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Planning Support Systems (PSS)-Based Spatial Plan Alternatives and Environmental Assessment

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Abstract: Spatial planning is at the core of national land and urban development. Many countries and cities seek sustainable development through various means such as coordinated environmental planning, environmental assessment, and internalization of environmental analysis and planning. A Planning Support System (PSS) is a GIS (Geographic Information System)-based, spatial decision-making support system that incorporates a variety of theories and pertinent models. This study adopted the "What if?" model to design an alternative spatial plan that includes generation of predictive scenarios and is relatively easy to use. In the cities studied, we identified a total of six scenarios based on the main drivers of development—namely, population and spatial policies. Subsequently, we assessed the alternatives for their environmental impact, preparing sensitivity maps for each major environmental issue in the target area (natural ecosystem, air and microclimate, natural disasters). One projected advantage of the "What if?" model is that its digital visualization of proposed plans may improve public awareness and involvement. Furthermore, the tool is expected to be highly useful in ensuring the objectivity of quantitative analyses. However, it is necessary to develop a PSS that is both standardized and tailored to the particular needs of each area. Finally, the development of an e-governance system will be beneficial in ensuring public access to the decision making process.

Keywords: "What if?"; decision-making system; spatial plan alternative; land use scenario; GISEA (GIS-based Strategic Environmental Assessment)

1. Introduction

Sustainable land development is achieved through a spatial plan that considers environmental values and changes in future socioeconomic conditions. Many countries and cities systemically link urban development and environmental conservation in an effort to promote sustainability through spatial plans designed according to environmental analyses and planning [1–6]. Korea has been actively exploring potential revisions of laws and regulations, as well as the adoption of new policies under the banner of "Land Development in Harmony with the Environment" [7]. A crucial part of implementing these policies is the practical linking of spatial planning and environmental planning. As such, we highlight the importance of spatializing traditional indicator- and program-oriented environmental plans [8,9]. In fact, environmentally conscious land use scenarios can play an important role in promoting a pattern of sustainable spatial planning. Additionally, spatialization and visualization of spatial data can ensure an effective and rational decision making process [10–12].

A Planning Support System (PSS) is a tool that can be used in the process of developing spatial plan alternatives [13]. It is an integrated system that can incorporate various urban development theories and pertinent models, as well as spatial decision-making support systems [14–17]. The tool also provides the functions of data collection, management, analysis, and visualization [18].

The demand for PSS is increasing in many areas of urban development, including urban sprawl, overpopulation, traffic congestion, environmental damage, and pollution. PSS is also valuable in pursuing eco-friendly and sustainable land development, expanding the participation base in land use planning, and effectively mediating conflict between parties of interest. For these reasons, it is widely used in spatial decision-making support systems and spatial planning support systems [13,19]. Utilization of PSS in the area of spatial planning facilitates scientific analysis and prediction as well as rational decision making. Furthermore, it can reduce the likelihood of errors resulting from planners' limited experience, as well as alleviate problems resulting from unilateral decision-making on the part of the planners [18,20].

Planning assessment or SEA (Strategic Environmental Assessment) is a field dominated by qualitative assessment methods [21,22]. There is a great demand for objective and quantitative assessment methods (scenario method, GIS method, modeling, and cost-benefit analysis), which can provide accurate and quantitative prediction of future impact, increased assessment potentials [15,23], prediction of temporal and spatial environmental variability, and increased potential for predicting the cumulative impact of a plan or project [15,23,24]. Spatial assessment is sometimes presented with GISEA (Geographic Information System-based Strategic Environmental Assessment, or GIS-based SEA) [25,26]. The current study prepared a variety of land use scenarios, using PSS, in an effort to ensure a more scientific and integrative approach to spatial planning and environmental assessment. As to environmental assessment, we performed a quantitative analysis on the compatibility of the derived land usage scenario with the environment in question. The study then constructed a framework designed to analyze and assess the scenarios' environmental impact. Scenarios were created in consideration of both the environment and the demand for development, and we employed a case study to assess their feasibility.

2. Research Method and Rationale

2.1. Method

This study comprises two parts—namely, the development of land use scenarios and environmental assessment. The PSS used in this study to project land use scenarios facilitates an objective environmental impact analysis, and suggests potential responses based on the predicted outcome. We used the "What if?" model, taking into account the ease of scenario preparation, feasibility of generating predictive scenarios, various environmental circumstances, and policy potentials [18,27,28]. The model's basic algorithm was applied with necessary modifications of indicators and factors to accommodate Korea's circumstances.

In the environmental assessment part of the study, we applied a quantitative analysis to the generated land use scenarios. A map overlay analysis was performed for each area of interest against the environmental sensitivity maps containing spatial data pertaining to preservation and management. Environmental sensitivity maps can be variegated in accordance with the policies, goals, and sensitivity factors of the target land. Future scholars wishing to adopt some of the methods presented in this study will need to adapt the relevant environmental factors according to their target areas of research.

2.2. Conceptual Scope: What if?

The PSS used in the study is the application "What if? 2.0" (referred to as "What if?" throughout this study), created by Richard E. Klosterman, a professor at the University of Akron, Ohio in the United States. "What if?" is one of the GIS-based PSSs that predicts future land use demand based on current land use, population and household data, employment data, and other factors [13,20,27,29]. It allows a wide range of prediction, as the user can define the variables required to establish policies pertaining to land use, development density, and development restriction [20,29]. These functions allow a clearer vision of future land use patterns in terms of changes that can accompany a particular policy or plan [27,29]. The tool is also advantageous because it makes it easy to create scenarios predicting future land use and its impact. The tool also offers the public an immediate and easy-to-understand view of the changes in spatial patterns resulting from particular changes in the scenario. These benefits can increase public participation and promote efficiency in the agreement process [18,27,30]. This kind of tool can also be used in connection with existing land use policies, ranging from suitable land identification to regional plan creation [17].

"What if?" consists of the three sub-models of land use demand, land supply (suitability), and land allocation. The sub-models have a similar logical structure to the land use design process of Urban Land Use Planning [28,31]. In other words, the program structure is designed to first identify the location and area of developable land by usage, then to project the demand in a non-spatial manner by usage, and finally to allocate the demand to the lands deemed suitable for development [27,32].

2.3. Spatial-Temporal Scope

The main spatial scope of this study was Gyeonggi Province, which includes the neighboring city of Seoul and the Incheon metropolitan area in Korea (Figure 1). We reviewed current environmental and policy issues, focusing on Gyeonggi Province in particular. We considered relevant materials such as the Gyeonggi Province Environment Conservation Plan [33]. For population we took into consideration the entire Seoul metropolitan area. Most of the data used in the analyses came from the 2020 Gyeonggi Province Comprehensive Plan (2011–2020) [34], the 2020 Incheon City General Plan [35], the 2020 Seoul City General Plan [36], the 3rd 2020 Seoul Metropolitan Area Adjustment Plan (2006–2020) [37], and Statistics Korea's database [38,39]. The survey period was 2010–2011. In general, 2009 data were used in an effort to ensure accuracy.

