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Analysis of Changes in Suitable Habitat Areas of Paridae through Rooftop Greening Simulation—Case Study of Suwon-si, Gyeonggi-do, Republic of Korea

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Abstract: As many people live in cities that lack green space, biodiversity in such areas is decreasing. Suwon, the study site, a city that strives to improve its biodiversity, is close to the capital city of the Republic of Korea (ROK), and has a large population. This study aims to identify habitat-suitable areas using the longitudinal distribution model in Suwon-si, examine habitat changes when rooftop greening scenarios are applied to various use areas, and distinguish efficient use areas to expand the number of forms. To establish a rooftop greening creation scenario, the area was calculated based on the rooftop greening promotion plan in the metropolitan area, and a representative use area where rooftop greening can be applied was selected. To generate a scenario for creating rooftop greening, the property of the green area was assigned to the corresponding use area, and it was produced as an environmental variable, while the species distribution model was driven. As a result of the study, the area of increase in habitat area according to the rooftop greening for each usage area was derived, and the efficiency of the increase in habitat area compared to the rooftop greening area for each usage area was derived. To improve biodiversity in Suwon-si, rooftop greening in residential areas was found to be the most efficient, and rooftop greening efficiency in commercial areas was the lowest. It is expected that information on the increase and efficiency of the habitat of the wild birds due to rooftop greening by area of use derived from this study will help establish a rooftop greening plan and support decision-making to promote biodiversity in the city.

Keywords: species distribution model; green roof scenario; type of building; MAXENT model

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1. Introduction

Urbanization is progressing rapidly, with more than half of the world's population living in cities [1]. As the city develops, land-use changes, natural environment is lost, and green space becomes scarce, making it difficult for species to inhabit an area. Recognizing this crisis globally, the Convention on Biological Diversity (CBD) proposed five strategic objectives and 20 detailed objectives to be achieved by 2020 in the Aichi biodiversity target [2]. As of 2020, the target year, many countries were striving to achieve the target.

The Republic of Korea is also a country that has developed rapidly since the 1950s and is currently undergoing rapid urbanization nationwide [3]. Among areas undergoing rapid urbanization, Suwon-si, which is the subject of this study, is playing a leading role in promoting biodiversity by holding biodiversity forums to raise the interest of citizens and for them to participate in the creation of a biodiversity map. During the event, Suwon-si citizens recognize the importance of biodiversity, and they ultimately contribute towards its advancement [4].

It is essential to secure green space areas to promote biodiversity in cities [5]. However, due to the limited budgets of the national and local governments, it is not easy to purchase expensive city sites and create public green areas. In Suwon's new city plan, efforts are being made to secure enough green space and create a compressed city that concentrates residential and commercial areas in specific spaces [6]. However, it is challenging to secure land for green space in cities that have already been developed.

Rapid urbanization leads to changes in land-use, climate, hydraulic systems, and biodiversity [7]. Therefore, technologies for introducing green spaces that are economically efficient and effective for living species are being developed in existing cities. Representatively, some technologies utilize scrap spaces in the city, such as rooftop greening, wall greening, rain gardens, and street greening [8]. Among them, rooftop greening has the advantage of being able to choose between lightweight and heavy types depending on the load that existing buildings can withstand [9]. Rooftop greening is gathering increasing attention as an essential means to overcome environmental problems related to urbanization [10]. It can also serve as a resting place for birds during flight and as a habitat for stepping stones to supply water. In terms of buildings' energy use, it is also suitable for persuading building owners and applying it as it reduces the use of cooling energy and provides a resting space for visitors [11]. Recently, green roofs and walls have emerged as conservation tools, providing the only additional opportunity to improve the biodiversity of cities [12].

Some studies have analyzed the effect of improving biodiversity when applying such rooftop reforestation. In 2010, in order to improve the function of the green area network in Jung-gu, Seoul, ROK, algae were used as a target species. The ecological characteristics and location criteria of the target species were given a rating, and the building was graded and analyzed to study the selection of a rooftop greening site [13]. Reviewing the preceding studies, many studies select the green area of the downtown area (that is, the stepping stone green area or green roof area that connects the core green areas) and anticipate the effects and economic value. However, preliminary studies evaluate the quantitative effect according to the construction area and whether it is adequate to construct a building belonging to a type of site when constructing a rooftop.

On the other hand, many studies have investigated urban parks and urban green areas from wildlife habitat environments. Considering the size of urban parks and citizens' active use, most studies are limited to birds. In particular, the target species suitable for evaluating urban ecosystems' health are birds living in cities [14]. Birds can fly and move across cities, so they have fewer mobility restrictions than other animals. Therefore, algae appearing in a city can be interpreted as a green network in which algae can move in the area [15]. The Paridae, which is commonly found nationwide in ROK, is a small bird of the order of Paridae and is a representative species living in ROK cities due to its relatively rich population [16]. It can be seen that vegetation cover and natural vegetation biomass in urban areas are significant factors for the diversity of the urban algae.

The purpose of this study is to analyze the changes in habitat suitability through a rooftop greening composition scenario for the Paridae family in Suwon-si using the species distribution model (SDM) and to propose a compelling rooftop greening composition plan. When developing a scenario, this study searched for the most suitable one by setting different types of buildings that can create rooftop greening and construction areas. This study can be used as a scientific basis to support policy decision-making in creating rooftop greening to improve biodiversity in urban areas that will be developed in the future. In particular, it can be used as primary data for preparing spatial planning policies and strategies to apply rooftop greening.

2. Literature Review for Rooftop Greening Simulation

This study searched for reports that simulated rooftop greening's application effect, but most of the studies consisted of thermal environment improvement or energy performance evaluation. It was not easy to find the contents of similar studies at home and abroad. Therefore, the concepts related to this study were found and applied to the rooftop greening simulation. Since this study aims to see the change in the habitat suitable for the Paridae family through the rooftop greening creation scenario, a preceding study was conducted using the green infrastructure and land-use scenarios as keywords.

