions appropriate for future development. As physical constraint factors, each rural cell is assigned a specific value based on elevation and slope (Fig. 3 and Fig. 4).

Figure 3 Elevation in the study area

Figure 4 Slope in the study area
Chapter 5

Results

5.1 The results of logistic regression model

Assuming that future urban growth is influenced by the growth pattern in each administrative district, each logistic regression is executed for three districts: Songpa, Eunpyung, and Bundang districts.

5.1.1 Songpa district

Logistic regression in Songpa district is executed based on the dependent variable and the four independent variables extracted from the boundary of Sonpa district. The observed growth between 1990 and 2000 is used as a dependent variable, while distance from the existing urban and roads, elevation, and slope are considered the four independent variables. The result of the logistic regression in Songpa is as follows.

Logistic regression                              Number of obs  =  103142
LR chi2(4)                                      =  13140.95
Prob > chi2                                     =   0.0000
Log likelihood = -61789.768                    Pseudo R2     =   0.0961
------------------------------------------------------------------------------
urb |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
urbdist |  -.0175675   .0002438   -72.05   0.000    -.0180454   -.0170897
roaddist |   -.002839   .0000881   -32.23   0.000    -.0030116   -.0026664
dem |  -.0273608   .0006197   -44.15   0.000    -.0285754   -.0261461
slope |  -.0249573   .0040529    -6.16   0.000    -.0329007   -.0170138
   _cons |    1.02055   .0158293    64.47   0.000     .9895252    1.051575
------------------------------------------------------------------------------

As a result of the logistic regression, all independent variables are very statistically significant at the 95% confidence interval. All coefficients of the variables have a negative sign which means that nearer distance from urban and roads, lower elevation, and gentler
slope make the probability to change from rural to urban higher. Goodness-of-fit of the model indicates that 58.45% of developed cells and 81.62% of undeveloped cells are correctly classified. Overall correctness for classification is 72.45%.

5.1.2 Eunpyung district

Like the logistic regression in Songpa district, the binomial logistic regression is executed based on the variables extracted from the Eunpyung district boundary. The result of the regression is as follows.

Logistic regression                               Number of obs   =     179710
LR chi2(4)      =   64196.69
Prob > chi2     =     0.0000
Log likelihood = -23476.341                       Pseudo R2       =     0.5776
------------------------------------------------------------------------------
urb |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
urbdist |  -.0267171   .0003671   -72.78   0.000    -.0274367   -.0259976
roaddist |    -.00784   .0001492   -52.54   0.000    -.0081325   -.0075476
         |         |         |         |         |         |         |         |
dem |  -.0783626   .0010331   -75.86   0.000    -.0803874   -.0763379
slope |  -.0920421   .0028877    31.87   0.000    -.0977019   -.0863824
         |         |         |         |         |         |         |
_cons |   3.619348   .0381664    94.83   0.000     3.544543    3.694152
------------------------------------------------------------------------------

As a result of the regression, all independent variables for Eunpyung district are very statistically significant and all the variables have a negative sign of the coefficients. Goodness-of-fit of the model for Eunpyung district shows that 64.94% of developed cells and 97.62% of undeveloped cells are correctly classified, while 94.95% of cells are correctly classified overall.

5.1.3 Bundang district

The logistic regression in Bundang district is as follows.
Logistic regression

Number of obs = 534946
LR chi2(4) = 68669.50
Prob > chi2 = 0.0000
Log likelihood = -156904.07  Pseudo R2 = 0.1795

------------------------------------------------------------------------------
urb |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
urbdist |  -.0014348   .0000482   -29.78   0.000    -.0015292   -.0013403
roaddist |  -.0025742    .000035   -73.57   0.000    -.0026428   -.0025056
dem |  -.0156795   .0001536  -102.11   0.000    -.0159805   -.0153785
slope |  -.0194499   .0009711    20.03   0.000    -.0213533   -.0175465
_cons |   .0372392   .0099003     3.76   0.000      .017835    .0566434
------------------------------------------------------------------------------

The result of the regression indicates that all variables are statistically significant at the 95 percent confidence interval and all the independent variables have a negative sign of coefficient like the models of other districts. In terms of goodness-of-fit, 41% of developed cells and 93.47% of undeveloped cells are correctly classified. Overall, 87.48% of cells are correctly classified.