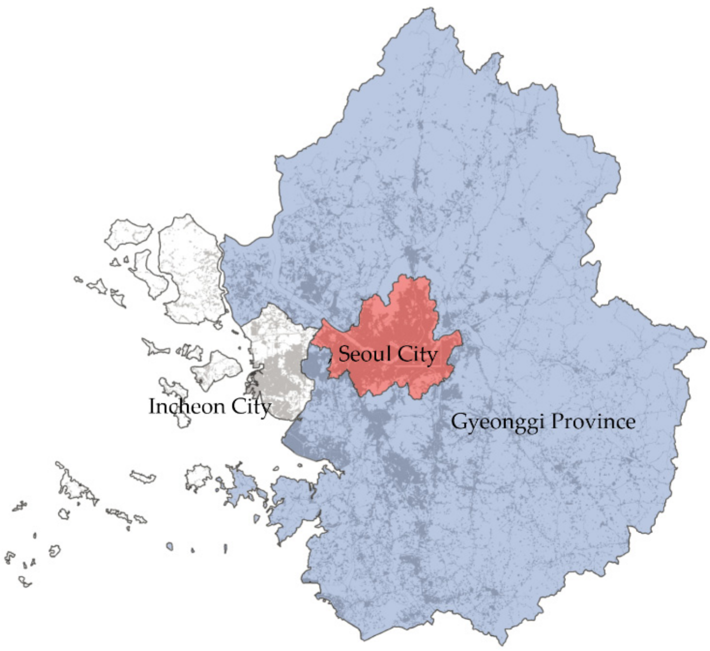


Figure 1. Spatial scope: Seoul metropolitan area.

3. Framework for Applying PSS

For Phase one of the study, to create land use scenarios, the following steps were taken based on a comprehensive literature review [25,27,40,41]: determine the environmental indicators, define the driving force, and develop scenarios using "What if?" (Figure 2).

The second phase of the study concerns environmental assessment. Our assessment focused on quantitative evaluation of land use change, damaged area, and other factors, based on the sensitivity maps of major environmental issues in the target area.

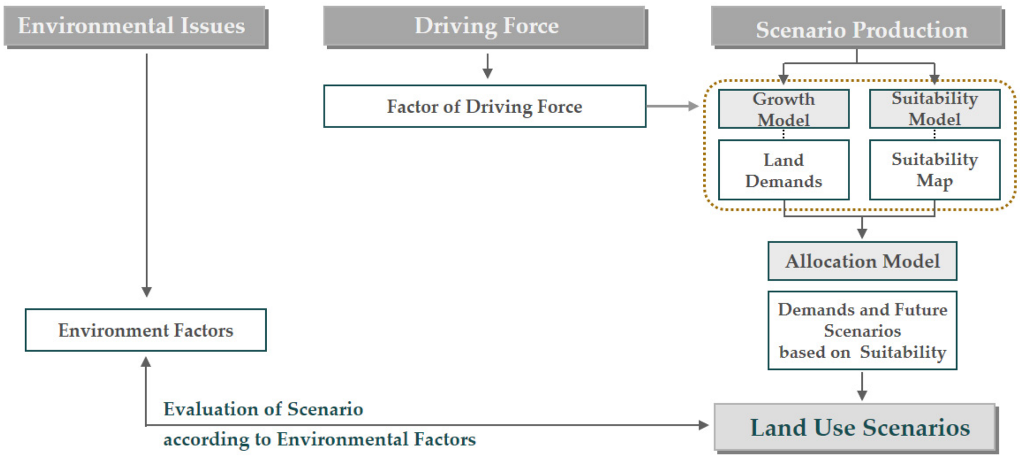


Figure 2. Scenario creation process using "What if?".

3.1. Determining the Environmental Indicators

Selecting environmental indicators is a matter of selecting the most important factors that influence an area's growth pattern and land use. It is necessary to identify the area's environmental issues, tasks, and planning goals. Selected environmental indicators are important factors to consider when developing spatial planning policies. For developing a spatial plan alternative using "What if?", such factors are used to determine the plan's suitability and application of the layout model. Also, these indicators can be used as assessment elements when evaluating possible alternatives. Higher level plans, area plans, and environmental laws and regulations are referenced to establish the environmental indicators and major issues.

3.2. Defining the Driving Force

In order to produce a land use scenario, it is necessary to define the driving forces that determine future land use demand. This means determining major elements of the spatial plan. In the case of a regional plan, population and land use policies are considered major driving forces [40]. Population can be expressed with population growth rate or projected future population, which can be determined using the data available from Statistics Korea, or the spatial plan's population goal. Determining the policies is at the core of land use scenario preparation, and the scenario's policy direction is shaped here. On the basis of the plan's environmental goals, environmental issues shaping the growth pattern, and problems or necessary tasks, policies are determined while taking into account the administrative goals and their direction, implementation strategies and methods, demand, and supply, as well as location and timing. A minimum of two policies are established, including "no action."

3.3. Developing Spatial Plan Alternatives Using "What If?"

The study's spatial plan alternatives are prepared with "What if?" through the following three processes: land use demand model (growth model), land supply model (suitability model), and land allocation model (allocation model). A variety of scenarios can be prepared depending on the established policy direction, population projection, scope of variables, and application of weighted values.

3.3.1. Land Use Demand Model (Growth Model)

A land use demand model is based on the projected future population. Land use demand is determined both by external decision factors like population prediction and selective decision factors like density and land use rate (Figure 3). Future population can be projected from the general plans created at the regional level or data obtained from Statistics Korea. The estimation can be adjusted according to the plan's direction. Land use demand can also be identified for the entire city, or by usage type if necessary (residential, commercial, manufacturing, *etc.*).

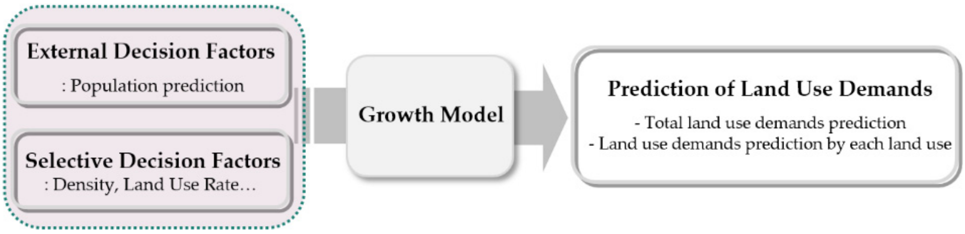


Figure 3. The analysis process of the land use demand model (growth model).