As a result of reviewing previous studies related to green infrastructure to increase biodiversity in cities, many studies dealt with the expansion of green areas in cities via such modifications as rooftop greening, street trees, open spaces, and rain gardens [17–19]. Among them, rooftop greening emerged as advantageous in that it can be applied even without creating a new space for securing green space [20]. It was also considered an advantage that different application levels were possible in lightweight and weight type depending on the building's durability condition [21,22]. Therefore, in this study, the city's habitat was secured by focusing on rooftop greening.

Research related to the land-use scenario was examined to refer to the method of applying rooftop rehabilitation. The land-use scenario study mainly deals with predicting future land-use changes based on development trends from the past to the present [23]. By considering the rate at which the urbanized area expands, how the future land use would be structured was estimated [24]. In predicting future land use, there was also a study that subdivided the degree of development pressure to establish a scenario and predict the future [25].

This paper focused on studying land-use scenarios in which different development areas were calculated, considering the level of development pressure. It applied a rooftop greening scenario by subdividing the types of buildings to which rooftop greening can be applied and then subdivided the area that can be created. Although it was not possible to refer directly to the study that constituted the scenario for rooftop greening, the basis was prepared by referring to the green infrastructure study and land-use scenario.

3. Methods

3.1. Scope of the Study

The spatial scope of this study is Suwon-si, Gyeonggi-do. Suwon-si has 121.05 km^2, a population of 1,192,018 people, and a population density of 9847.31 people/km^2, which is one of the largest cities in ROK (Figure 1). Looking at the study's overall flow chart, the scope of the study is Suwon-si, South ROK, and the temporal range is set to 2019, the same as the year of biotope map production in Suwon-si. The input data used in the study consist of simulation information as a rooftop rehabilitation scenario that is expected to expand the range of habitats of the Paridae family, Suwon-si environmental variables related to the Paridae family, and coordinates of the Paridae family appearing in Suwon-si. As a research method, a statistical model was selected based on these input data, and the dependent variable (appearance coordinates), independent variable (environmental variable), and rooftop greening composition scenario were made and utilized to drive and verify the model. The effect of expanding the habitat area was confirmed by comparing the result values before and after according to the current habitat of the Paridae family and the rooftop greening creation scenario. The efficiency of each rooftop greening composition scenario was likewise derived (Figure 2).

3.2. Species Occurrence Data

The study's target species is a large number of birds that appeared in Suwon-si and had a sufficient population necessary to use as a representative model. As a result of analyzing the emergent data on the bird species in the 2019 Urban Ecosystem Status Map produced by Suwon-si to select the target species, it was confirmed that a significant number of individuals appeared in the central area of Suwon-si and the outskirts of Suwon-si (Table 1). Among the emergent data of several identified individuals, the Paridae family, whose number of individuals was relatively large among the Paridae, Picidae, and Muscicapidae families, was designated as the target species, with the appearance information used as a dependent variable.

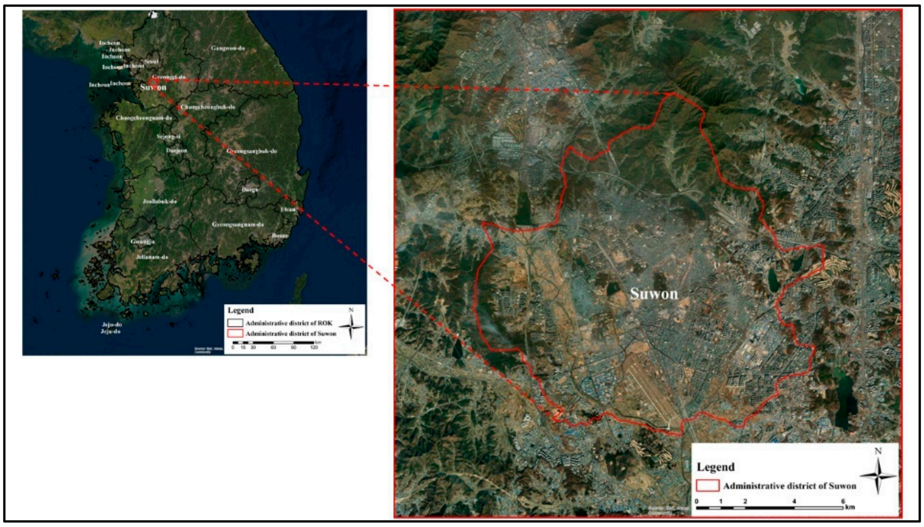

Figure 1. Study site.

