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Biotope Map Creation Method and Utilization Plan for Eco-Friendly Urban Development

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Abstract: A biotope map provides ecological and spatial information that reflects the natural and ecological features and values of a city. In South Korea, efforts have been made to create a map that includes grades based on evaluating the ecological value of a specific surface space. However, plans for applications have not been established, except for development restrictions or regulations for biotopes with high ecological value ratings. The aim of this study was to promote environmentally friendly and sustainable urban management through ecological land use management for all biotope types that are influenced by anthropogenic land use. Strategies for maintenance, protection, recovery, improvement, creation, and reduction based on ecological restoration principles were set as management goals. To achieve these management goals, evaluation items and indicators were suggested for minor-classification types and applied to Dongducheon City. Management strategies were suggested for target sites based on grades and thematic maps of biotope types to be utilized, such as urban ecological axes, river naturality restoration, and wetland and forest preservation. These findings support sustainable and environmentally friendly urban development by providing fundamental data for ecological and environmental management, including the preservation and restoration of natural environments and the creation of urban ecological networks.

Keywords: biotope; biotope map; biotope-type; biotope evaluation; urban ecological map

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1. Introduction

The word biotope is derived from the Greek words "bios," meaning life and species, and "topos," meaning place and space [1]. Biotope refers to a spatial unit of habitat for a specific biotic community with spatial boundaries [2,3]. Since the 1970s, when urban densification and expansion accelerated, the balance between natural ecological system and anthropogenic development started to break; consequently, efforts have been made to have a landscape perspective that further encompasses ecological aspects to restore the imbalance of urban ecological systems and human behavioral aspects [4]. From this perspective, biotope maps offer a valuable perspective by visually presenting species distributions and habitats. This visual representation helps identify and determine areas to be protected and identify patterns of the areas. In Germany, biotope types are determined by analyzing aerial photographs. The natural environment of research target sites is not investigated individually, but the current status of the entire area is examined through biotope-type classification [5]. A biotope map mainly consists of biotope-type classification and evaluation. Biotope-type classification is used to classify similar areas with ecologically unique and persistent environmental conditions for flora and fauna [6]. Biotope evaluation involves assigning grades to evaluation targets using an objective scale that can be utilized to compare the importance of relationships with humans against other values [7]. Biotope evaluation criteria have been studied by Ractliffe [8], Auhagen and Sukopp [9], Johnston [10], Placher [11], Marsh [12], Caldecott et al. [13], and Dießen and Roweck [14]. These authors suggested the following criteria: rarity, naturality, typicality, recuperative

ability, vulnerability, ecological functionality, and usefulness. In South Korea, research has been conducted by Choi [15], Kwon [16], Kim [17], Choi [18] and naturality, diversity, rarity, potential, representativeness, and area have been commonly utilized as criteria.

In Korea, the need for urban environmental management through biotope maps for sustainable urban management has been increasing [19]. Amidst concerns about insufficient consideration of natural environments during urban planning, the Land Planning-Environmental Planning System was introduced in 2014 (Enactment of the joint order between the Ministry of Land, Infrastructure and Transport, and the Ministry of Environment); if ecological and spatial information is insufficient, it is difficult to obtain a balance between development and conservation and thus the application of a biotope map becomes essential [20]. Since the 2017 amendment of the Natural Environment Conservation Act (Article 34-2: Drafting and Utilization of Urban Ecological Maps), it has been required to create a biotope map for each city [21].

Although each city has created a biotope map, it has primarily been utilized as a tool to restrict and regulate development by identifying biotope types with high ecological value [22]. This limited utilization of biotope maps may overlap with ecosystem and nature maps (provided by the Ministry of Environment, the Korean government ministry) or other data for ecologically protected areas, which may undermine the intended purpose of introducing a biotope map. This is due to the lack of consideration of utilization while creating a biotope map. A biotope map enables the classification and evaluation of biotope types. However, before this can be achieved, it is essential to establish classification criteria that consider resource utilization when classifying biotope types. Without these classification criteria, a simple classification based on biotic and abiotic differences makes it challenging to anticipate future utilization. Additionally, the evaluation of classified biotope types typically does not include recommendations for increasing their environmental value. Biotopes are evaluated and assigned grades ranging from 1 to 5, where 1 represents the highest ecological value. Biotope types assigned to Grade 1 are mainly utilized for conservation. It is difficult to suggest a utilization plan for biotope types rated as Grades 2 to 5 because the purpose for utilization remains unclear. Therefore, it is crucial to develop biotope maps that can be utilized for various plans and policies, such as environmental ecology plans tailored to their objectives [23], as well as the necessary research to support their creation.

The scope of biotope maps has expanded beyond abiotic environments, such as biological habitats with high species diversity, soil, water, and climate conservation spaces, to spaces with sociological and aesthetic significance for humans, such as spaces for urban leisure and recreational activities, spaces providing visual and aesthetic comfort, and areas designated for educational purposes [24]. When assessing a natural environment, which is generally considered to be excellent, it is crucial to consider biological and abiotic factors. Abiotic factors, such as soil conditions, topography, surface temperature, human use, and cultural human behavioral factors, should be thoroughly evaluated alongside these biological factors. A biotope map is closely related to human land use. As a concept based on which data on ecological environments are spatialized, it is necessary to identify which areas should be conserved, restored, and improved [25]. Thus, a more comprehensive utilization plan for environmentally friendly urban development is required. This plan can be established using ecological improvement plans for each biotope evaluation grade, which are appropriate for urban characteristics, including biotope types with low and high ecological values.

The aims of this study were (1) to clarify the purpose of each biotope type to obtain a balance between development and conservation in the entire city instead of limited utilization of biotope maps for development regulation only, and (2) to derive evaluation indicators for each purpose. We established a method that can be utilized to create a biotope map that includes the purpose of each biotope type and corresponding evaluation indicators. The new biotope map creation method was applied to a target site. We present evaluation results for different biotope types that can be used for environmentally friendly

urban development, utilization plans for each evaluation grade, and a thematic map for environmental improvement based on the biotope type.

2. Materials and Method

2.1. Site Selection in Previous Studies

It can be easily applied when precisely setting purposes to be obtained through biotope categorization and evaluation. After collecting a list of biotope types and evaluation results from previous studies, we derived management goals for each biotope type as well as evaluation indicators for the goals. In this study, the Gyeonggi Province, which experiences the highest levels of urbanization and development pressure in South Korea, was selected as the study site. We collected data from urban ecological maps (biotope maps) for six cities: Siheung City, Goyang City, Gwangju City, Pyeongtaek City, Hwaseong City, and Guri City. These cities were chosen because they represent the country's environment, encompassing new and old cities, coastal and inland areas, industrial and agricultural areas, and forested and plain regions (Figure 1), (Table 1).

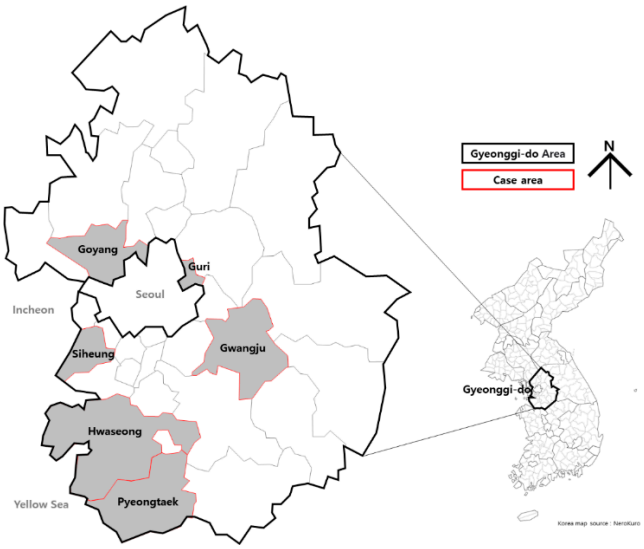


Figure 1. Map of the locations of previous study sites.

Table 1. Characteristics of previous study sites.

Study Site	Biotope Map Creation Year	Area	Environmental Characteristics of the City	Meso-Classification Evaluation Sections
Siheung	2020	139.9 km^2	Coast-inland, industry-agriculture, high urban density	Meso-classification evaluation grade I–V
Goyang	2022	268.1 km^2	Old town-new town, flatland-mountain, high development of flatland	Meso-classification evaluation grade I–V
Gwangju	2021	431 km^2	industry-agriculture, forest, high development around the forest	Meso-classification evaluation grade I–V
Pyeongtaek	2021	457.9 km^2	Coast-inland, old town-new town, flatland, high development flatland	Meso-classification evaluation grade I–V
Hwaseong	2021	700.6 km^2	Coast-inland, old town-new town, flatland, high development flatland	Meso-classification evaluation grade I–V
Guri	2022	33.3 km^2	Forest-flatland, high urban density	Meso-classification evaluation grade I–V

2.2. Biotope Meso-Classification Type Evaluation Grades for Previous Study Sites

Overall, a biotope map was used to evaluate the conservation value of biotopes while considering their relationship with humans [26]. The biotope taxonomy is designed to have a major-, meso-, and minor-classification system. Major- and meso-scale classifications follow the types specified by the Guidelines on Standardized Maps at the regional and national levels [23]. Therefore, it is necessary to review the grade of the meso-classification type when arranging common biotopes in order of ecological importance. First, we examined the average grade of biotope meso-classification types in six regions in the Gyeonggi Province, which experiences the highest urbanization and development pressure in South Korea. We observed the following trends: biotopes with Grade 1, which are the most stable ecosystems, including green biotopes (e.g., Natural river, Natural wetland, Natural coast, and Natural forest), to Grade 5, including urban biotopes with the lowest preservation value, tend to be rated similarly in regions (Table 2).

Table 2. Biotope meso-classification type evaluation grade for each site.

Biotope Major-Classification Types	Biotope Meso-Classification Types	Biotope Meso-Classification Type Evaluation Grade for Each Site						Average Meso-Classification Type Evaluation Grade
		Siheung [27]	Goyang [28]	Gwangju [29]	Pyeongtaek [30]	Hwaseong [31]	Guri [32]	
Residential area	Urban detached housing	5	5	4	5	5	4	4.7
	Rural detached housing	4	4	4	4	4	4	4.0
	Low-rise apartment complex	5	5	5	5	5	5	5.0
	Mid-rise apartment complex	5	5	5	5	5	5	5.0
	High-rise apartment complex	5	5	5	5	5	4	4.8
Commercial and business area	Low-rise commercial business district	5	5	5	5	5	5	5.0
	Mid-rise commercial business district	5	5	5	5	5	5	5.0
	High-rise commercial business district		5		5	5	5	5.0
Mixed residential and business area	Mixed residential and business areas with low-rise buildings	5	5	5	5	5	5	5.0
	Mixed residential and business area with mid-rise buildings	5	5	5	5	5		5.0
	Mixed residential and business areas with high-rise buildings	5						5.0
Public-use area	Educational institutions	4	4	4	4	4	4	4.0
	Administrative and public institutions	5	5	5	5	5	5	5.0
	Hospitals and nursing facilities	5	5	5	5	5	5	5.0
	Large exercise facility site	5	4	4	4	4	4	4.2
	Religious facility site		5	5	5	5	5	5.0
	Other public-use areas	4	5	5	5	5		4.8
Industrial area	Large factories	5			5	5		5.0
	Small factories	5	5	5	5	5	5	5.0
	Warehouse	5	5	5	5	5	5	5.0