3.3.2. Land Supply Model (Suitability Model)

The purpose of the land supply model (suitability model) is to locate on a map developable land that is suitable for a particular use, according to the locational requirements [31]. Suitability analysis of "What if?" consists of the following five processes (Figure 4): select suitability assessment items, determine assessment items' weighted values, convert each item requirement into scores, determine land use conversion elements, and convert suitability into scores [29]. Maps are then created that show suitable land according to use and scores.

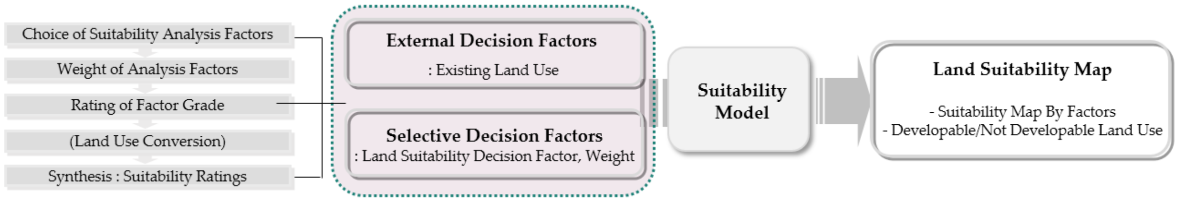


Figure 4. The analysis process of the land supply model (suitability model).

The land supply model, which shares a great deal of similarity with the suitability assessment process, tends to focus on the environmental aspect. Recently, however, the market and other factors are increasingly being incorporated. In the current study's suitability analysis, assessment criteria that examine both preservation values and development values of a land were applied in order to deduce a realistic picture of useable land and changes in land use.

Suitability assessment items are selected during the general review process, while taking into account the area's environmental issues and selected environmental indicators. Suitability assessment items typically selected for regional spatial plans include slope, altitude, green ratings, proximity to major thoroughfare, proximity to existing urban areas, *etc.*, which can be modified or added on according to the area's environmental needs and policies.

Subsequently, weighted values for the items are determined in discussion with the region's environmental experts and relevant public employees, urban planners, and community members, and based on the region's environmental needs and selected environmental indicators. Upon determination of the weighted values, suitability assessment items are ranked by each item category. For the ranking, legal and institutional definitions of each assessment item are applied. According to the land's development and preservation value, land usages can be distinguished into five ranks, ranging from developable area to high preservation area.

3.3.3. Land Allocation Model (Allocation Model)

The land allocation model determines the size of useable land, based on suitability assessed in the supply model. In this process, policy variables are suggested and applied, which include growth promotion/restriction area, land use area/district, minimum infrastructure demand, and so forth (Figure 5).

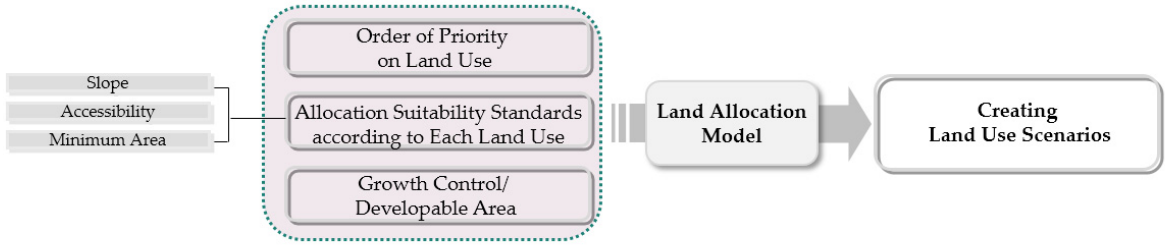


Figure 5. The analysis process of the land allocation model (allocation model).

The land allocation model can distribute the projected land use demand (residential, commercial, manufacturing, *etc.*) based on the land's suitability for these uses. By entering in the model the order of priority attached to potential land uses, land allocation can be prioritized according to prioritization of land use. Also, by establishing the preservation area (development restriction zone), development area, *etc.*, the direction of land allocation can be controlled.

Preservation zones (development restriction zones) are designated where absolute conservation is required, while taking into account the relevant characteristics of the area. Preservation zone designation criteria incorporate the Guidelines for Land Use Suitability Assessment (2010) by the Ministry of Land, Infrastructure and Transport [42], as well as regional ordinances. The Guidelines include criteria for designation of preservation zones, stock maps, and water quality preservation. If these criteria are inapplicable to a particular region's circumstances, they may be modified by the review of the local urban planning council.

3.4. Environmental Assessment of Spatial Plan Alternatives

One of the notable advantages of utilizing a PSS such as "What if?" in preparing spatial plan alternatives is that it allows for quantitative assessment. Quantitative assessment methods are based on spatial environmental plan drawings or sensitivity maps, which are used to assess the suitability of alternatives. The GIS-based map overlay technique is used to spatially assess each scenario. Environmental assessment of spatial plan alternatives allows evaluation of the alternatives' consistency with existing environment plans, as well as their environmental soundness and sustainability. As for spatial environmental plans in Korea, details of the Environment Conservation Plan mandated by law are reflected in its entirety, or sensitivity maps incorporating specific preservation zones and vulnerable areas are prepared, which are then overlaid in order to determine environmentally vulnerable areas or problem areas. Assessment results are presented with overlaid maps, which can be quantified via spatial changes and changes in area size. Because using spatial information in land use planning and its assessment is based on specific and objective evidence, it enables clear decision making. Moreover, an assessment based on quantitative data—such as changes in the size of green area, reduction in green belt area, *etc.*—can increase the assessment's validity and provide the data required to modify the alternatives.

4. Applying the PSS to a Case Study

4.1. Establishing the Environmental Indicators

In order to establish the environmental indicators that affect the growth patterns of Gyeonggi Province, a comprehensive review of existing plans for the area was performed. The review subjects included current issues identified by the 2020 Gyeonggi Province Comprehensive Plan (2011–2020) [34], the Gyeonggi Province Environment Conservation Plan [33], and the 2020 Seoul City General Plan [36]. According to the review results, major environmental issues pertaining to the area include designation of conservation areas, such as legally protected zones and green zones, designation of green networks, designation of air pollution control zones, and designation of natural disaster hazard zones. As for factors influencing the area's growth pattern, growth centered on old city centers and infrastructure-oriented growth were identified. Thus, natural eco-system (green networks, preservation zones, development restriction zones, *etc.*), air and micro climate (air pollution control zones, *etc.*), and natural disaster prevention (flood hazard zone, landslide hazard zone, *etc.*) were selected as the environmental indicators for the Gyeonggi Province area.