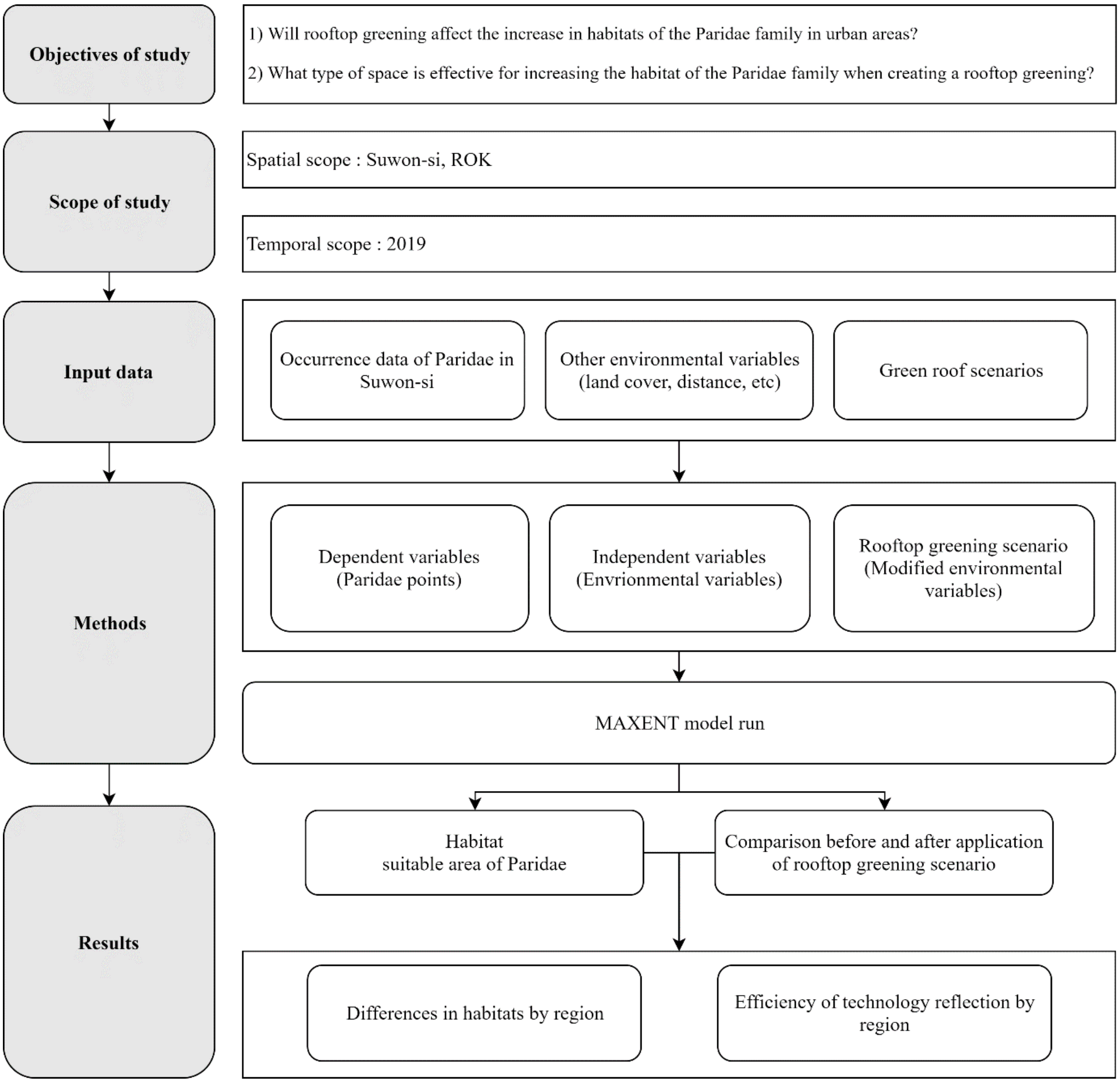

Figure 2. Research flow chart.

Table 1. Occurrence data of Paridae in Suwon-si.

Family	Species	Population
Paridae	Parus minor	93
	Periparus ater	4
	Poecile palustris	81
	Parus varius	23
Total		201

3.3. Environmental Variable Data

To select environmental variables for evaluating the habitat suitability of the target species, the environmental variables used in the birds' habitat suitability analysis, such as green space, cultivated land, human influence, climate, and topography, were positively correlated with the Paridae family. The displayed environmental variables were selected [26–28]. The representative space types of Suwon-si were divided into residential areas, industrial areas, public areas, and commercial areas, and the distance variables and land-use categories of slopes, roads, green areas, and rivers were created as environmental variables. These were produced in high resolution and in units of 5 × 5 m (Table 2). ESRI's ArcGIS 10.5 was used to edit and create all environmental variables.

Table 2. Environmental variables.

No	Variable	Type	Content
1	lc_type	Categorical	Land Cover (7 types) (1) Urbanization area, (2) Agricultural area, (3) Forest, (4) Grassland, (5) Wetland, (6) Bare land, (7) River
2	dist_resi	Continuous	Distance from residential area/Reflect recovery technology
3	dist_indus	Continuous	Distance from industrial facility area/Reflect recovery technology
4	dist_public	Continuous	Distance from public facilities area/Reflect recovery technology
5	dist_comm	Continuous	Distance from commercial area/Reflect recovery technology
6	dist_road	Continuous	Distance from road
7	dist_green	Continuous	Distance from greenery
8	dist_river	Continuous	Distance from river

(Source: Land Environment Geospatial Information, 2019).

3.4. Species Distribution Model

In this study, the Maxent 3.4.1 model, proven through several previous studies, was used to predict species' distribution using the species appearance data of the target species [29–32]. Maxent is one of the machine learning models and predicts species' distribution based on the theory of maximum entropy [33]. The concept of maximum entropy is a method of estimating species' distribution when the degree of disorder is maximum [34]. The model is nonlinear, a statistical distribution model that predicts organisms based on new data and environmental factors.

In general, it is possible to use the appearance and non-appearance coordinates for some species that have been thoroughly surveyed, but it is not easy to generate non-appearance coordinates for most species [35]. Therefore, the Maxent model has the advantage of being useful when the data such as species appearance and non-appearance are minimal or when the probability distribution cannot be derived by conventional statistical inference methods [36]. For this reason, Maxent is suitable for domestic species distribution studies [37]. In addition, machine learning models effectively derive optimal results by manipulating data and applying environmental variables, whereas statistical analysis of variables is possible through the contribution of each variable [38].

3.5. Developing Rooftop Greening Scenarios

To verify the assumption that the suitable habitat area's expansion effect will vary depending on the building target for rooftop greening and the area of construction, a rooftop greening construction scenario applicable to the species distribution model of the Paridae family was developed. There are two scenarios for creating rooftop greening; the first is to select a target space in which to apply rooftop greening. For this purpose, the criteria for the classification of use areas was used. Buildings in cities in the ROK are administratively classified according to their use area classification, and the location and distribution of buildings are also different by use area. Therefore, it is judged that the rooftop greening effect may vary by use area, and it can be a good criterion for decision-makers to approach policy. Therefore, in this study, public facilities, industrial facilities, commercial facilities, and residential areas were selected as the rooftop greening areas and as the urbanized area among the seven land-use areas in Suwon-si (Figure 3). They were selected to consider the effect of rooftop greening as a representative use area in the city.