Table 2. *Cont.*

Biotope Major-Classification Types	Biotope Meso-Classification Types	Biotope Meso-Classification Type Evaluation Grade for Each Site						Average Meso-Classification Type Evaluation Grade
		Siheung [27]	Goyang [28]	Gwangju [29]	Pyeongtaek [30]	Hwaseong [31]	Guri [32]	
Supply processing facility area	Water-related facility site	4	4	5	4	5	5	4.5
	Waste-related facility site	5	5	5	5	5	5	5.0
	Energy-related facility site	4	5	5	5	5	5	4.8
	Communications-related facility site	5				5		5.0
Transportation facility area	Road	5	5	5	5	5	5	5.0
	Parking lot	5	5	5	5	5	5	5.0
	Railroad	4	5	5	5	5	5	4.8
	Port	5			5	5		5.0
	Transportation-related supplementary facility site	4	5	5	5	5	5	4.8
Special area	Construction site							Not evaluated
	Open-air storage yard		5	5	5	5	5	5.0
	Site that could not be surveyed							Not evaluated
River	Natural river						1	1.0
	Close-to-nature river	1	2	2	2	2	2	1.8
	Artificial river	2	3	3	3	3	3	2.8
	Small river	3	3	3	3	3	3	3.0
	Agricultural waterway	4	4	4	4	3	4	3.8
Lake and wetland	Natural wetland	1	1	1	1	1		1.0
	Artificial wetland	2	3	2	3	2	2	2.3
Coast	Natural coast				1	1		1.0
	Artificial coast				3	4		3.5
	Coastal structures					5		5.0
Forest	Natural forest			1	1	1	1	1.0
	Natural–artificial forest	2	2	2	2	2	2	2.0
	Artificial forest	3	2	2	2	2	2	2.2
	Shrub vegetation area		3	3	3	3	3	3.0
	Deforested and damaged area	4						4.0
	Rock outcrop		3					3.0
Grassland	Natural grassland	3	3	3	3	3		3.0
	Artificial grassland	3	3	3	3	3	4	3.2
Farmland	Wet farmland	3	3	3	3	3		3.0
	Dry farmland	4	4	4	4	4	4	4.0
	Facility-type farmland	5	5	5	5	5	5	5.0
Created green space	Artificially created park green space	4	3	3	3	3	3	3.2
	Facility-type green space	4	3	3	3	3	3	3.2
Bare land andruins	Urban abandoned land	4	5	5	5	5	5	4.8
	Rural abandoned land	4						4.0
	Mining site			5		5		5.0

2.3. Naturality Categorization for Each Biotope Meso-Classification Type Evaluation Grade

Table 3 presents the average grade of meso-classification biotopes in Siheung, Goyang, Gwangju, Pyeongtaek, Hwaseong, and Guri in the Gyeonggi Province. The grading system ranges from Grades 1 to 5 and is based on ecological value. Accordingly, naturality can be classified into three categories: nature, near-nature, and semi-nature.

(1) Nature: Nature refers to an original ecosystem with significant value or potential as a biological habitat. It falls under the meso-classification biotope evaluation Grade 1, necessitating absolute preservation due to the absence of anthropogenic disturbance or long-term stability.
(2) Near-nature: Near-nature characterizes an area with low intensity of land use and a close proximity to natural conditions. This category corresponds to meso-classification biotope evaluation Grades 2 and 3. Near-nature biotopes experience human interference and are sensitive to damage. However, they possess a certain level of naturality and a high potential for enhancing their ecological value through restoration efforts.
(3) Semi-nature: Semi-nature denotes areas constantly affected by human interference and influence. These areas can be classified as a form of human-created nature. Semi-nature biotopes are examples of meso-classification biotope evaluation Grades 4 and 5. Their potential for regeneration into natural ecosystems is low. They exhibit excessive energy utilization and disconnected circulation systems.

Table 3. Naturality categorization setting for each biotope meso-classification type evaluation grade.

Biotope Meso-Classification Type Evaluation Grade	Biotope Meso-Classification Type	Naturality Categorization
1	Natural river, Natural wetland, Natural coast, Natural forest	Nature
2	Close-to-nature river, Artificial River, Artificial wetland, Natural–artificial forest, Artificial forest	Near-nature
3	Small river, Artificial coast, Shrub vegetation area, Rock outcrop, Natural grassland, Artificial grassland, Wet farmland, artificially created park green space, Facility-type green space	
4	Rural detached housing, Educational institution, Large exercise facility site, Water-related facility site, Agricultural waterway, Deforested and damaged area, Dry farmland, Rural abandoned land	Semi-nature
5	Urban detached housing, Low-rise apartment complex, Mid-rise apartment complex, High-rise apartment complex, Commercial and business area (Major classification), Mixed residential and business area (Major classification), Administrative and public institutions, Hospitals and nursing facilities, Religious facilities, Other public-use areas, Industrial area (Major classification), Waste-related facility site, Energy-related facility site, Communications-related facility site, Transportation facility area (Major classification), Open-air storage yard, Coastal structures, Facility-type farmland, Urban abandoned land, Mining site	

2.4. Management Objectives Based on Naturality Category

In the context of landscape ecology, nature can be defined as a compilation of diverse biotopes with distinct environmental characteristics and varying spatial scales and boundaries [33]. Given the broad spectrum of biotope types, from those heavily impacted by human activities to those that are minimally disturbed, it becomes imperative to establish appropriate management goals that correspond to the level of degradation. It becomes feasible to implement ecological restoration principles based on the proximity to natural conditions, that is, based on the categorization into nature, near-nature, and semi-nature, as determined by the meso-classification evaluation grade.

Ecological restoration refers to the process of returning an ecosystem to its original state before it was impacted by external factors. This process can be categorized into

different types and stages depending on the level of change and current conditions. In other words, considering the two axes necessary for an ecosystem to play an independent role in terms of function and structure, it can be divided into several types depending on the extent to which the damaged ecosystem can be restored (Figure 2) [34]. Terms commonly used to describe the preservation and restoration of biotopes are preservation, restoration, and creation [35]. The term restoration was originally derived from the term recovery; currently, various terms are used to refer to different levels of ecological restoration [36,37]. Thus, to establish management goals for different biotope types based on their naturality (i.e., nature, near-nature, and semi-nature), we propose using the concepts of preservation, restoration, and improvement within the naturality category based on ecological restoration strategy theory correlating with the function and structure of ecosystems (Table 4).

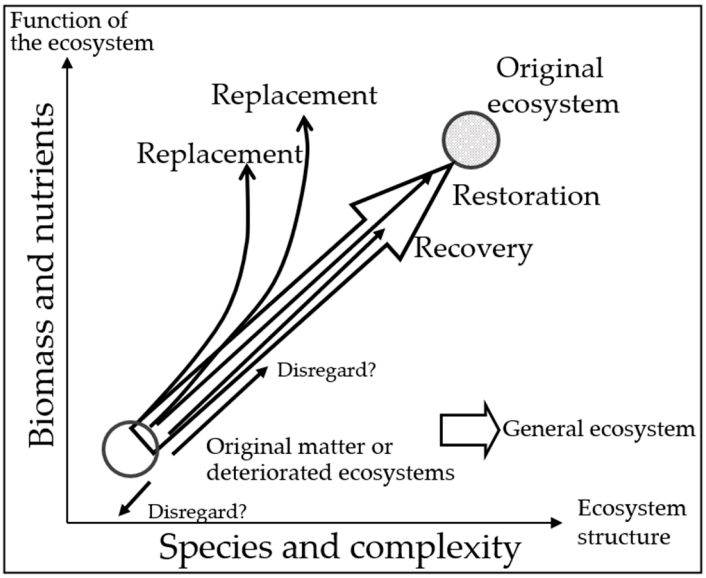


Figure 2. Stages and types of ecological restoration [38].

Table 4. Management goals based on the naturality category.

Naturality Category	Management Goals		Definition of Terms
Nature	Preservation	Maintenance	Maintain the status quo of biotopes with high ecological potential
		Protection	Protect ecologically sensitive biotopes from surrounding influences
Near-nature	Restoration	Recovery	Restore damaged or artificially modified biotopes to their previous or similar state
		Improvement	Improve the ecological quality of current biotope types through ecological management such as extensive vegetation management and induction of transition processes
Semi-nature	Advancement	Creation	Improve the ecological quality of biotope types through the creation of new biotope elements such as the creation of ecological ponds
		Reduction	Pollution source management to safeguard human health and the surrounding environment

2.5. Biotope Meso-Classification Type Evaluation Criteria with Management Goals

After analyzing the biotope meso-classification type per grade according to the naturality category, we established the grade criteria and management goals for each type (Table 5).

Table 5. Biotope meso-classification type evaluation grade criteria and management goal setting.

Naturality Category	Biotope Meso-Classification Type Evaluation Grade	Biotope Meso-Classification Type Evaluation Grade Criteria	Biotope Meso-Classification Type	Management Goals
Nature: Areas with value or high potential as biological habitats	1	Little or no human intervention; Long-term stable and mature vegetation structure; Declining biotope with high sensitivity to damage; Biotope type whose naturality is so high that alternative creations are impossible; Biotope type with very high biological habitat and ecological network functions; Biotope types with international, national, and regional importance	Natural forest	Maintenance / Protection / Recovery
			Natural wetland	
			Natural coast	
			Natural river	
Near-nature: Areas with low-intensity land use	2	Declining biotope with human interference and moderate sensitivity to damage; Certain level of naturality and conditional substitution is feasible; Biotope type with high biological habitat and ecological network functions	Close-to-nature river	Protection / Recovery / Improvement / Creation
			Natural–artificial forest	
			Artificial forest	
			Artificial wetland	
			Artificial river	
	3	Biotope with high human interference and low sensitivity to damage; Creation closer to nature from the perspective of natural protection and landscape management; Low naturality requires mid-to-long-term regeneration period; Measures to increase biotope value are required; Biotope type with medium levels of habitat function and ecological network function	Small river	
			Shrub vegetation area	
			Rock outcrop	
			Natural grassland	
			Artificial grassland	
			Wet farmland	
			Artificially created park green space	
			Facility-type green space	
			Artificial coast	
			Dry farmland	
Semi-nature: Areas continuously subject to human interference and influence	4	Biotope with very high human interference and little value as a biological habitat; Low naturality and high availability	Agricultural waterway	Improvement / Creation / Reduction
			Deforested and damaged area	
			Large exercise facility site	
			Rural detached housing	
			Rural abandoned land	
			Facility-type farmland	
			Urban detached housing	
			Other public-use areas	
			Urban abandoned land	
			Mining site	

Table 5. *Cont.*

Naturality Category	Biotope Meso-Classification Type Evaluation Grade	Biotope Meso-Classification Type Evaluation Grade Criteria	Biotope Meso-Classification Type	Management Goals
Semi-nature: Areas continuously subject to human interference and influence	5	Low naturality and low possibility of natural regeneration due to excessive energy consumption and extensive impervious pavements	Low-rise apartment complex	Improvement / Creation / Reduction
			Mid-rise apartment complex	
			High-rise apartment complex	
			Educational institution	
			Administrative and public institutions	
			Hospitals and nursing facilities	
			Religious facilities	
			Commercial and business area (Major classification)	
			Mixed residential and business area (Major classification)	
			Coastal structures	
			Urban abandoned land	
			Industrial area (Major classification)	
			Waste-related facility site	
			Energy-related facility site	
			Communications-related facility site	
			Water-related facility site	
			Transportation facility area (Major classification)	
			Open-air storage yard	

Grade 1 areas are mostly in an intact natural state and have value or high potential as biological habitats; therefore, the management goals for these areas are maintenance, protection, and recovery. Grades 2 and 3 are near-nature categories with low land use intensity, but they also include rare green biotopes, which are threatened by urbanization or haphazard development and may disappear due to high development pressure. Management goals for these grades therefore include protection, recovery, improvement, and creation. Grades 4 and 5 belong to semi-nature categories and are areas that are continuously subjected to human interference and influence. The management goals for these grades focus on improvement, creation, and reduction, such as improving urban environments, creating green spaces, and reducing pollutants.

2.6. Biotope Minor-Classification Type Evaluation Indicators

The biotope minor-classification type is based on a more detailed classification than the meso-classification type because it reflects regional characteristics of the major- and meso-classification types. The biotope meso-classification type represents standardized biotope types in a large area. The biotope minor-classification type can vary according to the unique environmental characteristics of corresponding regions. Before classifying biotope minor-classification types, evaluation criteria must be considered, that is, evaluation purposes and types corresponding to purposes must be set.

Based on the review of previous studies, we extracted the evaluation factors of minor classification types for Si-heung City, Goyang City, Gwangju City, Pyeongtaek City, Hwaseong City, and Guri City in the Gyeonggi Province and reconstructed the data using evaluation indicators. During this process, we initially sought out commonalities among the terms used in related data and utilized Hancom Office 2022 and Microsoft Excel to establish a common language. Items were grouped based on these terms, and detailed evaluation indicators were derived for each assessment item. These evaluation indicators were classified into a total of 11 evaluation items using an expert FGI (Focus Group Interview). Based on the use of a secondary FGI, the 11 evaluation items were grouped into five biotope management goals: maintenance, protection, recovery, improvement, creation, and reduction (Tables 6 and 7).

Table 6. FGI (Focus Group Interview) outline.