4.2. Defining the Driving Force

Typically, the strongest driving forces of spatial planning are spatial planning policies and population [40,43]. Considering the trends in planning and Gyeonggi Province's circumstances, the projected population size of the target year, 2020, was used. The projected future population was based on estimates by Statistics Korea's provincial and city plans and the combined estimated population of cities and counties. Spatial planning policies were established while taking into account the environmental issues, problems, and tasks that are shaping Gyeonggi Province's growth pattern, as well as the administration's planning goals and direction, implementation strategies, and methods. The results of examining Gyeonggi Province's environmental issues indicated that designating preservation zones (*i.e.*, legally protected zone, green zone, *etc.*), establishing a green network, growth centered on old city centers, and infrastructure-oriented growth were elements to consider. The resulting spatial policies are: a spatial plan with minimal preservation effort and preservation-oriented spatial planning (stringent application of environmental regulations), both of which were analyzed.

4.3. Developing Alternative Land Use Scenarios Using "What If?"

4.3.1. Land Use Demand Model (Growth Model)

Projected population size of the target year (2020) was obtained upon comparing Statistics Korea's estimated population size, estimated population size of the provincial plan, and combined estimated population size of the sub-cities and counties. Projected population size was for the target year of 2020, and it was based on the total population of Seoul metropolitan area, which includes the Seoul, Gyeonggi Province, and Incheon City area. Statistics Korea's estimated population was obtained based on The Future Population Special Prediction of Cities and Counties [38]. As for the general plan's estimated population, the estimated population size suggested by the Gyeonggi Province Comprehensive Plan and the estimated population size suggested by the general city plans of Seoul City and Incheon City were combined. Estimated population sizes suggested in the general city plans of cities and counties in Gyeonggi Province, and estimated population sizes suggested in the Seoul City General plan and Incheon City General Plan were combined.

Considering that the estimated industrial population is directly associated with land use demand in the Seoul metropolitan area, industries were distinguished as primary, secondary, and tertiary. As for data regarding the industry-specific population in 2020, because the estimated population suggested in each city's and county's basic city plan was the only data source, the remaining items were arbitrarily created so as to be proportional to the estimated population.

Table 1 presents the details of estimated population entered into the demand model, and Table 2 presents the results and estimated land use demand.

Although variables such as population data (total population, population by industry, population by generation, *etc.*), land use proportion, and density (planned density by region) can be plugged in to the model to predict scenarios, the current study only incorporated total population, population by industry, and population by generation, while taking into account regional hierarchy. The other variables for 2009, such as density, were projected according to the assumption that they will continue through the target year.

Table 1. Projected population of the Seoul metropolitan area in 2020. (Unit: no. of persons).

Contents		Statistic Korea		Gyeonggi Province, Seoul and Incheon Cities' Plan		Each Sub-City's and County's Plan	
		2009	2020	2009	2020	2009	2020
Population		24,524,765	25,786,376	24,524,765	27,179,000	24,524,765	29,428,800
Industry Population	Primary Industry	14,074	275,239	14,074	290,104	14,074	314,118
	Secondary Industry	2,035,430	3,249,575	2,035,430	3,425,073	2,035,430	3,708,591
	Tertiary Industry	6,947,357	9,151,233	6,947,357	9,645,456	6,947,357	10,443,880

Table 2. The prediction of total land demands according to the 2020 predicted or planned population.

Contents		Statistic Korea	Gyeonggi Province, Seoul and Incheon Cities' Plan	Each Sub-City's and County's Plan
Population (No.)	2020 Predicted Population	25,786,376	27,179,000	29,428,800
Land Demands (km^2)	Spatial Plan for Basic Preservation	655.25	759.17	927.63
	Spatial Plan for Strict Preservation	650.40	754.04	921.26

4.3.2. Land Supply Model (Suitability Model)

Suitability assessment examined a land's preservation value and development suitability. For preservation value, current land usage and environmental suitability items (altitude, slope, and natural ecosystem) were considered. Development suitability factors include proximity to existing city centers, major thoroughfares, highway exits, and subway or railway stations. Assessment items and evaluation criteria for each item were based on existing literature and ordinances, and in discussion with experts and other relevant personnel (Table 3). The same weighted value was applied for all assessment items (Figure 6).

Table 3. The factors and grades for land suitability analysis.

Analysis Factors		1	2	3	4	5
Existing Land Use		Urbanized Area	Farm Land	Grassland, Bare Land	Forest	Water and Wetland
Natural Suitability	Slope	Under 5°	5°–15°	15°–20°	20°–25°	25° or more
	Altitude	Under 100 m	-	100–200 m	-	200 m or more
	Eco-Natural Map	3 grade	-	2 grade	-	1 grade
Distance	Distance from Expressway Gate	Under 1 km	1–2 km	2–3 km	3–5 km	5 km or more
	Distance from Main Road	Under 500 m	500–1000 m	1000–2000 m	2000–3000 m	3000 m or more
	Distance from Train or Subway Station	Under 1 km	1–2 km	2–3 km	3–5 km	5 km or more
	Distance from Existing Urban Area	Under 1 km	1–2 km	2–3 km	3–5 km	5 km or more