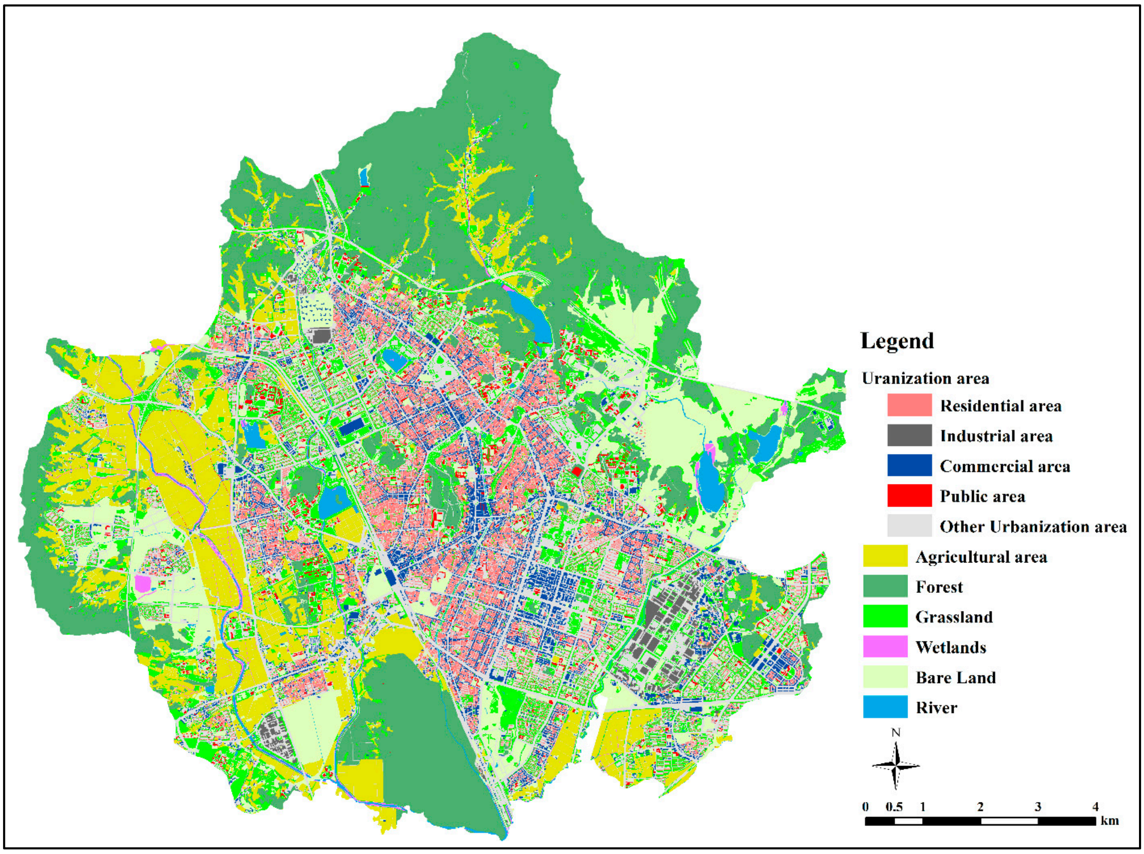

Figure 3. Land cover in Suwon-si.

The second is the composition area of the rooftop greening. It is necessary to establish a standard for how much rooftop greening will be developed for each area. For calculating the appropriate rooftop greening area, the "rooftop greening promotion plan" of Seoul, the capital city of ROK, was used as reference [39]. Seoul City has established a plan to expand the rooftop greening area to 1, 3, and 5% through a mid-to-long-term plan and is carrying out the project. Accordingly, in this study, a scenario was developed to create rooftop greening for buildings with the top 1, 3, and 5% areas of each use area.

To apply the developed rooftop greening construction scenario to the species distribution model, it was necessary to change the properties of the buildings in each use area selected as the target site for rooftop greening to green. Buildings corresponding to the top 1, 3, and 5% of public facilities, industrial facilities, commercial facilities, and residential areas were selected, and the properties of green areas were assigned to produce them as environmental variables. By inputting the produced environmental variables into the species distribution model's projection, it is possible to confirm the change of the habitat distribution when only rooftop greening is added in the model developed based on the existing habitat environment. As described above, by applying the building and construction area differently to be used for rooftop rehabilitation according to the scenario, this research analyzed the change in the Paridae family's habitat under various conditions and compared the effects.

4. Results

4.1. Analysis Result of a Suitable Area for Paridae Habitat

As a result of the analysis of suitable habitats of the Paridae family, it was found that large-scale habitats are concentrated in the northeast and southwest of Suwon, and the habitats are distributed around some green areas in the center of the city (Figure 4). The habitats in the northeast and southwest are mainly large green patches (forests), and the habitats in the center of the city were identified as green park areas. Previous studies have also evaluated that the Paridae family often appears in urban parks [40].