5.2 The results of simulation of future urban growth

5.2.1 The probability map for each district

Based on the results of the regression model, urban growth probability maps for each district are created to simulate the future development (Fig. 5, Fig. 6, and Fig. 7). The pictures show the probability both within each district and within neighborhoods to be simulated. The paper assumes that future development in Songpa district will occur only in three neighborhoods which belong to Songpa new town area, Geoyeo-dong, Jangji-dong, and Bukjung-dong. Similarly, the paper also considers only two neighborhoods in Eunpyung district including Jinkwannae-dong and Jinkwanoe-dong as simulated areas for future development. The reason to choose these two neighborhoods is that they are released from
urban growth boundary in 2004 and continue to be under additional development pressure. Finally, simulated neighborhoods in Bundang district are 4 neighborhoods of 19 neighborhoods in Bundang district, which are Yatap-dong, Imae-dong, Seohyun-dong, and Pankyo-dong. These neighborhoods are chosen because they are more close to Seoul than other neighborhoods in Bundang district.

Figure 5 The urban growth probability for Songpa district
Figure 6 The urban growth probability in Eunpyung district

Figure 7 The urban growth probability in Bundang district
5.2.2 The future urban growth for each district

Assuming that Songpa new town will be developed to accommodate 100,000 residents with a density of 227 per hectare, the paper changes 40,000 of rural cells into the residential land use. Figure 8, 9, and 10 shows how the transition in each simulated area occurs.

Figure 8 The result of simulation in Songpa district
Figure 9 The result of simulation in Eunpyung district

Figure 10 The result of simulation in Bundang district
Table 2 shows that which land use types of undeveloped area change into urbanized area. In Songpa district, 36.5% of newly developed area is open space, followed by agricultural land use, woods and meadow. New development in Eunpyung district transforms 1.5 $km^2$ of woods and 1.4 $km^2$ of open space to residential land use. Unusually, in Bundang district, the change of agricultural land use occupies over half of newly developed areas, followed by transition of open space (35.5%).

<table>
<thead>
<tr>
<th>Land use type</th>
<th>Songpa District</th>
<th>Eunpyung District</th>
<th>Bundang District</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Space</td>
<td>1,462,200 (36.6%)</td>
<td>1,420,300 (35.5%)</td>
<td>1,301,700 (32.5%)</td>
</tr>
<tr>
<td>Agriculture</td>
<td>1,075,200 (26.9%)</td>
<td>1,025,300 (25.6%)</td>
<td>2,291,300 (57.3%)</td>
</tr>
<tr>
<td>Woods</td>
<td>919,300 (23.0%)</td>
<td>1,524,300 (38.1%)</td>
<td>336,400 (8.4%)</td>
</tr>
<tr>
<td>Meadow</td>
<td>543,300 (13.5%)</td>
<td>30,100 (0.8%)</td>
<td>70,600 (1.8%)</td>
</tr>
<tr>
<td>Total</td>
<td>4,000,000 (100%)</td>
<td>4,000,000 (100%)</td>
<td>4,000,000 (100%)</td>
</tr>
</tbody>
</table>

5.3 The results of estimation of run-off

Through SCS weighted curve number method, the paper estimates direct run-off volume in each simulated area for pre-development and post-development. Table 3 shows run-off volume of pre-development and post-development in simulated areas for storms of 12mm, which is a typical heavy rainfall event for Seoul. As a result of estimation of run-off volume, new development in Songpa district causes 1.34 mm of additional run-off volume for 12 mm rainfall, which is 26.02% increase in run-off volume. On the other hand, new development in Eunpyung district generates 1.14 mm of additional run-off volume for 12
mm rainfall, with 59.73% increase in run-off volume by new development. Finally, in Bundang district, 0.48 mm of additional run-off volume is generated by simulated new development, showing 15.56% increase in run-off volume.