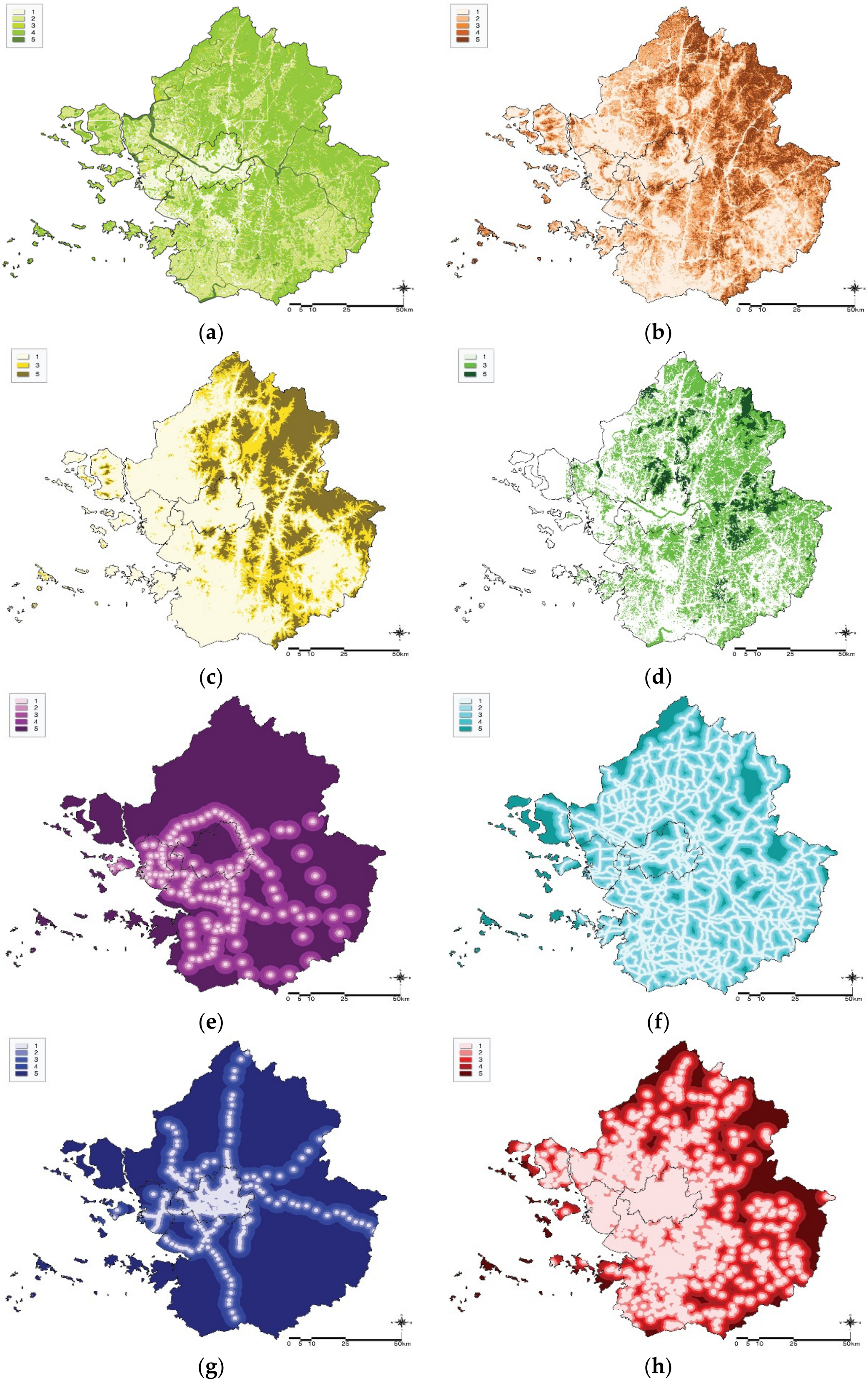
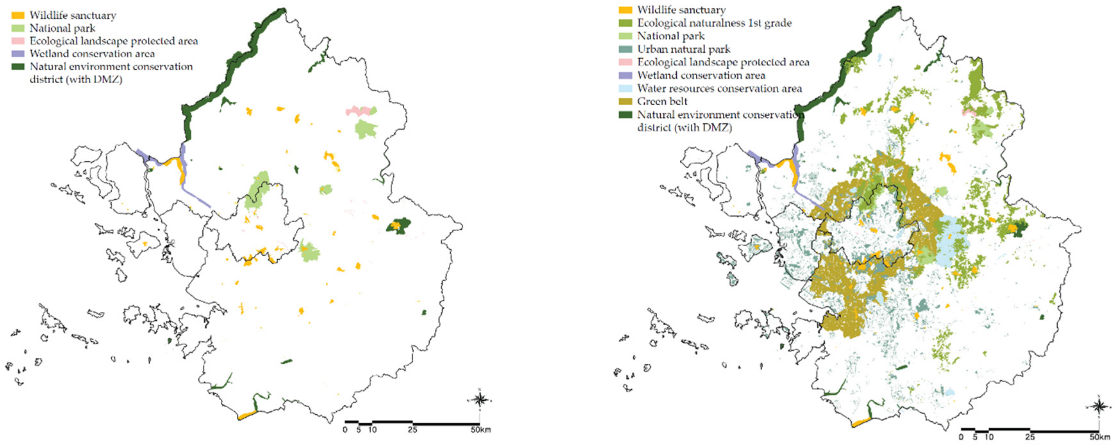


Figure 6. The analysis results according to elements for suitability evaluation: (**a**) existing land use; (**b**) slope; (**c**) altitude; (**d**) eco-natural map; (**e**) distance from expressway gate; (**f**) distance from main road; (**g**) distance from train or subway station; (**h**) distance from existing urban area.

Regarding legally protected areas, strict preservation areas were selected and applied in the suitability model. Considering that the preservation areas are at the regional rank, the smallest possible area was established for preservation area (Table 4; Figure 7). Other areas in need of preservation were reflected in the assessment process using the sensitivity maps.

Table 4. Conservation areas where development is impossible.

Contents	Applied Areas
Spatial plan for basic preservation	Ecological landscape protected area, DMZ, Wildlife sanctuary, National park, Wetland conservation area
Spatial plan for strict preservation	Ecological landscape protected area, DMZ, Wildlife sanctuary, National park, Wetland conservation area, Eco-natural map 1st Grade, Green belt, Urban natural park, Water resources conservation area



(**a**) (**b**)

Figure 7. The analysis of preservation areas: (**a**) spatial plan for basic preservation; (**b**) spatial plan for strict preservation.

4.3.3. Land Allocation Model

Determining development promotion areas in the land allocation model was done while using the projected new city areas and the suitability assessment's development-related proximity indicators. First, we wanted to include the areas confirmed for development according to existing development plans, including new city plans and industrial complex plans. However, due to the difficulty of obtaining data, we limited the study to areas projected for a large-scale new city development (areas confirmed for new city development as of 2009).

In addition, development promotion areas were determined with a focus on infrastructure. An examination of the Seoul metropolitan area's environmental issues identified growth centering on old city centers and infrastructure-oriented growth to be important elements for consideration. As such, while focusing on urban infrastructure (major roads and railway), development promotion areas were distinguished according to proximity indicators (Table 5).

Development promotion areas were ranked based on the aforementioned details. Expected new city development zones took first priority. The rest were determined based on the combined ratings pertaining to proximity to infrastructure and public facilities. On the basis of these results, land use demand was to be allocated according to the development promotion areas' ranking (Figure 8).

Table 5. The grade and standard of developable areas based on existing plans and infrastructure.