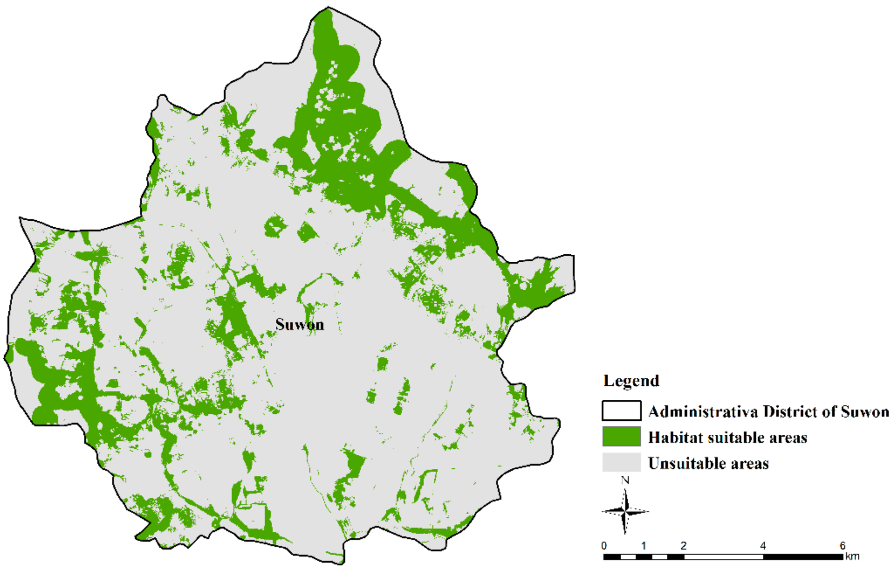

Figure 4. Suitable habitat area of the Paridae family.

The model results were verified with Area Under the Curve (AUC) values through Receiver Operating Characteristic (ROC) analysis. ROC analysis is used to evaluate the performance of the model [41]. ROC has been commonly used in medical decision making, but in recent years, it is increasingly used in machine learning and data mining studies [42]. In this study, the AUC value of the ROC curve was used to determine how well the probability of predicting the appearance of the species distribution model by Maxent coincides with the species' actual occurrence. AUC refers to the probability that a randomly selected point of appearance will be evaluated higher than a randomly selected point of non-emergence. Even if only appearance coordinates are used, like the Maxent model, the AUC value can be measured using pseudo-absence data uniformly randomly selected within the target site instead of the actual non-appearance coordinates [43].

As for the reliability of the model, the Area Under Curve (AUC) value derived through the Receiver Operating Characteristic (ROC) curve analysis was 0.855, indicating a meaningful reliability value. In general, studies using statistical models are evaluated as excellent when the AUC value is between 0.9 and 1.0, good when the value is between 0.8 and 0.89, fixed when the value is between 0.7 and 0.79, and poor when the AUC value is between 0.51 and 0.69 [44]. The logistic output result, which shows the estimated value of the species appearance probability as a value between 0 and 1, was selected, and the threshold value used as the species appearance criterion was found to be 0.337, in order to determine the suitable habitat area in the habitat fitness probability map.

The environmental variables before the greening were reflected as follows: the distance from industrial facilities, the distance from residential areas, the distance from roads, and the land cover showed high contribution (Table 3). Concerning the reaction curve, as the distance from industrial facilities and residential areas increases, the probability of algae emergence increases. Therefore, if resilience technology is applied to industrial facilities and residential areas, habitat suitability is expected to be significantly improved (Figure 5).

Table 3. Contribution of environmental variables.

Variables	Contribution
Distance from a residential area	0.398
Distance from an industrial facility area	0.194
Distance from the road	0.148
Distance from the greenery	0.073
Distance from the river	0.068
Land cover (7 types)	0.053
Distance from the public facilities area	0.052
Distance from the commercial area	0.014

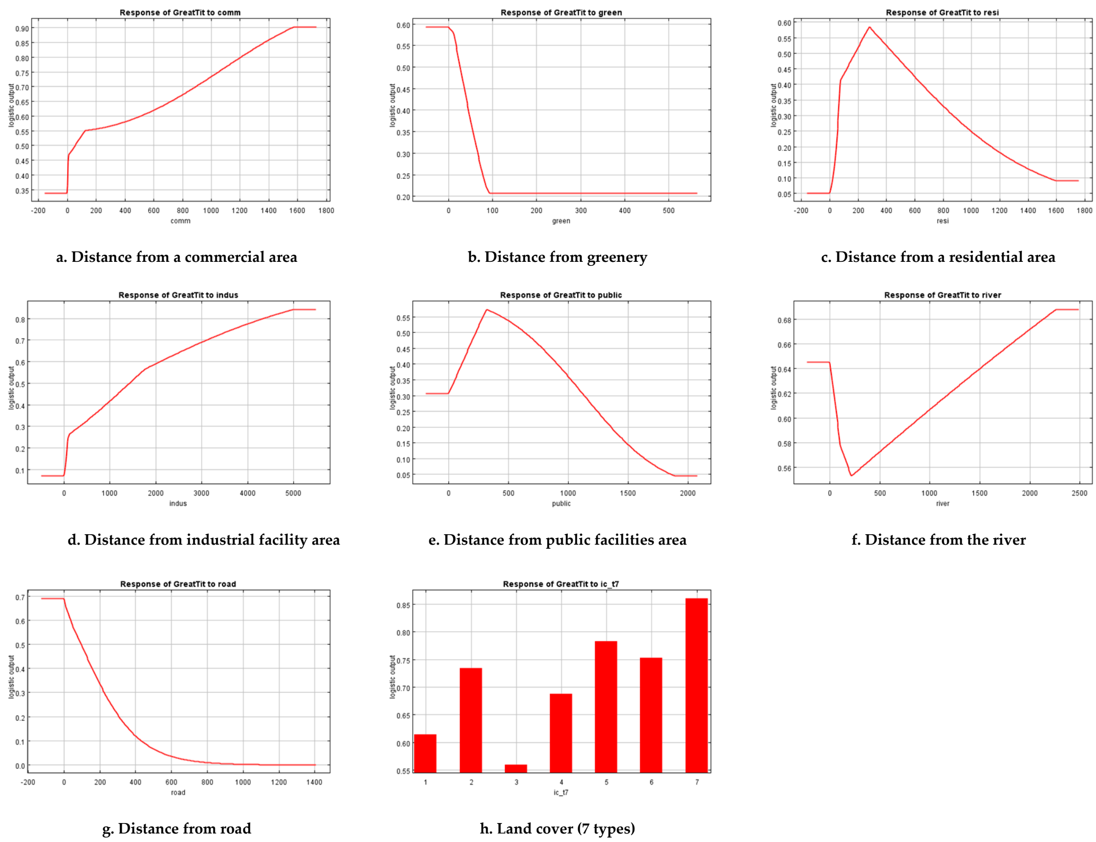

Figure 5. Response curve graphs of environmental variables. (**a**–**g**): x = probability of presence, y = distance (m), (**h**): x = probability of presence, y = land cover (7 types; (1) urbanization area, (2) agricultural area, (3) forest, (4) grassland, (5) wetland, (6) bare land, and (7) river).