Field	Research Participants	Description	Interview Method	Interview Time
Plant	Botanical taxonomist with minimum 5 years of experience: 2 persons PhD in plant field: 2 persons	1st: · Review reorganization of evaluation metrics for biotope minor classification types in the study site · Group reorganized evaluation indicators into evaluation items (Derive 11 evaluation items) Second: · Group evaluation items into five management goals	In-person, written, and phone interviews	In-person: 1 h Written: e-mail recovery 10 days after sending it Phone: additional questions
Animal	Zoological taxonomist with minimum 5 years of experience: 2 persons Ph.D. in animal field: 2 persons			
Ecological restoration	Natural ecological restoration engineer with minimum 5 years of experience: 2 persons Natural environment management engineer, environmental impact assessor: 2 persons			
Landscape	Landscape architect with minimum 5 years of experience: 1 person Ph. D. in landscape architecture: 1 person			
Urban planning	Urban planning specialist with minimum 5 years of experience: 1 person			

The management goal for maintenance requires evaluation indicators in the category of naturality, and the management goal for protection is based on the categories of naturality, rarity, and connectivity. The management goals for recovery require the categories of recuperative ability, diversity, and vulnerability. The management goals for improvement involve the categories of ecological functionality and risk of damage. The management goals for creation are based on the categories of potential habitat, availability, and urban environment improvement functionality and the management goals for reduction involve the categories of urban environment improvement functionality. The use of evaluation indicators as the criteria for categorizing biotope minor classification types will help to clarify evaluation purposes.

Table 7. Setting of biotope minor classification type evaluation indicators.

Naturality Category	Biotope Meso-Classification Type	Management Goals	Biotope Minor-Classification Type Evaluation Item	Reconfiguration of Minor- Classification Type Evaluation Indicators for Target Sites
Nature	**Grade** 1 Natural forest Natural wetland Natural coast Natural river	Maintenance	Naturality	International importance (migratory bird habitat), national importance (legally protected area, vegetation area with extreme climate), regional importance (wildlife habitat)
		Protection	Naturality	Naturality of vegetation, naturality of dominant species, naturality of rivers
			Rarity	Preservation of the community with value, rare habitat, legally protected species habitat, biotope area ratio, number of biotopes
			Connectivity	Forest size, river size, wetland size, proximity to forest and water source, density of core ecological axis
		Recovery	Recuperative ability	Stability of the community (similarity between the tree layer and low-tree layer), average age of vegetation, average diameter at breast height of vegetation, possibility of forest erosion, development level of organic matter layer
			Diversity	Forest basin area (mountainous stream), forest type, habitat characteristics, stratified structure, presence of river flow, open surface of wetland
			Vulnerability	Proximity to hiking trails, proximity to roads, hydrological control in wetlands, rate of contact with disturbed patches, possibility of landslides, areas of pests and diseases, terrain damage, status of artificial management after damage (land treated for erosion control), spread possibility of invasive species
Near-nature	**Grades** 2–3 Close-to-nature river Natural–artificial forest Artificial forest Artificial wetland Artificial river Small river Shrub vegetation area Rock outcrop Natural grassland Artificial grassland Wet farmland Dry farmland Artificially created park green space Facility-type green space Artificial coast	Protection	Rarity	Historical value (cultural heritage planting site), legally protected species habitat, biotope area ratio, and number of biotopes
			Connectivity	Forest size, river size, wetland size, proximity to forest and water source, density of core ecological axis
		Restoration	Recuperative ability	Age class, breast height, naturality of dominant species, naturality of late-successional species
			Diversity	Forest floor type, habitat characteristics, stratified structure, river size, presence or absence of aquatic spaces in the river bank, wetland size, and development level of organic matter layer
			Vulnerability	Distance from hiking trails, distance from road, management intensity, spread possibility of invasive species
		Improvement	Ecological functionality	Biotope area, forest and stream separation distance, elevation, slope
			Risk of damage	Location, pervious pavement ratio, floor pavement material

Table 7. *Cont.*

Naturality Category	Biotope Meso-Classification Type	Management Goals	Biotope Minor-Classification Type Evaluation Item	Reconfiguration of Minor- Classification Type Evaluation Indicators for Target Sites
Near-nature	**Grades** 2–3 Close-to-nature river Natural–artificial forest Artificial forest Artificial wetland Artificial river Small river Shrub vegetation area Rock outcrop Natural grassland Artificial grassland Wet farmland Dry farmland Artificially created park green space Facility-type green space Artificial coast	Creation	Potential as habitats	Green area ratio, stratified structure, vegetation cover ratio, presence or absence of rice paddy land readjustment, size of rice paddies, size of parks, pervious pavement ratio, tree crown cover, location, topographic conditions, movement of wild animals, ecological axis connectivity, green space connectivity, vegetation characteristics, green space width, habitat characteristics, impervious pavement ratio, growth base, possibility of amphibian road kill, habitat features (cutting and fill-up), adjacency to road, adjacency to ecological axis and buffer function, distance to urbanized areas
			Availability	Cultural function, popular function, recreational function
Semi-nature	**Grades 4–5** Agricultural waterway Deforested and damaged area Large exercise facility site Rural detached housing Rural abandoned land Facility-type farmland Urban detached housing Other public-use areas Urban abandoned land Mining site Facility-type farmland Low-rise apartment complex Mid-rise apartment complex High-rise apartment complex Educational institution Administrative and public institutions Hospitals and nursing facilities Religious facilities Commercial and business area (Major classification) Mixed residential and business area (Major classification) Coastal structures Urban abandoned land Industrial area (Major classification) Waste-related facility site Energy-related facility site Communications-related facility site Water-related facility site Transportation facility area (Major classification) Open-air storage yard	Improvement	Ecological functionality	Biotope area, wildlife movement function
			Risk of damage	Location, management intensity, use intensity, artificial topography (non-compartment and compartment), rural landscape ratio, agricultural waterway maintenance type
		Creation	Potential as habitats	Green area ratio, stratified structure, vegetation cover ratio, pervious pavement ratio, playground pavement material, tree crown cover, presence or absence of retention, presence or absence of wetlands, vegetation characteristics, road adjacency, ecological axis adjacency, and buffer function
			Availability	Historical value, cultural function, popular function, recreational function
			Urban environment improvement functionality	Green space ratio, Impervious pavement ratio, Pervious pavement ratio
		Reduction	Urban environment improvement functionality	Green area ratio, impervious pavement ratio, pervious pavement ratio, building height, building-to-land ratio, presence or absence of street green space (trees + shrubs), presence or absence of street trees, type of street tree arrangement, presence or absence of median strip of green space, pavement material, average diameter at breast height, presence of ground parking lot, adjacency to forest, proximity per type of created green spaces, adjacency to park green spaces, green roof area, presence of vegetation, tree crown cover, green building certification, particular matter emissions

2.7. Biotope-Type Classification and Evaluation Method

Biotope-type classification was used to sort out identical or similar biotopes by identifying the attributes of individual biotopes. Biotope-type classification is based on biotope attributes and environmental spatial data. Biotopes in urbanized and green areas in Dongducheon City were classified into major-, meso-, and minor-classification types based on the classification hierarchy shown in Figure 3.

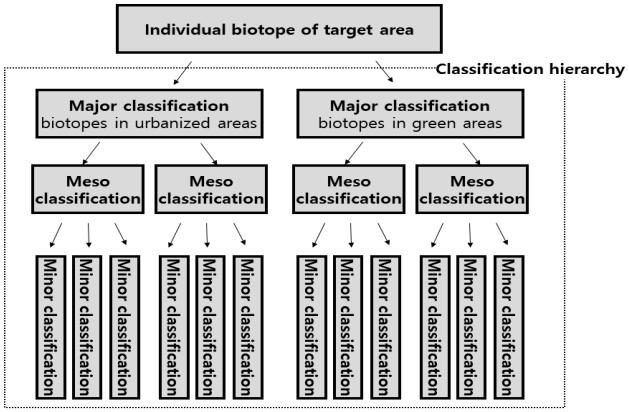


Figure 3. Biotope type classification hierarchy.

Biotope evaluation was used to evaluate the biotope value, which is mainly expressed using a grade [39]. Grading was conducted in two steps (Figure 4): biotope meso-classification type evaluation and biotope minor-classification type evaluation. Biotope meso-classification types were assigned Grades I–V (five-grade system). Criteria for each grade are listed in Table 5. Subsequently, the purpose for each minor classification type was set (Table 7) and minor-classification type evaluation (evaluation items, evaluation indicators, and evaluation criteria) was carried out for each purpose. The minor classification type was evaluated using a three-grade system and decision tree method (Figure 5). Finally, meso- and minor-classification type evaluations were combined to categorize the final minor-classification type in Grades I–VII.

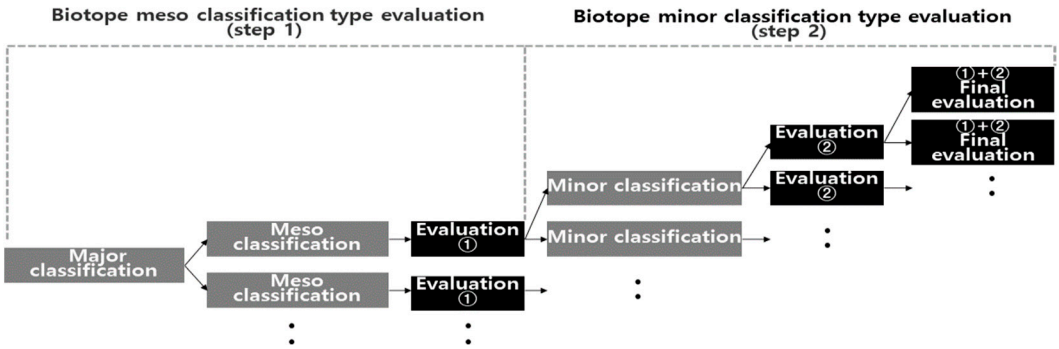


Figure 4. Phases of biotope-type evaluation.

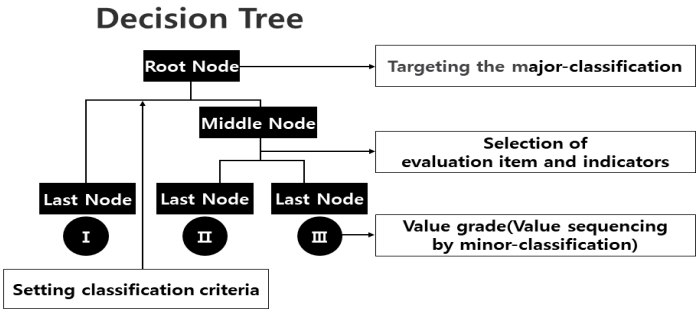


Figure 5. Decision tree method.

2.8. Application to the Study Site

We applied the biotope map to Dongducheon City, Gyeonggi Province, including the purpose derived for each type and evaluation indicator for each purpose. The map scale is 1:5000. We created the map using the Geographic Information System (GIS) program

by classifying biotope types and visualizing biotope evaluation data. The boundaries of biotopes were established by comparing with land cover map (2020), ecological and natural map (2018~2020), aerial photographs (2018, 2020), land register map (2021), topographic map (2018), building management ledger (2021), land use map (2020), urban planning map (2021), and satellite image (Google Earth Pro, 2023). Then, polygon shapes were created manually using a GIS program (Figure 6).