Grade	2009 New City Plan	Main Transportation Infrastructure	Cities, Counties, Boroughs
1	Development Arranged Area	-	-
2	-	1 km or less	3 km or less
3	-	1–3 km	3–5 km
4	-	3–5 km	5–10 km
5	-	5 km or more	10 km or more

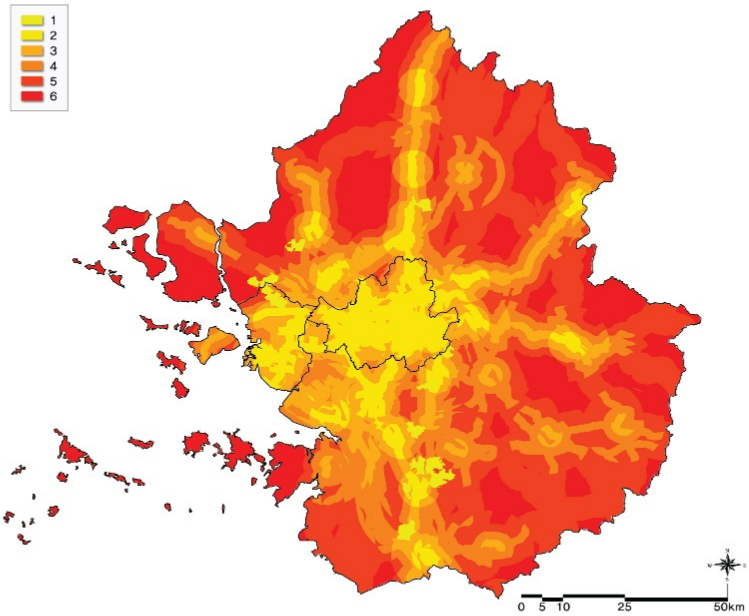
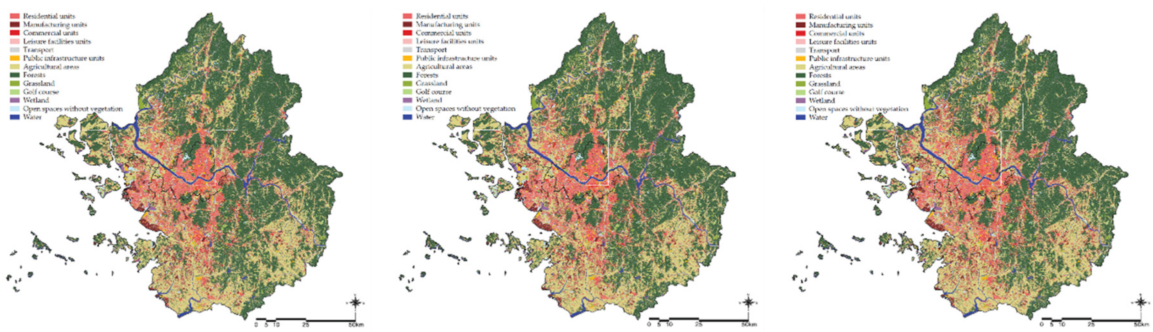


Figure 8. The result of developable areas analysis.

4.3.4. Producing the Spatial Plan Alternatives (Land Use Scenarios)

The current study produced a total of six scenarios (Figure 9), three (1, 2, 3) of which pertain to the demand according to changes in population and industry, two (A, B) to supply/allocation considering the designation of preservation zones (areas where development is prohibited). Changes in land use were analyzed for each scenario.



(**A1**) (**A2**) (**A3**)

Figure 9. *Cont.*

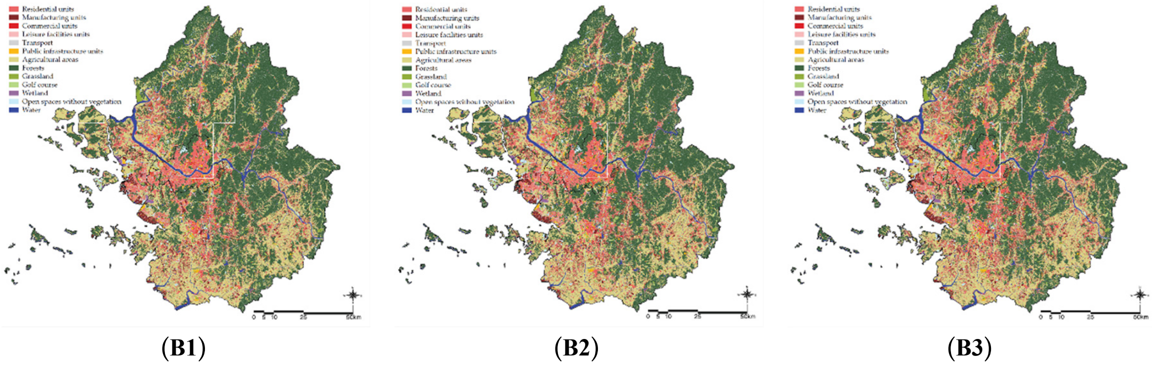


Figure 9. The alternative scenarios. Spatial policy: (**A**) spatial plan for basic preservation; (**B**) spatial plan for strict preservation. Population: (**1**) Statistics Korea's predicted population; (**2**) metropolitan cities' (Gyeonggi Province/Seoul/Incheon) planned population; (**3**) each city's and county's planned population.

4.4. Environmental Assessment for the Spatial Plan Alternative

The environmental assessment of the scenarios examined the three issues most crucial for land use planning: natural ecosystem, air and microclimate, and natural disasters. For the assessment, we considered the Gyeonggi Province's Spatial Environmental Plan using sensitivity maps (Figure 10).