4.2. Rooftop Greening Scenarios

To apply the rooftop greening scenario by space type, a building with the top 1–5% of the rooftop areas of residential, public, commercial, and industrial areas within the target site was selected as the rooftop greening area. The roof greening composition effect was applied by assigning the property of green space to public facilities, industrial facilities, commercial facilities, and residential areas in the middle category of land cover, which is believed to be easy to apply rooftop greening technology. The spatial characteristics of rooftop greening targets for each region are distributed evenly throughout Suwon-si in public areas, in small amounts in the industrial region's northern and southern regions, and collectively in the southeastern region. Commercial areas are widely distributed in the northwest and central and eastern regions. Residential areas are widely distributed in the central and southeastern areas of Suwon-si and are evenly distributed throughout. The general tendency is evenly distributed throughout Suwon-si, but facilities are distributed in the central and eastern areas.

4.3. Change of Habitat Suitability according to Rooftop Greening Scenarios

If the current status map of the top 1–5% of the area is observed for each purpose that will serve as a stepping stone (roof greening) connecting green areas in Suwon-si, one can see that residential areas are evenly distributed throughout Suwon-si. In the case of the area, it is correct that it is distributed throughout the city, but it is relatively small compared to the residential area. In the case of the rest of the commercial areas, it is possible to confirm that the distribution is similar to that of the residential areas, and in the case of industrial areas, it is possible to confirm that they are concentrated in a relatively small amount compared to other areas outside the downtown area (Figure 6).

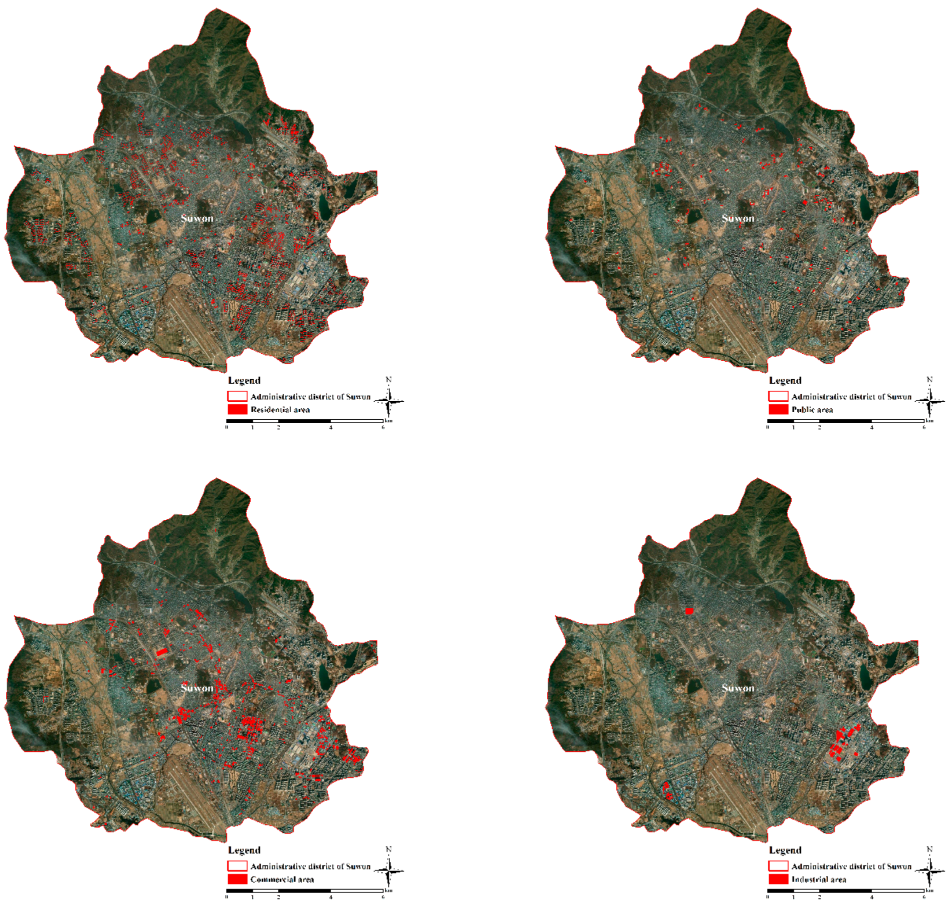

Figure 6. Four types of spatial areas for green roofs.

In residential areas, from the 1% scenario to the 5% scenario, the habitats in the northeast and southeast parts of Suwon-si increased considerably. In the case of the 1% scenario, a considerable number of habitats increased in the northeastern part of Suwon-si, and in the case of 3%, the habitats increased from the northeast to the east and southeast, with the last 5% showing a noticeable increase to the south and southwest. One can also check the appearance. As shown in Figure 6, rooftop greenery in residential areas is mostly concentrated on the right side, such as in the northeast and southeast, but in 1% of the cases, the Paridae habitat is concentrated in the northeast. In addition to the central and eastern parts, it can be confirmed that a significant number is also distributed in the southwest. The reason why the residential area shows this pattern is that it is distributed as a whole in addition to the northeast, eastern, and southeastern areas near Suwon-si, and the locational characteristics of the residential area are located close to parks or mountain city green areas (city parks), acting as a stepping stone connecting green areas and green areas. Moreover, the increase in habitat area is high (Figure 7; Table 4).