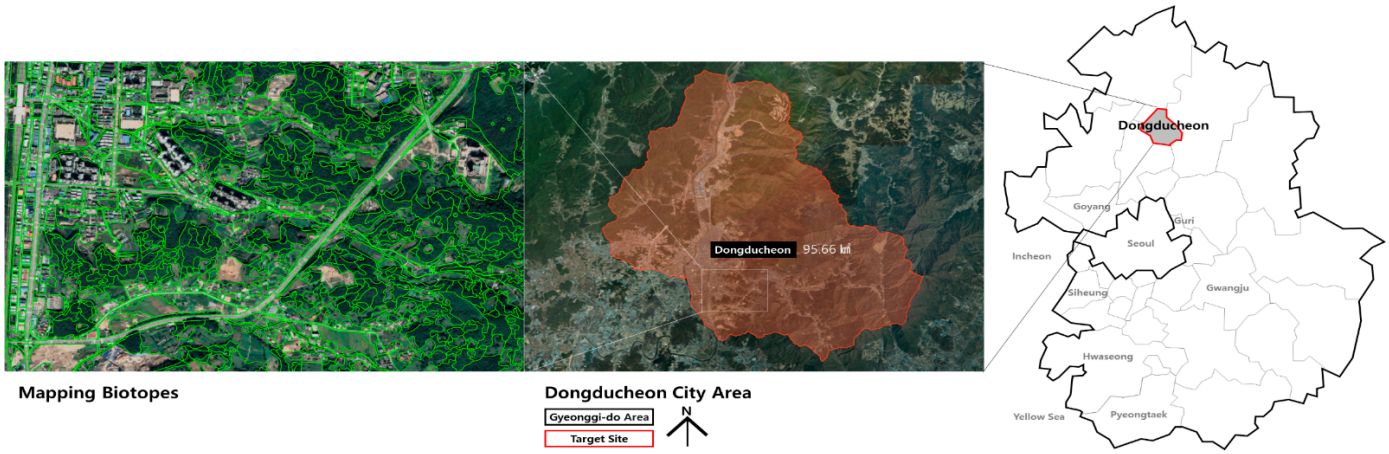


Figure 6. Map showing the location of the study site.

We chose Dongducheon City in the Gyeonggi Province as our study location because of the lack of biotope maps available for this city. Meso-classification type evaluation, which is a standard used at local and national levels, was applied as a five-grade system and the minor-classification type evaluation (final type evaluation), which reflects the ecological characteristics of the region based on the results of the meso-classification evaluation, was applied as a seven-grade system (Figure 7).

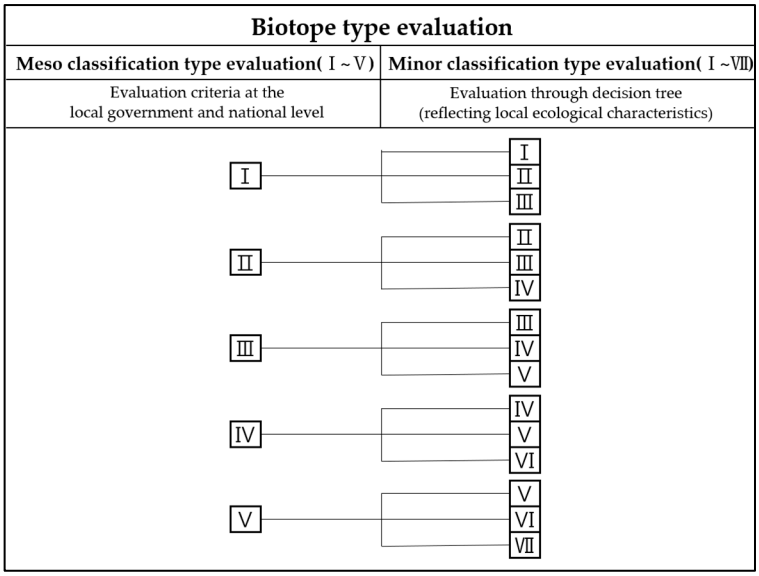


Figure 7. Biotope-type evaluation system.

Setting management goals is crucial for the evaluation system because it determines the indicators and standards used in the evaluation [7]. For the naturality category, management goals were set in the following order: maintenance > protection > recovery > improvement > creation > reduction. The range of types, evaluation indicators, and evaluation grades were established based on these goals (Table 8).

Table 8. Biotope-type evaluation system for Dongducheon City.

Naturality Category	Management Goals	Biotope Meso-Classification Type	Meso-Classification Type Evaluation Grade	Biotope Minor-Classification Type Evaluation Items	Minor-Classification Grade
Nature	Maintenance	Natural river, Natural forest	I(1)	Naturality	I(1)
					II(2)
	Protection	Natural wetland, Artificial wetland		Rarity, Connectivity	II(2)
					III(3)
Near-nature	Protection	Small river, Natural–artificial forest, Artificial–Natural forest *, Mountain forests *, Hill land *, Wet farmland	II(2)	Naturality, Rarity, ecological axis (Connectivity)	II(2)
					III(3)
	Recovery	Artificial river		Vulnerability	III(3)
					IV(4)
	Recovery	Artificial forest, Shrub vegetation area, Rock outcrop, Secondary grassland (Natural grassland)	III(3)	Recuperative ability	III(3)
					IV(4)
	Improvement	Artificial grassland, Dry farmland, Urban parks (Artificially created park green space), Small parks and children's parks (Artificially created park green space)		Ecological functionality	IV(4)
					V(5)
Semi-nature	Improvement	Agricultural waterway, Deforested and damaged area, Created green spaces for uses *, Created green spaces for environmental improvements *, Other landscaping tree planting sites *	IV(4)	Ecological functionality, Risk of damage	IV(4)
					V(5)
	Creation	Urban detached housing, Rural detached housing, Exercise facility site, Other public-use areas, Urban abandoned land, Rural abandoned land, Facility-type farmland, Mining site		Urban-environmental function, Availability, Potential as habitats	V(5)
					VI(6)
	Creation	Low-rise apartment complexes, Mid-rise apartment complexes, High-rise apartment complexes, Low-rise commercial business districts, Mid-rise commercial business districts, Mixed residential and business areas with low-rise buildings, Educational institutions, Administrative and public institutions, Hospitals and nursing facilities, Religious facilities	V(5)	Urban-environmental function, Availability	V(5)
					VI(6)
	Reduction	Small factories, Water-related facility sites, Energy-related facility sites, Road, Parking lots, Railroad, Transportation-related supplementary facility sites, Primary forest road *, Open-air storage yard		Urban-environmental function	VI(6)
					VII(7)

* A meso-classification type was additionally created by researchers to reflect the environmental characteristics of Dongducheon City.

The meso-classification type evaluation grade standard suggested in Table 5 was applied. It was adjusted to fit the environmental features of Dongducheon City. The city has abundant forests. Initially, it had abundant wetlands and rice paddy fields in the lowlands. However, this area has considerably decreased due to rapid urbanization. Therefore, the grades of artificial wetland (scarce) and wet farmland (paddy fields) were raised from 2 to 1 and 3 to 2, respectively. In addition, artificial forest with low scarcity was lowered from Grade 2 to 3. Because small rivers originating from forests have excellent naturality, the small river type was upgraded from Grade 3 to 2.

3. Results

3.1. Biotope Types and Evaluation Results for Dongducheon City

The land use map, based on existing data, was revised by comparing aerial photographs, land register maps, building management ledgers, urban planning maps, and

satellite images. This map and the results from the creation of the vegetation, altitude analysis, slope analysis, and aspect analysis maps required for biotope categorization are shown in Figure 8.

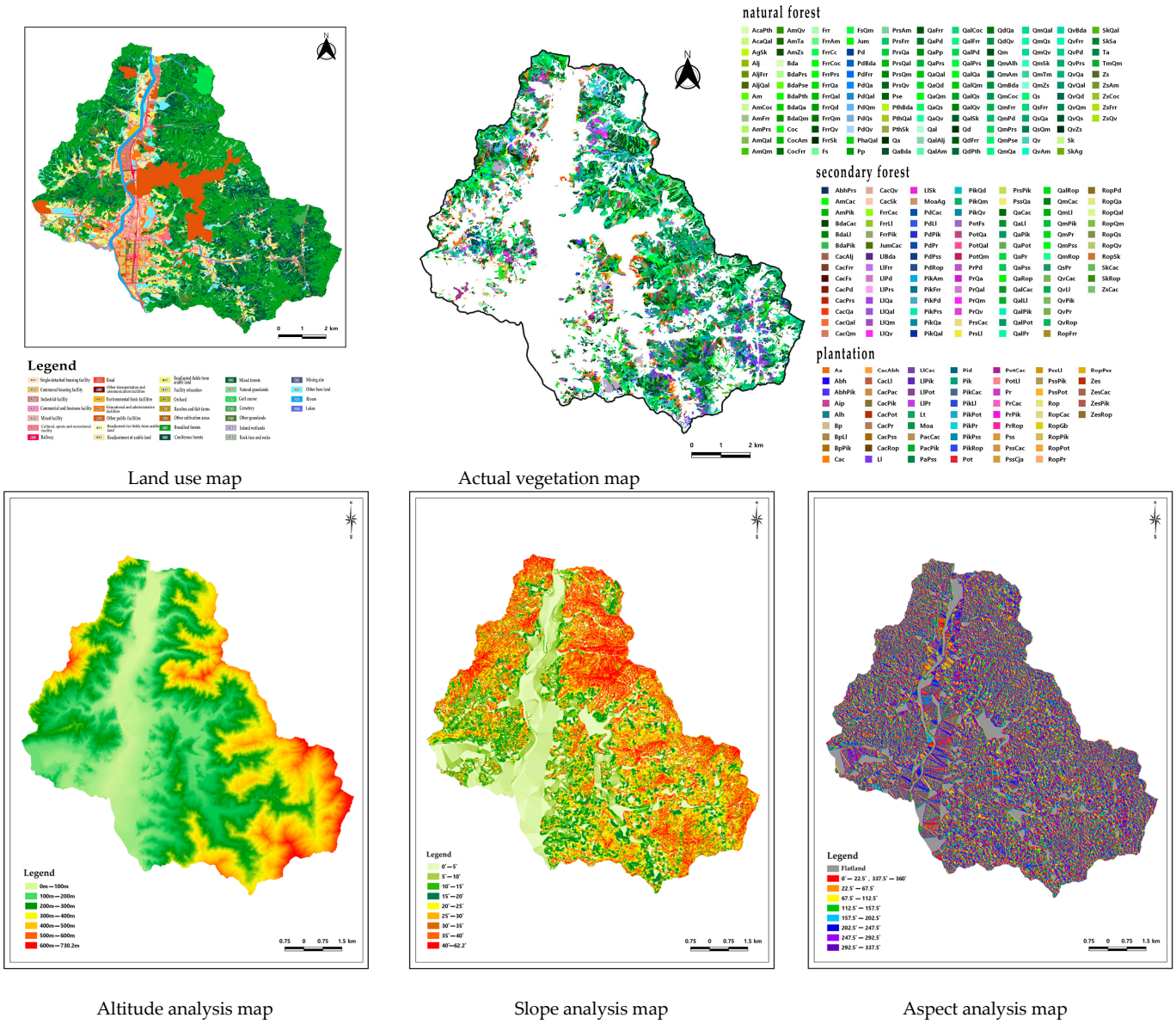
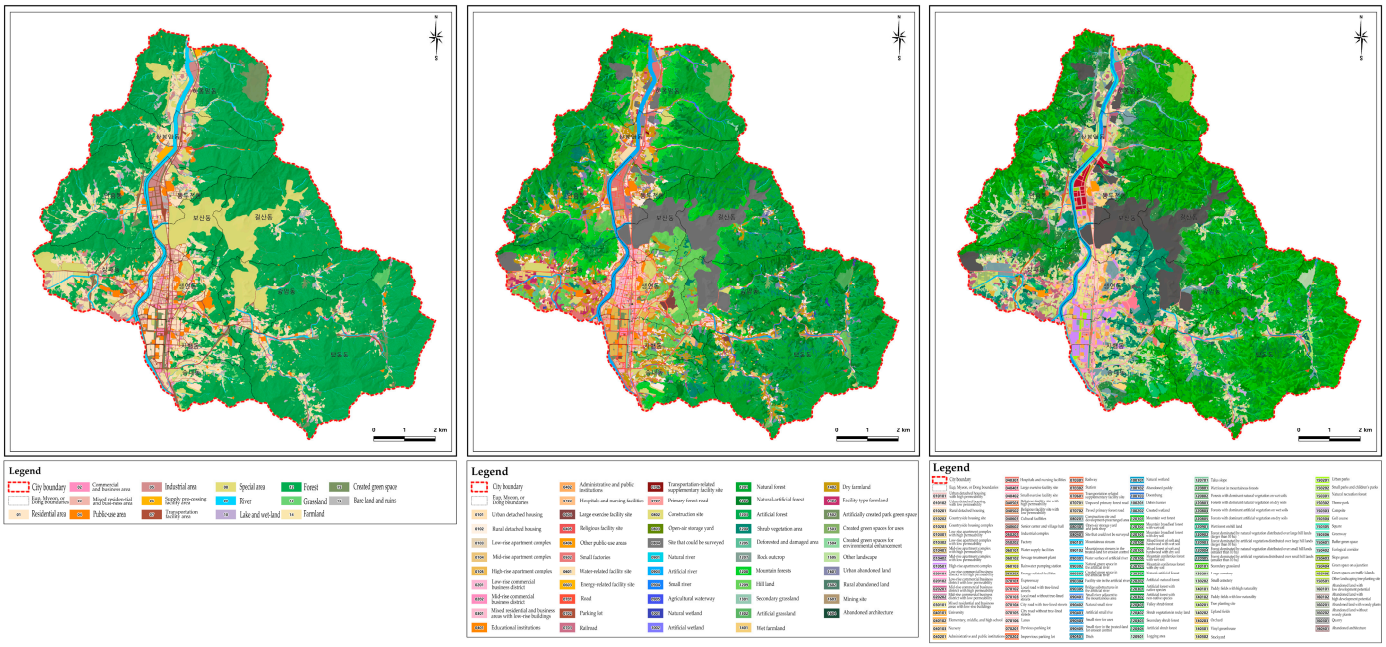


Figure 8. Basic thematic maps for the creation of biotope maps.