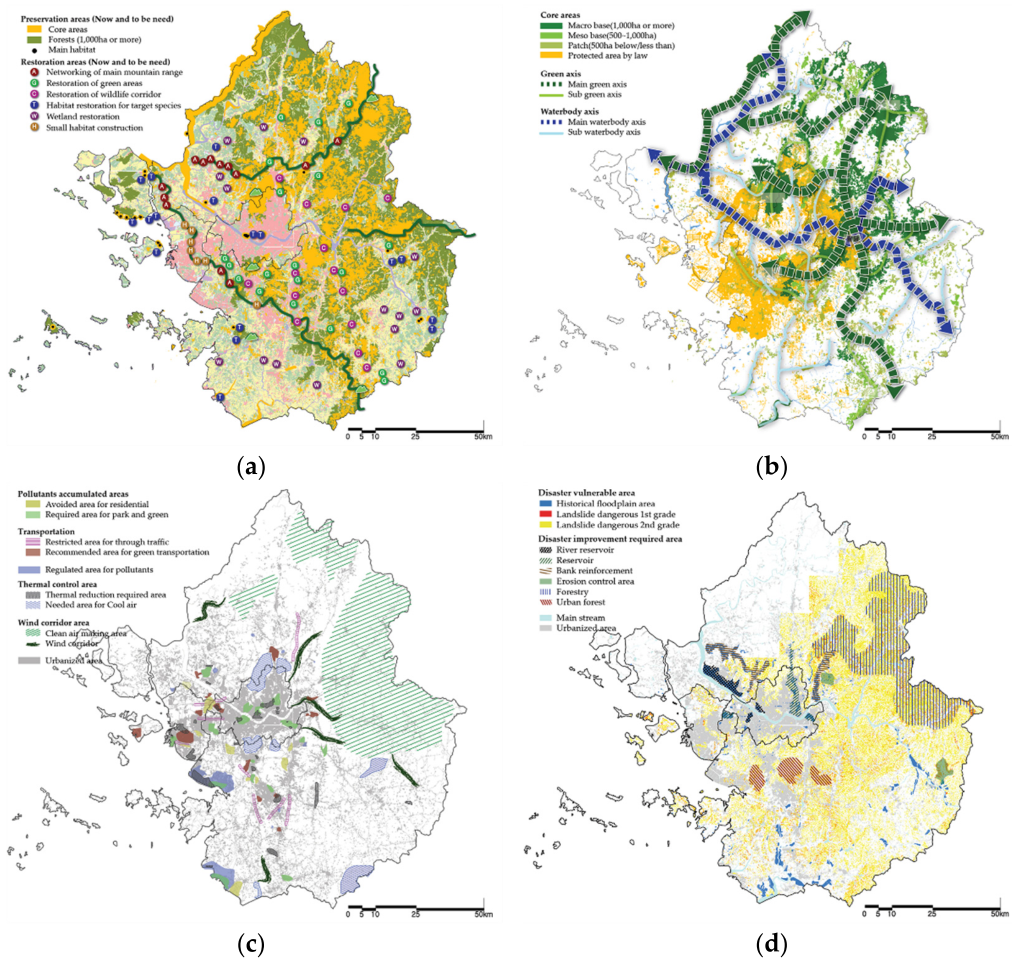


Figure 10. A sensitivity map of metropolitan areas by environmental issues: (**a**) natural ecosystem 1; (**b**) natural ecosystem 2; (**c**) air and microclimate; (**d**) natural disasters [10].

The sensitivity maps (spatial environmental plans) include not only the sensitivity of the current situation, but also land considered either sensitive and potentially subject to future development or unsuitable for exploitation, such as development zones. The natural ecosystem map was drawn with a focus on the green and waterbody axes that represent the circulation systems and natural network centered around the core area, and the thematic map centered on the preservation and restoration areas. The air and microclimate map included not only currently sensitive areas in which development needs to be avoided due to high pollution, winds, or microclimate, but also an area that needs to be secured as a wind corridor from the air and microclimate management perspective. The natural disaster map includes not only areas directly vulnerable to disaster, but also sensitive areas in terms of planning, including areas that will require improvements in order to ameliorate their vulnerability. In this sense, this is also a process for securing the conformity of the spatial planning and environment planning processes, similar to the overlap analysis of the spatial environment plans, which considers the land usage scenarios and the sensitivity maps.

For the assessment, the six land use scenarios and sensitivity maps created for each area of interest (natural ecosystem, air and microclimate, natural disaster prevention) were overlaid to deduce the preservation areas, areas with environmental vulnerabilities, and areas with potential problems, which were then expressed in a map. For instance, the results of overlaying A1 air/microclimate and natural disaster maps are displayed in Figure 11.

(**a**) (**b**)

Figure 11. The overlap result of A1 scenario and sensibility map: (**a**) vulnerable areas for air and microclimate; (**b**) vulnerable areas for natural disasters.

Comparing the land use patterns of the scenarios, in the case of the scenario based on the environmentally friendly spatial plan for basic preservation, land use was heavily concentrated along the Seoul–Gyeonggi border, which is thought to have a detrimental effect on the green zone around the area. Also, heavy land use was found in the southern and southwestern suburbs of Seoul, while no significant change in land use was found for the northern and eastern Gyeonggi Province area. In the case of the preservation-oriented spatial plan (stringent environmental regulations applied), changes in land use were negligible for Seoul–Gyeonggi border areas and parts of southern Gyeonggi Province, which is thought to decrease the negative impact on the area's green zone. Increase in land use appears to spread from city centers to the suburbs, and is fairly evenly distributed across the entire Gyeonggi Province with a focus on infrastructure (Figure 12).

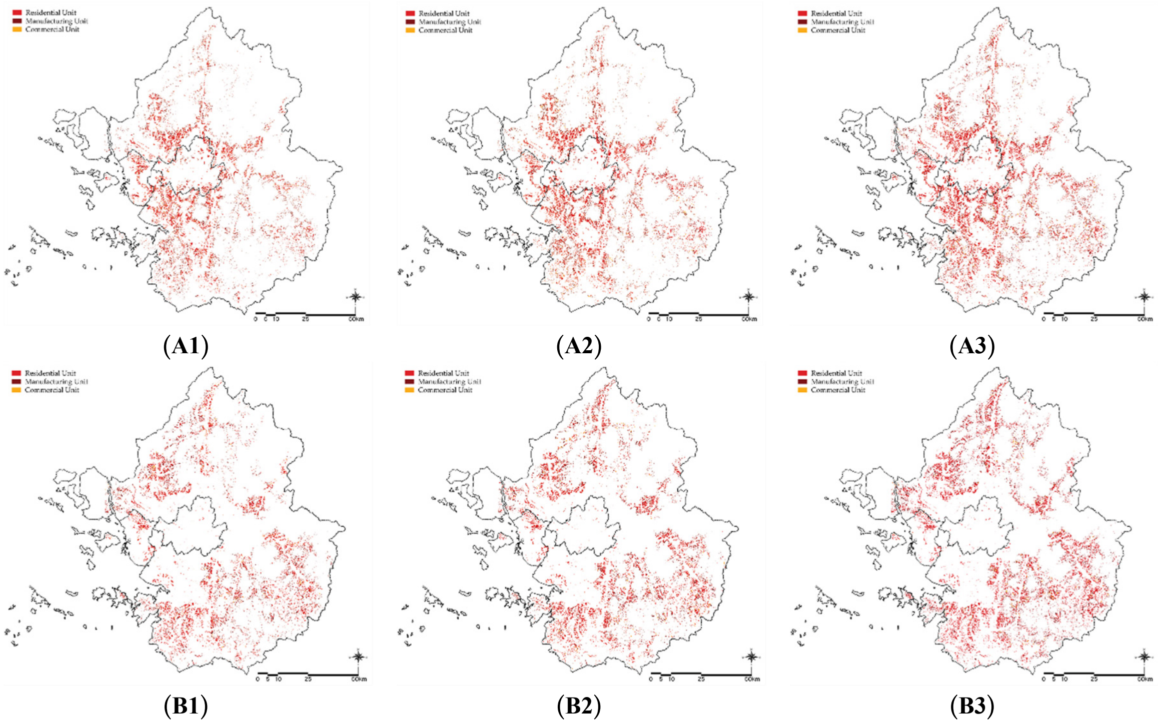


Figure 12. Land use patterns by scenario. Spatial policy: (**A**) spatial plan for basic preservation; (**B**) spatial plan for strict preservation. Population: (**1**) Statistics Korea's predicted population; (**2**) metropolitan cities' (Gyeonggi Province/Seoul/Incheon) planned population; (**3**) each city's and county's planned population.