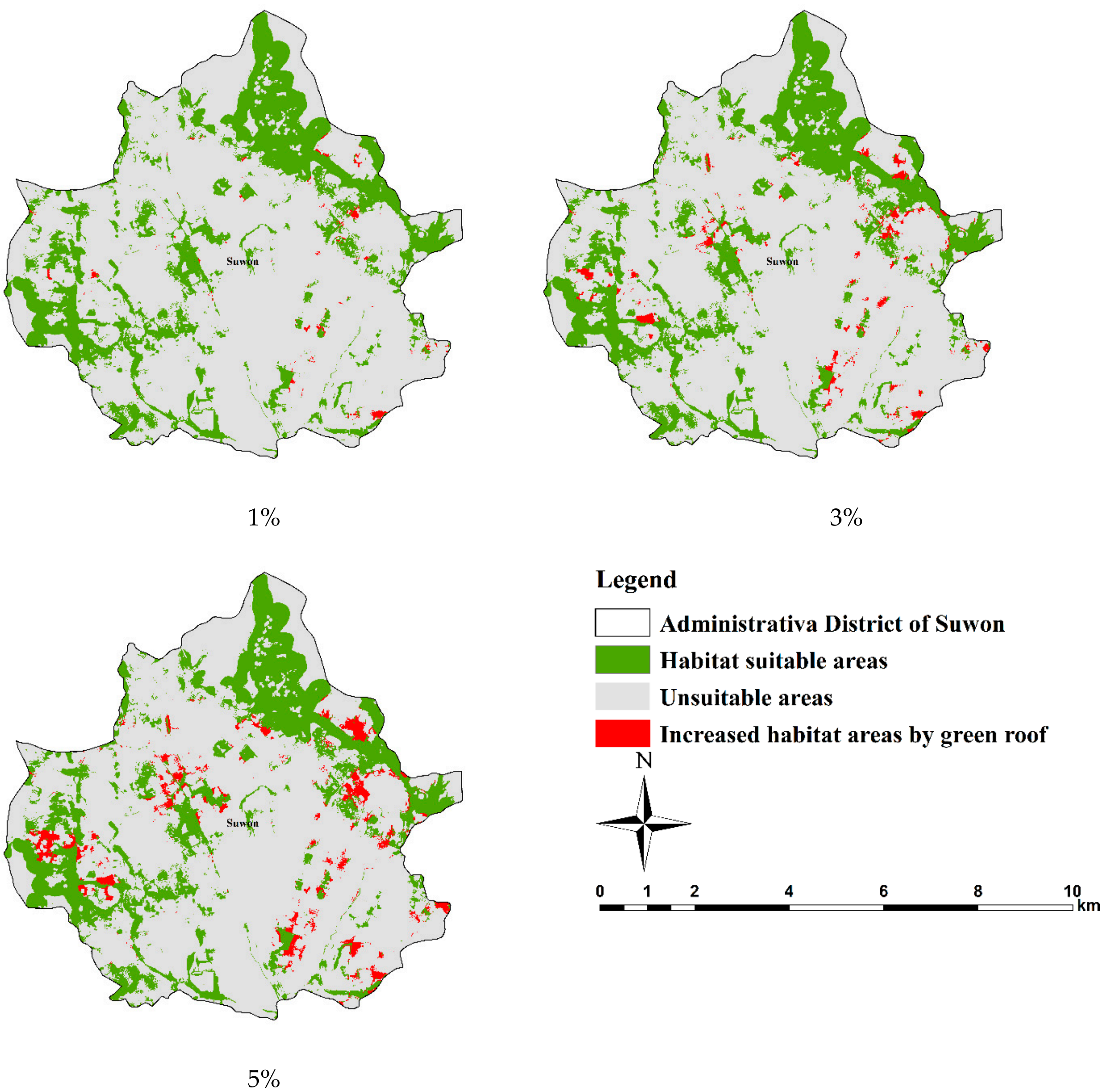

Figure 7. Application result of rooftop greening scenario in the residential area (RS below residential area rooftop greening scenario).

Table 4. The efficiency of rooftop greening for each target area.

The Target Area of the Green Roof	Scenario	1%	3%	5%
Residential area	Rooftop greening area (km^2)	0.51	1.18	1.70
	Habitat increase area (km^2)	0.53	1.88	3.99
	Efficiency compared to the area of technology reflected (%)	103.9	159.3	234.7
Industrial area	Rooftop greening area (km^2)	0.20	0.36	0.46
	Habitat increase area (km^2)	0.10	0.29	0.44
	Efficiency compared to the area of technology reflected (%)	50.0	80.6	95.7
Commercial area	Rooftop greening area (km^2)	0.75	1.41	1.86
	Habitat increase area (km^2)	0.51	0.61	0.91
	Efficiency compared to the area of technology reflected (%)	68.0	43.3	49.0
Public area	Rooftop greening area (km^2)	0.17	0.38	0.54
	Habitat increase area (km^2)	0.20	0.54	0.80
	Efficiency compared to the area of technology reflected (%)	117.6	142.1	148.1
Total area	Rooftop greening area (km^2)	1.65	3.34	4.58
	Habitat increase area (km^2)	1.39	3.64	6.52
	Efficiency compared to the area of technology reflected (%)	86.87	110.3	144.88

In industrial areas, the overall rooftop greening area increased from the 1% scenario to the 5% scenario, but the rooftop greening area increased significantly in the southern area. In the 1% scenario, habitats increased intensively in the southwestern part of Suwon-si, but the 3% and 5% scenarios did not show a high positive increase. Figure 5 shows that rooftop greening in industrial areas is concentrated in a small amount in the northwest and a small amount in the south, but in all three scenarios, 1%, 3%, and 5%, the increase in habitat area is distributed in the southwest. Even though rooftop greening was concentrated in the southern area in industrial areas, this result was because the rooftop greenery in the southeastern area had more buildings than the surrounding green areas. In the southwest industrial area, natural green areas were widely distributed in the lower-left corner, and the result was that the increase in habitat was concentrated by acting as a stepping bridge (Figure 8; Table 4).