Based on the biotope-type classification for Dongducheon City, 16 major, 23 meso, and 123 minor classification types were identified (Figure 9). The biotope minor classification type evaluation (final type evaluation) showed that 8, 15, 16, 18, 26, 24, and 14 biotopes belong to Grades 1, 2, 3, 4, 5, 6, and 7, respectively. Two biotopes (Construction site and development-prearranged area, Site that could not be surveyed) were excluded from the evaluation.

Figure 10 shows an evaluation thematic map with colored grades for the biotope minor-classification type evaluation. With respect to the proportion of the area per grade, Grades 1, 2, 3, 4, 5, 6, and 7 account for 31.27%, 12.22%, 17.20%, 12.90%, 5.61%, 7.64%, and 3.60% of the area, respectively (Table 9).



Biotope major-classification type map | Biotope meso-classification type map | Biotope minor-classification type map

Figure 9. Biotope-type thematic maps.

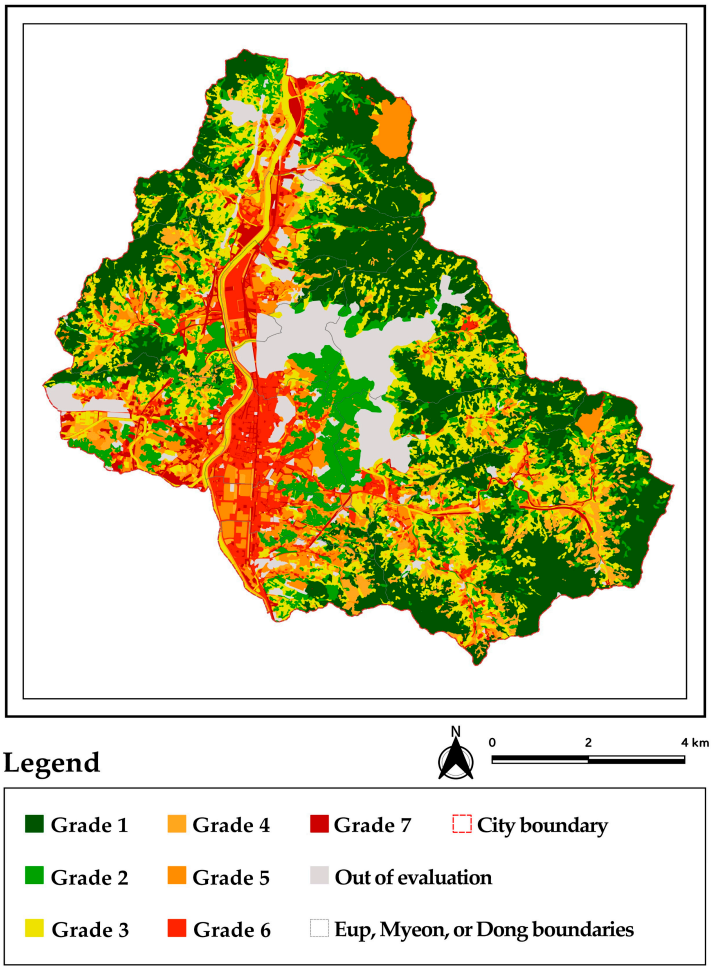


Figure 10. Minor-classification type evaluation map (final type evaluation) for Dongducheon City.

Table 9. Areas and percentages for each biotope minor classification type evaluation grade.

Grade	Area (m^2)	Percentage (%)
I(1)	29,920,033.6	31.27
II(2)	11,687,563.9	12.22
III(3)	16,454,464.1	17.20
IV(4)	12,342,063.0	12.90
V(5)	5,364,863.6	5.61
VI(6)	7,307,668.4	7.64
VII(7)	3,445,086.1	3.60
Non-evaluation (special sites)	9,146,204.6	9.56
Total	95,667,947.2	100.00

The thematic maps for biotopes according to grade are shown in Figure 11. Biotope minor-classification type evaluation Grade 1 was evaluated in 8 types, such as mountainous stream and natural forest in meso-classification. In terms of location, they are distributed where there is a high altitude and steep slope within the forest, thus maintaining its intact natural state.

Biotope minor-classification type evaluation Grade 2 was evaluated in 15 types, such as mountainous streams in land treated for erosion control, natural wetlands, abandoned paddies, doombungs, created wetlands, natural-artificial forests, wet forests among the mountainous forests, forests with dominant natural vegetation, and large hill lands. These types are gradually decreasing and exhibit rarity. They are isolated from the city or the inside of the forest in terms of location, but they can be identified by large dots.

Biotope minor-classification type evaluation Grade 3 was evaluated in 16 types, such as water surface of artificial rivers, natural green space in the artificial rivers, artificial small rivers, small rivers for use, small rivers in land treated for erosion control, debris barriers, artificial–natural forests, forests with dominant artificial vegetation, and small hill lands. They have naturality but are damaged by humans. They are located along forest edges, while rivers pass through the city.

Biotope minor-classification type evaluation Grade 4 was evaluated in 18 types, such as created green spaces in the artificial rivers, secondary grasslands, shrub vegetation areas, dry farmland, urban parks, and buffer green spaces. They are located on the outskirts of the city and have the potential for development due to future urban expansion.

Biotope minor-classification type evaluation Grade 5 was evaluated in 26 types, such as ditches, vinyl greenhouses, campsites, golf courses, or urban areas with relatively high permeability such as residential areas, as well as commercial and business areas. Located in the city, many of these types feature green spaces created along with buildings.

Biotope minor-classification type evaluation Grade 6 was evaluated in 24 types, most of which cause urban environmental problems due to excessive energy consumption and extensive impervious pavements.

Biotope minor-classification type evaluation Grade 7 was evaluated in 14 types, such as abandoned buildings, factories, sewage treatment plants, and roads without tree-lined streets that cause the urban environment to deteriorate.

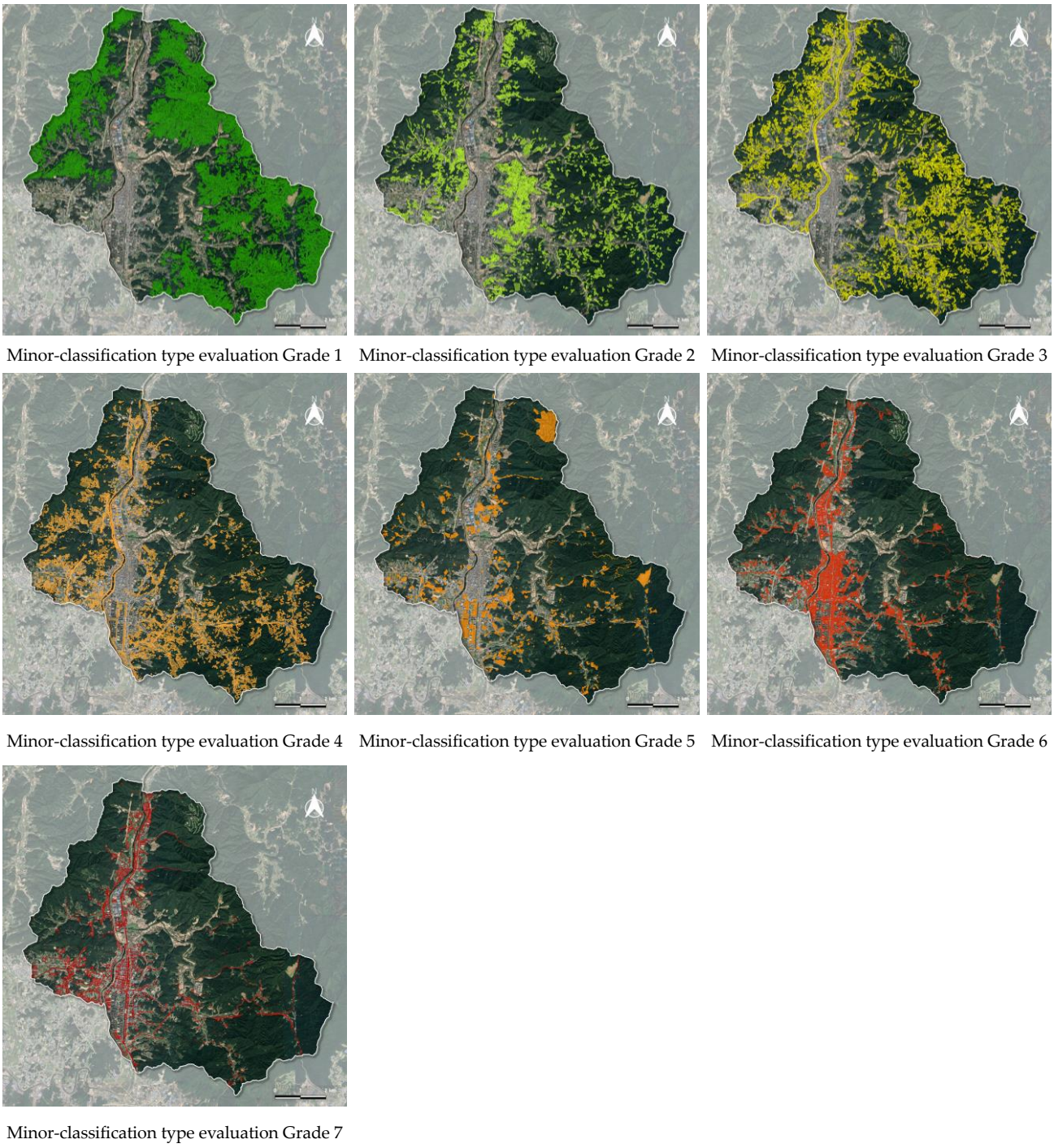


Figure 11. Biotope minor-classification type evaluation map for each grade.

3.2. Detailed Results of Biotopes in Urbanized Areas according to Management Goals

As a result of setting the reduction management goal, meso-classification types were rated as Grade 5, classified into 9 total types. Minor-classification types were ultimately rated as Grades 5–7, classified into 20 total types. Reduction was evaluated using indicators to improve urban-environmental functions, such as installing pollution purification facilities, planting street trees, applying pervious pavement materials, and adopting green space (see Table 10 and Figure 12).

Table 10. Biotope types and evaluation results after applying reduction (biotopes in urbanized areas).

Biotope Meso-Classification Type	Meso-Classification Type Evaluation Grade	Management Goals	Biotope Minor-Classification Type	Evaluation Item	Evaluation Indicator	Evaluation Criteria	Minor-Classification Type Evaluation Grade
Small factory	V(5)	Reduction	Industrial complex	Urban-environmental function	Pollution purification facility	Presence	VI(6)
			Factory			Absence	VII(7)
Water-related facility site	V(5)	Reduction	Water supply facilities	-	-	-	VII(7)
			Sewage treatment plant			-	VII(7)
			Rainwater pumping station			-	VII(7)
Energy-related facility site	V(5)	Reduction	Energy-related facilities	-	-	-	VII(7)
Road	V(5)	Reduction	Expressway	Urban-environmental function	Presence or absence of street trees	Absence	VII(7)
			Local road with tree-lined streets			Presence	VI(6)
			Local road without tree-lined streets			Absence	VII(7)
			City road with tree-lined streets			Presence	VII(6)
			City road without tree-lined streets			Absence	VII(7)
			Lanes			Absence	VII(7)
Parking lot	V(5)	Reduction	Pervious parking lot	Urban-environmental function	Pavement material	Pervious pavement	VI(6)
			Impervious parking lot			Impervious pavement	VII(7)
Railroad	V(5)	Reduction	Railway	Urban-environmental function	Presence or absence of landscape green space	Absence	VII(7)
			Station			Presence	VI(6)
Transportation-related supplementary facility site	V(5)	Reduction	Transportation-related supplementary facility site	-	-	-	VII(7)
Primary forest road	V(5)	Reduction	Unpaved primary forest road	Urban-environmental function	Status of being paved	Unpaved	V(5)
			Paved primary forest road			Paved	VI(6)
Open-air storage yard	V(5)	Reduction	Open-air storage yard and junk shop	-	-	-	VII(7)

Biotope types and evaluation after applying reduction | Small factory | Primary forest road

Figure 12. Detailed biotope maps after applying reduction.