Changes in land use demand and the size of environmentally vulnerable areas were deduced to facilitate a quantitative assessment. Results obtained by overlaying the spatial plan alternatives and the sensitivity maps indicated that the preservation-oriented spatial plan was superior to the basic preservation spatial plan across all indicators, in terms of preservation (Table 6). The size difference was twice as great in the development area not recommended for residence. On the other hand, the size of the damaged area varied greatly by population indicator. A significant difference was found with a small population, while the difference was not significant with a large population.

Table 6. The comparison of scenarios by evaluation indicator levels: Area change.

Evaluation Factors	Evaluation Indicator	Analysis Results by Scenarios (km^2)					
		A1	A2	A3	B1	B2	B3
Natural Ecosystem	Land Use Change	655.25 2	759.17 4	927.63 6	650.40 1	754.04 3	921.26 5
	Forest to be Damaged	545.04 2	631.30 4	789.33 6	526.07 1	624.11 3	777.76 5
	Preservation Areas to be Damaged	222.25 2	256.90 4	335.68 6	202.22 1	256.22 3	334.64 5
Air and Micro-climate	Development Area Not Recommended for Residence	11.73 4	12.52 5	13.59 6	4.86 1	5.77 2	6.26 3
Natural Disaster	Development Area in Vulnerable Area for Disaster	24.89 3	27.98 4	32.25 6	21.52 1	24.47 2	28.81 5
	Ranking	1459.16 2	1687.87 4	2098.48 6	1405.07 1	1664.61 3	2068.73 5

Spatial policy: (**A**) spatial plan for basic preservation; (**B**) spatial plan for strict preservation. Population: (**1**) Statistics Korea's predicted population, (**2**) metropolitan cities' (Gyeonggi Province/Seoul/Incheon) planned population, (**3**) each city's and county's planned population. Level of change: 1 < 2 < 3 < 4 < 5 < 6.

The scenarios were analyzed and compared for the three indicators of natural ecosystem, air and microclimate, and natural disaster prevention (optimal-1, worst case-0). Policy B was environmentally superior to Policy A across all population indicators. As for the environmental impact of increasing population, natural ecosystem was the indicator that exerted the greatest impact in both policies A and B (Figure 13).

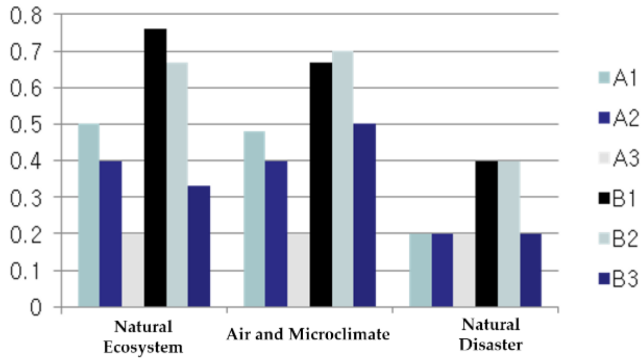


Figure 13. The comparison of scenarios according to environmental issues.

In summary of the assessment results, the B1 scenario—which is preservation-oriented (stringent environmental regulations applied) and uses Statistics Korea's population estimate—had the most positive environmental impact. B1 ensures consistency with higher level spatial plans pertaining to multicore connected spatial structure, balanced metropolitan area growth, underdeveloped metropolitan area development, and so forth. It also incorporates the green and water networks of the province's general plan to ensure consistency. In terms of the region's environmental issue of forest area reduction, it appears that major forests are protected. In terms of balancing preservation and growth, it appears that securing alternative development sites will not be difficult because damaged areas resulting from the development areas located within the preservation zones are seen in the city outskirts where development is relatively slow.

4.5. Summary of Alternatives and Environmental Assessment

In order to select the spatial plan alternative and the method with which to visually and quantitatively assess the plan, the developed framework was applied to the Seoul metropolitan area with a focus on Gyeonggi Province. Issues that were discussed in the analyses were: First, the size of an urban area increases in proportion with the area's land use demand resulting from population growth, and the total amount of change stayed more or less the same regardless of whether or not environmental policies were tightened. Second, changes in environmental policies have a negligible impact on the total land use demand. However, their impact on the land use pattern is significant. Third, in the case of Scenario A, the development area is spreading in a linear fashion along the existing infrastructure of roads and railways, while Scenario B shows a development consisting of wide areas centering on infrastructure.

5. Discussion and Conclusions

The current study was conducted to provide decision makers with environmental data and spatial alternatives that reflect policies and land use demand, in order to assist them in efficiently deducing optimal alternatives. In particular, visualized assessment results based on spatial alternatives and spatial environmental plans (e.g., sensitivity maps) are thought to help decision makers plan a more sustainable future. However, many cities currently lack a sufficient spatial environmental database, and spatial environmental plans are not actively being established based on such data, which suggests that a great deal of time and effort will be needed before an environmental assessment can be made.

Each city needs to develop guidelines for spatial environmental plans (or sensitivity maps) that include the environmental standards and planning techniques appropriate to that city. The current study offers the following implications and recommendations for the future.

First, it is necessary to develop a standardized PSS that can be adapted to suit the needs of each country and city. The "What if?" model used in the study is easier to use than other models. However, it has room for improvement in terms of accommodating the particular circumstances of all countries and cities. As such, improving and standardizing the tool to allow development projects that consider the distinct nature of each country and city are necessary in order to deduce the various logical and scientific alternatives that can be used in the decision-making process.

Second, research on environmental assessment techniques for spatial planning needs to be expanded. Environmental assessment for spatial planning can be used as a support tool for a land use plan (spatial plan) by creating spatialized alternatives and providing assessment results [44,45], thus paving the way for clear decision making [46]. It can also increase the likelihood of more accurate and quantitative future predictions and assessments [15,24]. Moreover, spatialized and visualized data—which are generally easier to understand—can increase the public's participation in the decision-making process. However, spatial environmental data are still scarce, and even the currently available data lack consistency in scale. Moreover, data tend to vary depending on the information source (central government, local governments, departments), and the imbalance of data between regions and fields makes it difficult to utilize the data. Therefore, in order to optimize environmental assessment for spatial planning, spatial environmental database must be established, and national standardization of the data system must be achieved. Furthermore, systematic management of environmental data is necessary.

Third, an e-governance system would be beneficial. Environmental assessment may be defined as a decision-making process in the sense that, at its core, it is a process for deducing a social agreement on sustainability and development [47]. Typically, opinions are converged via conferences, public hearings, information sessions, and other such venues. However, due to time and budgetary restraints, a more efficient and practical way to promote public participation is needed [23]. An e-government system allows easy online information-sharing pertaining to spatial planning, subject areas' current circumstances and issues, assessment and analysis results, and so on, to promote active public participation and consensus.

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