Table 3 Run-off volume of simulated areas

<table>
<thead>
<tr>
<th>District</th>
<th>Weighted Curve Number</th>
<th>Run-off volume</th>
<th>Change of run-off volume (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Songpa District</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-development</td>
<td>72.44</td>
<td>5.14 mm</td>
<td>26.02 %</td>
</tr>
<tr>
<td>Post-development</td>
<td>78.80</td>
<td>6.48 mm</td>
<td></td>
</tr>
<tr>
<td><strong>Eunpyung District</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-development</td>
<td>53.29</td>
<td>1.91 mm</td>
<td>59.73 %</td>
</tr>
<tr>
<td>Post-development</td>
<td>60.92</td>
<td>3.05 mm</td>
<td></td>
</tr>
<tr>
<td><strong>Bundang District</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-development</td>
<td>61.21</td>
<td>3.10 mm</td>
<td>15.56%</td>
</tr>
<tr>
<td>Post-development</td>
<td>64.07</td>
<td>3.58 mm</td>
<td></td>
</tr>
</tbody>
</table>
Chapter 6
Discussion and Conclusion

6.1 Discussion

Assuming that future development follows the past development patterns of each administrative district, this paper predicts the future development in Songpa new town as well as in two alternative areas to identify how the new development will change the existing land uses into the residential purpose. In addition, this study tries to examine how the future development in different areas affects run-off volume that is directly related to flooding and water quality. Although the binomial logistic regression model used in this study does not offer extremely accurate predictions by showing a little low goodness-of-fit for developed cells ranging from 41% to 61%, the model shows approximate predictions with available limited dependent variables, showing overall goodness-of-fit over 72% and negative signs of coefficients as expected. Moreover, the results of simulation to transform undeveloped cells to developed cells show that the nearer distance from the existing urban cells and roads is, the more transition from rural to urban occurs, at the same time, the lower and the gentler elevation and slope are, the greater the probability of change is.

The results of estimation for run-off volume show that change in run-off volume varies according to locations, soil types, and land use types. The simulated area in Bundang district shows the lowest increase rate in run-off volume compared to pre-development status because there still remain a lot of undeveloped areas consisting of open space, meadow, woods, and agricultural land after new development. On the other hand, the alternative area
in Eunpyung district results in the highest increase rate in run-off volume which is 59.73% increase much larger than 26.02% increase in Songpa new town. The remarkable gap between Eunpyung district and Songpa district comes from different composition of soil types in newly developed cells. Actually, in Eunpyung district, 57.5% of newly developed cells are green space under hydrologic soil group ‘A’ and only 0.54% of new development cells are green space under hydrologic soil group ‘D’, while in Songpa district 36.3% of newly developed cells are green space belonging to soil group ‘A’ and 25.4% of new development are undeveloped areas under soil group ‘D’. As undeveloped areas under soil group ‘A’ having high infiltration rates change into urbanized areas that are characterized by high curve number, it is natural for run-off volume to increase. However, one thing this study should pay attention to is that current run-off volume in Songpa new town area is very high beyond comparison with other simulated areas. The result may come from the existing urbanized areas adjacent to Songpa new town.

6.2 Conclusion

The purpose of this paper is not to say that Songpu new town plan should be withdrawn. Besides, it cannot conclude that new development should be built in one of the two alternative areas because there are a lot of factors to be considered as qualification for new development, such as demand, infrastructure to accommodate residents, the existing transportation system, and available budget of administrative districts, to name a few.

The real purpose of the paper is to consider environmental effects of new development that can be easily ignored. Through the process to predict future growth,
realistic evaluation of environmental effects may be conducted even in initial phase of new development plan. In order to make the study more accurate, it is required to collect more useful data to affect future growth, such as amenity not only in newly developed areas but also around the areas, infrastructure data, public facilities, and consumers’ preference. Since the paper uses remote sensing images of 1990 and 2000, Eunpyung new town and Pankyo new town, which are under construction, cannot be considered seed cells affecting surrounding undeveloped cells in identifying the past growth patterns and projecting the future growth. Therefore, simulated future growth might occur at developed cells in 2008 and 2009.

Furthermore, a variety of studies for environmental effects are needed to more specifically verify how new development has an effect on natural environment. In this paper, additional studies are necessary to find out how increase in run-off volume affects water quality and flooding in the proposed area or the surrounding areas.
Reference