As a result of setting the management goal as creation, meso-classification types were rated as Grades 4–5, classified into 14 total types. Minor-classification types were ultimately rated as Grades 5–6, classified into 26 total types. Creation was evaluated using indicators to improve urban-environmental functions and availability, such as the ratio of permeable area through which rainwater can infiltrate, the adoption of gardens, and the provision of open spaces, green areas, and cultural functions (see Table 11 and Figure 13).

Table 11. Biotope types and evaluation results after applying creation (biotopes in urbanized areas).

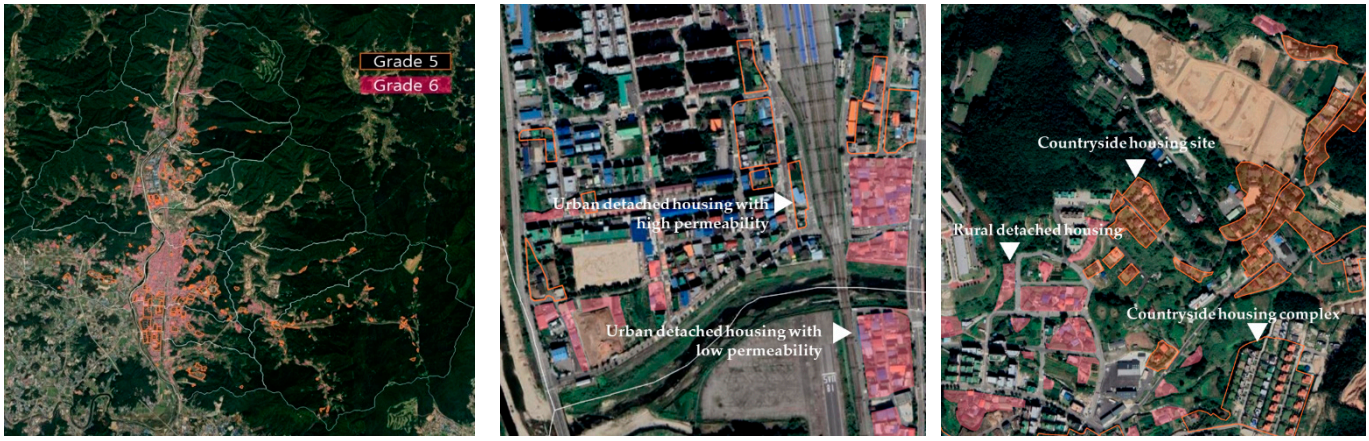
Biotope Meso-Classification Type	Meso-Classification Type Evaluation Grade	Management Goals	Biotope Minor-Classification Type	Evaluation Item	Evaluation Indicator	Evaluation Criteria	Minor-Classification Type Evaluation Grade
Urban detached housing	IV(4)	Creation	Urban detached housing with high permeability	Urban-environmental function	Permeability	>25%	V(5)
			Urban detached housing with low permeability			<25%	VI(6)
Rural detached housing	IV(4)	Creation	Rural detached housing	Availability	Absence/presence of gardens	Absence	VI(6)
			Countryside housing site			Presence	V(5)
			Countryside housing complex			Presence	V(5)
Low-rise apartment complex	V(5)	Creation	Low-rise apartment complex with high permeability	Urban-environmental function	Permeability	>20%	V(5)
			Low-rise apartment complex with low permeability			<20%	VI(6)

Table 11. *Cont.*

Biotope Meso-Classification Type	Meso-Classification Type Evaluation Grade	Management Goals	Biotope Minor-Classification Type	Evaluation Item	Evaluation Indicator	Evaluation Criteria	Minor-Classification Type Evaluation Grade
Mid-rise apartment complex	V(5)	Creation	Mid-rise apartment complex with high permeability	Urban-environmental function	Permeability	>10%	V(5)
			Mid-rise apartment complex with low permeability			<10%	VI(6)
High-rise apartment complex	V(5)	Creation	High-rise apartment complex	-	-	-	V(5)
Low-rise commercial business district	V(5)	Creation	Low-rise commercial business district with high permeability	Urban-environmental function	Permeability	>25%	V(5)
			Low-rise commercial business district with low permeability			<25%	VI(6)
Mid-rise commercial business district	V(5)	Creation	Mid-rise commercial business district with high permeability	Urban-environmental function	Permeability	>10%	V(5)
			Mid-rise commercial business district with low permeability			Less than 10%	VI(6)
Mixed residential and business areas with low-rise buildings	V(5)	Creation	Mixed residential and business areas with low-rise buildings	-	-	-	VI(6)
Educational institution	V(5)	Creation	University	Availability	Provision of open spaces	Presence	V(5)
			Elementary, middle, and high school			Absence	VI(6)
			Nursery			Absence	VI(6)
Administrative and public institutions	V(5)	Creation	Administrative and public institutions	-	-	-	VI(6)
Hospitals and nursing facilities	V(5)	Creation	Hospitals and nursing facilities	-	-	-	VI(6)

Table 11. *Cont.*

Biotope Meso-Classification Type	Meso-Classification Type Evaluation Grade	Management Goals	Biotope Minor-Classification Type	Evaluation Item	Evaluation Indicator	Evaluation Criteria	Minor-Classification Type Evaluation Grade
Exercise facility site	IV(4)	Creation	Large exercise facility site	Availability	Green areas	Large scale	V(5)
			Small exercise facility site			Small scale	VI(6)
Religious facilities	V(5)	Creation	Religious facility site with high permeability	Urban-environmental function	permeability	>30%	V(5)
			Religious facility site with low permeability			<30%	VI(6)
Other public-use areas	IV(4)	Creation	Cultural facilities	Availability	Cultural function	Presence	V(5)
			Senior center and village hall			Absence	VI(6)
			Factory			Absence	VII(7)



Biotope types and evaluation after applying creation | Urban detached housing | Rural detached housing

Figure 13. Specific biotope maps after applying creation (biotopes in urbanized areas).

3.3. Specific Results of Biotopes in Green Areas According to Management Goals

As a result of setting the management goal as creation, meso-classification types were rated as Grade 4, classified into 4 total types. Minor-classification types were ultimately rated as Grades 5–6, classified into 7 total types. Creation was evaluated using indicators of reducing damage risk and increasing potential as biological habitats. These indicators included pollutant emissions, the use of area management in urban planning, and the adoption of green spaces (see Table 12 and Figure 14).

Table 12. Biotope types and evaluation results after applying creation (biotopes in green areas).

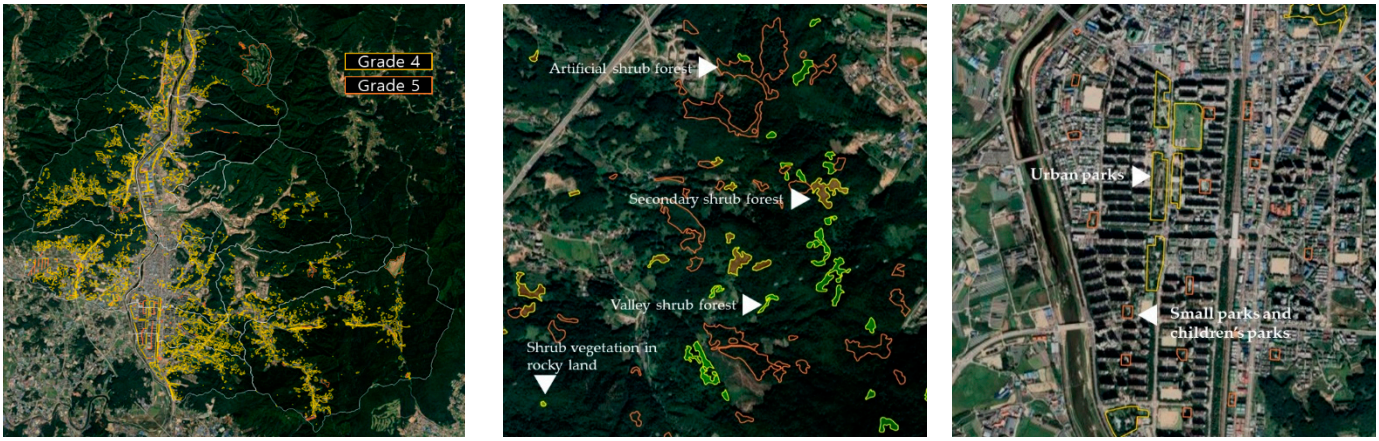
Biotope Meso-Classification Type	Meso-Classification Type Evaluation Grade	Management Goals	Biotope Minor-Classification Type	Evaluation Item	Evaluation Indicator	Evaluation Criteria	Minor-Classification Type Evaluation Grade
Facility-type farmland	IV(4)	Creation	Vinyl greenhouse	Risk of damage	Pollutant emission	Low	V(5)
			Stockyard			High	VI(6)
Urban abandoned land	IV(4)	Creation	Abandoned land with low development potential	Potential habitat	Use area	Green area/Preservation management	V(5)
			Abandoned land with high development potential			Residential, commercial, industrial, production, planning management	VI(6)
Rural abandoned land	IV(4)	Creation	Abandoned land with woody plants	Potential habitat	Absence and presence of woody plants	Presence	V(5)
			Abandoned land without woody plants			Absence	VI(6)
Mining site	IV(4)	Creation	Quarry	-	-	-	VI(6)

Figure 14. Specific biotope maps after applying creation (biotopes in green areas).

As a result of setting a management goal of improvement, meso-classification types were rated as Grades 3–4, classified into 8 total types. Minor-classification types were ultimately rated as Grades 4–5, classified into 21 total types. Improvement was evaluated using indicators of improved ecological functionality and reduced damage risk, such as topography damage, green space size, use intensity, location, and wild animal movement (see Table 13 and Figure 15).

Table 13. Biotope types and evaluation results after applying improvement (biotopes in green areas).

Biotope Meso-Classification Type	Meso-Classification Type Evaluation Grade	Management Goals	Biotope Minor-Classification Type	Evaluation Item	Evaluation Indicator	Evaluation Criteria	Minor-Classification Type Evaluation Grade
Agricultural waterway	IV(4)	Improvement	Ditch	-	-	-	V(5)
Deforested and damaged area	IV(4)	Improvement	Logging area	-	-	-	IV(4)
Artificial grassland	III(3)	Improvement	Large cemetery	Ecological functionality	Damage to the topography	Compartment	V(5)
			Small cemetery			Non-compartment	IV(4)
Dry farmland	III(3)	Improvement	Tree planting site	-	-	-	IV(4)
			Upland fields			-	IV(4)
			Orchard			-	IV(4)
Artificially created park green space	III(3)	Improvement	Urban parks	Ecological functionality	Size	>6500 m^2	IV(4)
			Small parks and children's parks			<6500 m^2	V(5)
Created green spaces for uses	IV(4)	Improvement	Natural recreation forest	Risk of damage	Use intensity	Low	IV(4)
			Theme park			Low	IV(4)
			Campsite			High	V(5)
			Golf course			High	V(5)
			Square			High	V(5)
			Greenway			High	V(5)
Created green spaces for environmental enhancement	IV(4)	Improvement	Buffer green space	Risk of damage	Location	Outside Road	IV(4)
			Ecological corridor	Ecological functionality	Movement of wild animals	Presence	IV(4)
			Slope green	Risk of damage	Location	Outside Road	IV(4)
			Green space on a junction			Within Road	V(5)
			Green spaces on traffic islands			Within Road	V(5)
Other landscape	IV(4)	Improvement	Other landscaping tree planting site	-	-	-	V(5)



Biotope types and evaluation after applying improvement

Artificial grassland

Artificially created park green space

Figure 15. Specific biotope maps after applying improvement.

As a result of setting recovery as a management goal, meso-classification types were rated as Grades 2–3, classified into 5 total types. Minor-classification types were ultimately rated as Grades 3–4, classified into 13 total types. Recovery was evaluated using indicators of reduced vulnerability and improved recuperative ability, such as artificial management strength, autogenous dominant species, and vegetation naturality (see Table 14 and Figure 16).

Table 14. Biotope types and evaluation results after applying recovery (biotopes in green areas).

Biotope Meso-Classification Type	Meso-Classification Type Evaluation Grade	Management Goals	Biotope Minor-Classification Type	Evaluation Item	Evaluation Indicator	Evaluation Criteria	Minor-Classification Type Evaluation Grade
Artificial river	II(2)	Recovery	Water surface of artificial river	Vulnerability	Artificial management strength	Low	III(3)
			Natural green space in the artificial river			Low	III(3)
			Created green space in the artificial river			High	IV(4)
			Facility site in the artificial river			High	IV(4)
			Bridge sub-structures in the artificial river			High	IV(4)

Table 14. *Cont.*

Biotope Meso-Classification Type	Meso-Classification Type Evaluation Grade	Management Goals	Biotope Minor-Classification Type	Evaluation Item	Evaluation Indicator	Evaluation Criteria	Minor-Classification Type Evaluation Grade
Artificial forest	III(3)	Recovery	Artificial forest with native species	Recuperative ability	Autogenous dominant species	Native	III(3)
			Artificial forest with non-native species			Non-native	IV(4)
Shrub vegetation area	III(3)	Recovery	Valley shrub forest	Recuperative ability	Naturality of vegetation	Natural	III(3)
			Shrub vegetation in rocky land			Natural	III(3)
			Secondary shrub forest			Natural	III(3)
			Artificial shrub forest			Artificial	IV(4)
Rock outcrop	III(3)	Recovery	Talus slope	-	-	-	IV(4)
Secondary grassland	III(3)	Recovery	Secondary grassland	-	-	-	IV(4)

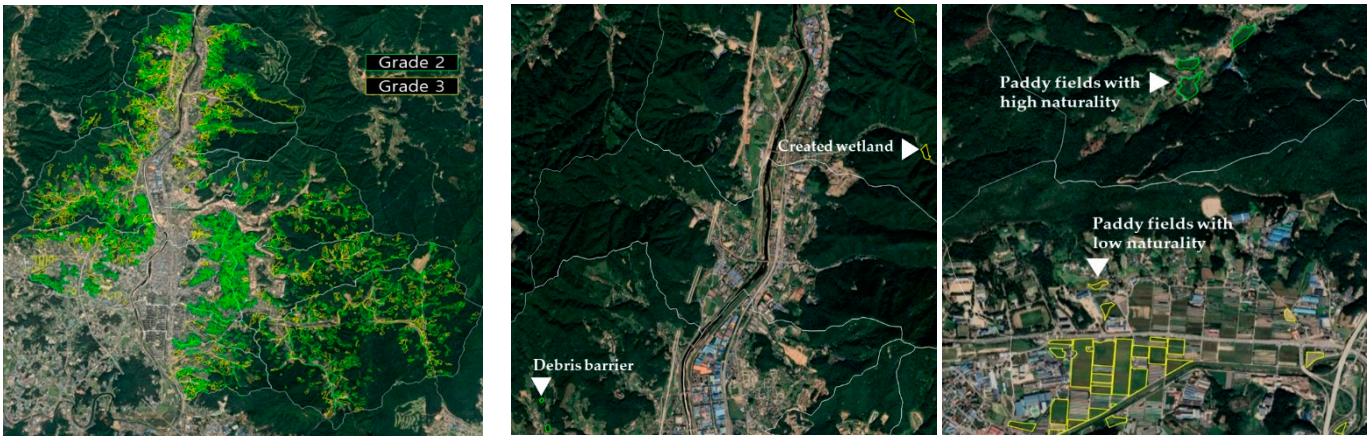
Figure 16. Specific biotope maps after applying recovery.

As a result of setting a protection management goal, meso-classification types were rated as Grades 1–2, classified into 7 total types. Minor-classification types were ultimately rated as Grades 2–3, classified into 24 total types. Protection was evaluated using indicators of protected areas being highly rated according to naturality, rarity, connectivity, and ecological axis. These indicators include river naturality, number of polygons, hydrological control, naturality of dominant species, habitat rarity, forest size, and topography damage (see Table 15 and Figure 17).

Table 15. Biotope types and evaluation results after applying protection (biotopes in green areas).

Biotope meso-Classification Type	Meso-Classification Type Evaluation Grade	Management Goals	Biotope Minor-Classification Type	Evaluation Item	Evaluation Indicator	Evaluation Criteria	Minor-Classification Type Evaluation Grade
Small river	II(2)	Protection	Small river adjacent to the mountainous area	Naturality	Naturality of rivers	Natural type	II(2)
			Natural small river			Natural type	II(2)
			Artificial small rive			Artificial type	III(3)
			Small river for uses			Artificial type	III(3)
			Small river in land treated for erosion control			Artificial type	III(3)
Natural wetland	I(1)	Protection	Natural wetland	Rarity	Number of polygons	-	II(2)
			Abandoned paddy			-	II(2)
			Doombung			-	II(2)
Artificial wetland	I(1)	Protection	Debris barrier	Connectivity	Hydrological control	Weir	III(3)
			Created wetland			No weir	II(2)
Natural-artificial forest	II(2)	Protection	Natural–artificial Forest	Naturality	Naturality of dominant species	Natural–Artificial	II(2)
			Artificial–natural forest			Artificial–Natural	III(3)
Mountain forests	II(2)	Protection	Wet forest in mountainous forests	Rarity	Rare habitat	Wet forest	II(2)
			Forests with dominant natural vegetation on wet soils	Naturality	Naturality of vegetation	Natural	II(2)
			Forests with dominant natural vegetation on dry soils			Natural	II(2)
			Forests with dominant artificial vegetation on wet soils			Artificial	III(3)
			Forests with dominant artificial vegetation on dry soils			Artificial	III(3)
Hill land	II(2)	Protection	Wet forest on hill land	Rarity	Rare habitat	Wet forest	II(2)
			Forest dominated by natural vegetation distributed over large hill lands (>10 ha)	Ecological axis	Forest size	Large	II(2)
			Forest dominated by artificial vegetation distributed over large hill lands (>10 ha)			Large	II(2)
			Forest dominated by natural vegetation distributed over small hill lands (<10 ha)			Small	III(3)
			Forest dominated by artificial vegetation distributed over small hill lands (<10 ha)			Small	III(3)
Wet farmland	II(2)	Protection	Paddy fields with high naturality	Rarity	Absence and presence of readjustment of arable land	No readjustment of arable land	II(2)
			Paddy fields with low naturality			Readjustment of arable land	III(3)

As a result of setting a maintenance management goal, meso-classification types were rated as Grade 1, classified into 2 total types. Minor-classification types were ultimately rated as Grades 1–2, classified into 9 total types. Maintenance was evaluated based on high naturality along with high grades in terms of preservation (see Table 16 and Figure 18).

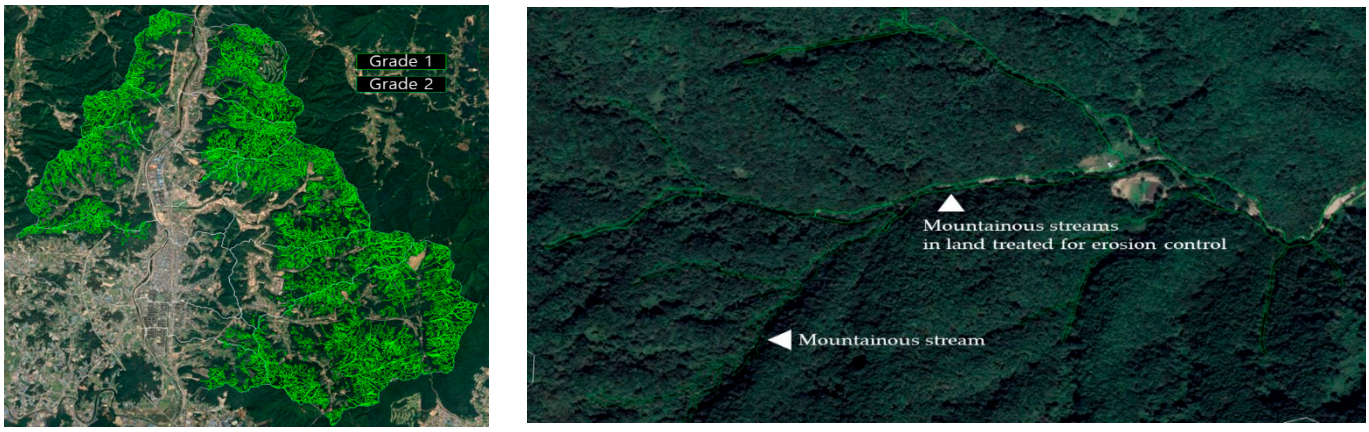


Biotope types and evaluation after applying protection Artificial wetland

Figure 17. Specific biotope maps after applying protection.

Table 16. Biotope types and evaluation results after applying maintenance (biotopes in green areas).

Biotope Meso-Classification Type	Meso-Classification Type Evaluation Grade	Management Goals	Biotope Minor-Classification Type	Evaluation Item	Evaluation Indicator	Evaluation Criteria	Minor-Classification Type Evaluation Grade
Natural river	I(1)	Maintenance	Mountainous stream	Naturality	Absence and presence of erosion control work	Absence	I(1)
			Mountainous streams in land treated for erosion control			Presence	II(2)
Natural forest	I(1)	Maintenance	Mountain wet forest	-	-	-	I(1)
			Mountain broadleaf forest with wet soil			-	I(1)
			Mountain broadleaf forest with dry soil			-	I(1)
			Mixed forest of soft and hardwood with wet soil			-	I(1)
			Mixed forest of soft and hardwood with dry soil			-	I(1)
			Mountain coniferous forest with wet soil			-	I(1)
			Mountain coniferous forest with dry soil			-	I(1)

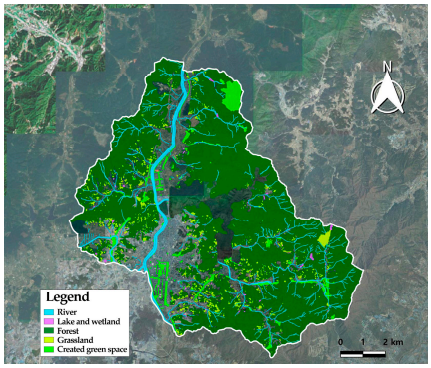


Biotope types and evaluation after applying maintenance Natural river

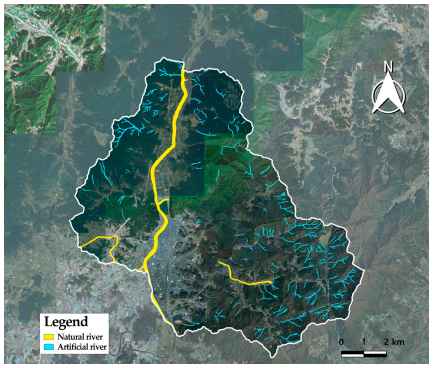
Figure 18. Specific biotope maps after applying maintenance.

3.4. Creation of Thematic Maps Using Biotope Minor-Classification Types

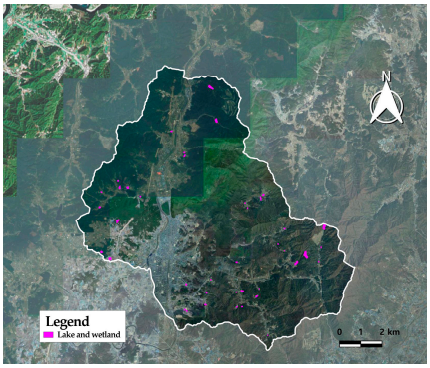
If the evaluation indicators are also applied to the criteria for categorizing biotope minor-classification types, usability can be enhanced. In other words, the classification of biotope types itself can become biotope evaluation, and confirming good and bad types becomes straightforward when these types are visually represented (Figure 19). For example, in the thematic maps of urban impervious surfaces, the meso-classification types such as urban detached housing, low-rise apartment complexes, mid-rise apartment complexes, low-rise commercial business districts, and mid-rise commercial business districts were evaluated based on permeability to enhance urban environmental functions. By mapping the minor-classification types with high and low permeability, it is possible to identify areas that require improvements in permeability. Furthermore, if biotope types that positively affect the urban environment—such as wind corridors, carbon sequestration, microclimate control, groundwater content, and green corridors—are visually presented, they can be utilized for various environmental thematic maps in the future.



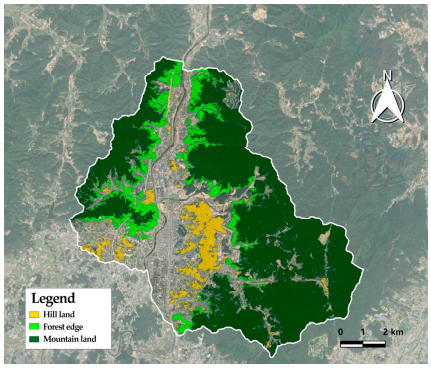
Thematic map of urban ecological axes



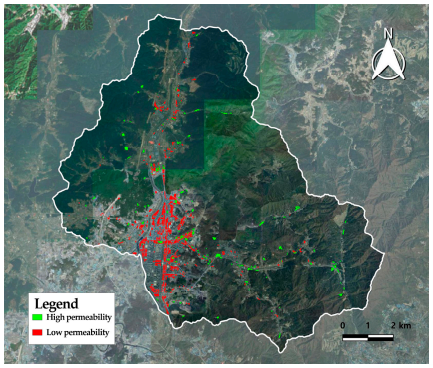
Thematic map of natural–artificial rivers



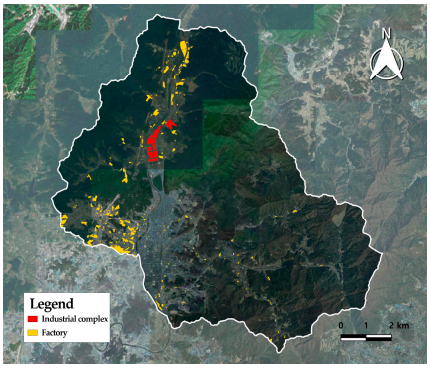
Thematic map of wetlands



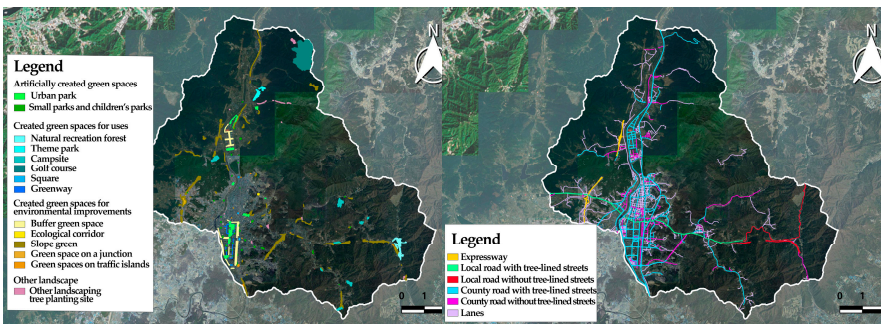
Thematic map of forests experiencing high development pressure



Thematic map of urban impervious surfaces



Thematic map of industrial areas



Thematic map of created green spaces biotope

Thematic map of street trees

Figure 19. Thematic maps for different biotope types.

4. Discussion

The meaning of each evaluation grade for the previous study sites was evaluated from a perspective of naturally superior biotopes (Table 17). The closer to Grade 1, the closer to conservation. Although conservative significance was confirmed, methods to manage and utilize the areas with low-graded naturality were lacking. In other words, since diverse applicability was not considered in the process of producing biotopes, they have been utilized primarily for policies that restrict development.

Table 17. Meaning of evaluation grades for previous study sites.

Evaluation Grade	Description
I(1)	- Biotopes that are free of human interference or have been stable and mature for a long period of time - Biotopes that have high naturality that they cannot be substituted and require absolute conservation
II(2)	- Declining biotopes with some human interference and moderate sensitivity to damage - Biotopes that have some degree of naturality, high potential for enhancement of ecological value after restoration, and possibility of conditional substitution
III(3)	- Biotopes that have high human interference, low sensitivity to damage, and low naturality, requiring medium- to long-term regeneration
IV(4)	- Biotopes with very high human interference and low potential for regeneration to nature
V(5)	- Biotopes that cannot be regenerated by nature due to excessive energy utilization and disconnected circulation systems

Biotope maps are constructed in two stages: biotope-type classification followed by biotope evaluation. Biotope-type classification identifies the characteristics of biotopes and classifies them into major-classification → meso-classification → minor-classification [40]. The standard for classification in subdividing biotopes from meso-classification to minor-classification types is referred to as examining classification indicators. Setting the classification indicators to be the same as or similar to the evaluation indicators will facilitate biotope evaluation. In other words, biotope classification itself can be regarded as biotope evaluation. Thus, it is necessary to consider how to perform evaluation at the stage of biotope-type classification.

This study set the management goals for biotope evaluation according to type at the stage of biotope-type classification and provided a biotope-type classification and evaluation method by applying evaluation indicators to meet the management goals.

The results of the biotope evaluation after applying the management goals for each type were as follows. Biotope types for maintenance were rated as Grade 1. Although Dongducheon City belongs to the Gyeonggi Province, which includes large cities and active development, 65% of the city is covered by forest. These forests exist on a large scale above a certain size, and large patches have important ecological value because they create diverse microhabitats that protect water quality, connect water systems, maintain populations of internal species, provide a habitat for wild animals, and serve as a source of species [41]. Numerous valuable biotope types were identified in the province including natural forests, which are in pristine state and account for 50.61%. They also include habitats with natural rivers flowing within forests, leading to a high biodiversity. Most of them are located at high altitudes. Therefore, they are difficult to access and are managed based on various development regulations. These types will likely remain in their current state.

Biotope types for protection were rated as Grades 2 or 3. The number of these biotope types is gradually decreasing despite their ecological values. Kim [42] analyzed the fragmentation levels of green space biotopes through biotope maps and found a gradual increase in small green space biotope patches, indicating habitat fragmentation. Hwang [43] noted that corresponding types have high carbon storage capacity, and Kim [44] identified

them as places generating cold air in a city or serving as wind corridors. Examples include lowland wetlands, forest edges close to cities, and forests fragmented by roads and cities. These types require protection measures because they are at risk of damage due to their proximity to cities. Therefore, we applied evaluation indicators that can reduce or recover from damage. If wetlands naturally retain water, forest edges restore damaged vegetation, and fragmented forests are connected, they were assigned to Grade 2. Otherwise, they were categorized as Grade 3.

Biotope types for recovery were evaluated as Grades 3 and 4. These types retain naturality to some extent. Examples include rivers in urban centers and forests or grasslands that have been damaged. We applied evaluation indicators that should be recovered to a state similar to nature by reducing artificial factors. Rivers are pivotal in the urban environment, but most rivers in Dongducheon City are artificially damaged. River biotopes can serve as habitats for birds, and Chae [45] found that river biotopes support diverse types of birds due to abundant insects. Han [46] confirmed a higher number of individuals in larger biotopes. Kim [47] indicated that these biotopes are crucial for regulating the urban microclimate. Therefore, evaluations can be based on the intensity of anthropogenic management. Grade 3 was assigned if the area of artificial structures was smaller or that of natural vegetation was larger and Grade 4 was used if the area of natural vegetation was smaller.

Biotope types in which the ecological quality should be improved were rated as Grades 4 and 5. Typical examples are urban parks and man-made green spaces. Grade 4 was assigned if the green spaces were larger, green spaces were connected or created, wild animals could move, and buffer functions existed related to the risk of damage to the surroundings. Otherwise, they were evaluated as Grade 5.

Biotope types for the creation category were rated as Grades 5 and 6. These types enhance environments based on the creation of green areas along with artificial elements in a city to improve the urban environment. Kang [48] suggested that there should be measures to increase groundwater storage, and Yoon [49] indicated that these types can lower temperatures and increase thermal comfort in a city. Grade 5 was assigned if green areas were identified around buildings or facilities, such as residential, commercial, and business buildings; the percentage of green areas was high, and rainwater collection and infiltration were possible. Otherwise, Grade 6 was assigned.

Biotope types for the reduction category were rated as Grades 6 and 7. Because these types are affected by contamination that degrades the environmental quality, measures should be implemented to reduce negative impacts. Examples include factories, power generation facilities, roads, parking lots, and railroads, which generate pollutants. Grade 6 was assigned if a purification facility was identified or a buffer function existed based on green areas. Otherwise, the biotope type was rated as Grade 7.

This study has several limitations. First, the management goals for each biotope type could be more diverse. It is difficult to generalize the management of biotope types because of regional, environmental, and institutional differences. However, considering that appropriate management targets were established for each damage level in correlation with the ecological value, it is important to emphasize how a biotope map that includes purposes can be created. Second, it is necessary to develop and supplement new indicators for the evaluation of each management goal. In this study, biotope evaluation factors were extracted from previous studies. All biotope types require indicators that can be used to clearly evaluate their status. Third, more objective evaluation criteria should be utilized when evaluating biotope types using indicators. Because biotope types are diverse and field surveys are limited, the coverage of accurate attributes for all biotope types is restricted. Therefore, it is necessary to reduce the intensity of fieldwork, add verifiable attribute data to biotope objects, and supplement criteria for evaluation with objective figures based on attribute data.

5. Conclusions

This study attempted to suggest a biotope mapping method to utilize the biotope map for environmentally friendly urban development in various ways.

First, we derived the management goals for each biotope type with ecologic value. The biotope types were categorized into nature, near-nature, and semi-nature according to the damage level. Because several types can easily be returned to their original state and other types cannot be returned to their original state due to severe damage, it was necessary to establish strategies according to the ecological value. Therefore, biotopes were reorganized based on low and high ecological values, and management goals were derived in the following order: maintenance, protection, recovery, improvement, creation, and reduction.

Second, we derived evaluation indicators for each management goal. They can be easily applied when setting purposes through biotope evaluation. Evaluation indicators were required to achieve the management goals of maintenance, protection, recovery, improvement, creation, and reduction. We extracted biotope evaluation factors from previous studies and processed the data with evaluation indicators. The derived indicators were categorized into 11 evaluation items by conducting an expert FGI: diversity, urban environment improvement functionality, recuperative ability, potential habitat, ecological functionality, connectivity, availability, naturality, vulnerability, risk of damage, and rarity. These evaluation items were classified into the five management goals of biotopes using the second FGI. Thus, the previous study suggested evaluation of Grades 1 to 5, but this study evaluated them more broadly from Grades 1 to 7 and improved the usefulness by further segmenting grades 4 and 5 of the previous study (mostly developed or in urban areas where biotopes are important to the urban environment, but are undervalued in the evaluation of biotope-type). The directions for the utilization of each grade were presented by reflecting the evaluation grade and management goals.

Third, the suggested biotope mapping method was applied to the biotope map of Dongducheon City, Gyeonggi Province. Biotope types were classified into 16 major-, 23 meso-, and 123 minor- classification types. The biotope evaluation showed that 8 (31.27%), 15 (12.22%), 16 (17.20%), 18 (12.90%), 26 (5.61%), 24 (7.64%), and 14 (3.60%) biotope types belong to Grades 1 through 7, respectively. Two types (9.56%) were excluded from the evaluation. The biotope type for maintenance was classified as Grade 1, the biotope type for protection as Grades 2 and 3, the biotope type for improvement as Grades 4 and 5, the biotope type for creation as Grades 5 and 6, and the biotope type for reduction as Grades 6 and 7; the management direction for each biotope-type was also presented.

This study suggested a biotope mapping method for all biotope types comprising the biotope map to be applied in various ways from the perspective of environmentally friendly urban development. Previous studies primarily focused on deriving an excellent natural environment by evaluating the conservation value, which led to a limitation: limited utilization as a means of development restriction and regulation. This study is significant in that it set management goals and suggested evaluation indicators for achieving these goals at the biotope-type classification phase, which is the biotope production process. This approach can facilitate the implementation of future management measures per type. Moreover, this study considered biotope mapping methods for a biotope map to be applied to environmental planning in a city.

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Conflicts of Interest: The authors declare no conflicts of interest.

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