In the commercial area, as the 1% scenario went from the 5% scenario, the rooftop greening area increased in the northwestern part of Suwon-si and the center of Suwon-si. In the 1% scenario, there was a small increase in habitats in the southeastern part of the center. The 3% and 5% scenarios also showed a small increase in the 1% habitat increase in the vicinity. As shown in Figure 5, rooftop greenery is clustered in the center and southeast of Suwon-si and is widely distributed in small quantities in the west. It can be seen that the area where the habitat increases is increased by a small amount in the center and an appropriate amount in the southeast. Commercial areas show such an increase in habitat area because it is located in a commercially appropriate place rather than in forests and green areas. After all, it is mainly located in a place with many vehicle movements and floating populations. This result appears because it does not exist in the location. There are also many buildings in the vicinity rather than green areas, so it cannot act as a stepping stone (Figure 9; Table 4).

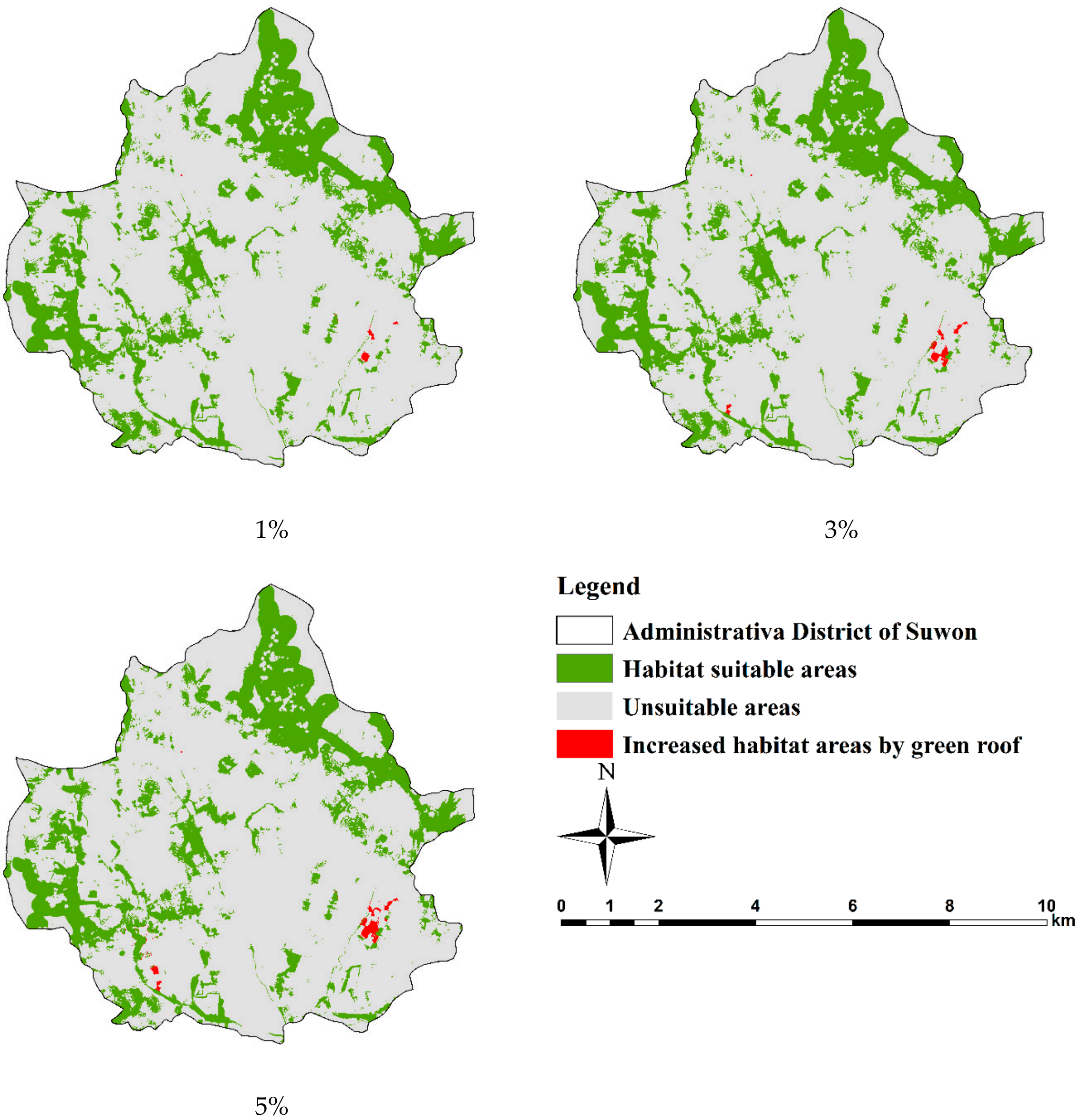

Figure 8. Application result of rooftop greening scenario in an industrial area (IS below industrial area rooftop greening scenario).

In the public area, the overall rooftop greening area increased from the 1% scenario to the 5% scenario. As the greening area increases, as shown in Figure 5, public areas are not concentrated throughout Suwon-si but are distributed evenly. The area of habitat increase also gradually augmented from the 1% scenario to the 5% scenario. In the case of public areas, unlike other use areas and due to the characteristics of use areas, they are not concentrated throughout the city and are distributed evenly, so increasing the rooftop greening area will increase more habitats (Figure 10; Table 4).

To examine the effect of technology applied for each space type of the Paridae family, the area of increased habitat area was synthesized after the technology was reflected. As the overall scenario went from 1% to 5%, the rooftop greening area increased throughout Suwon. From 1% to 5%, a large amount of habitat area increased in eastern and western central regions (Figure 11; Table 4).

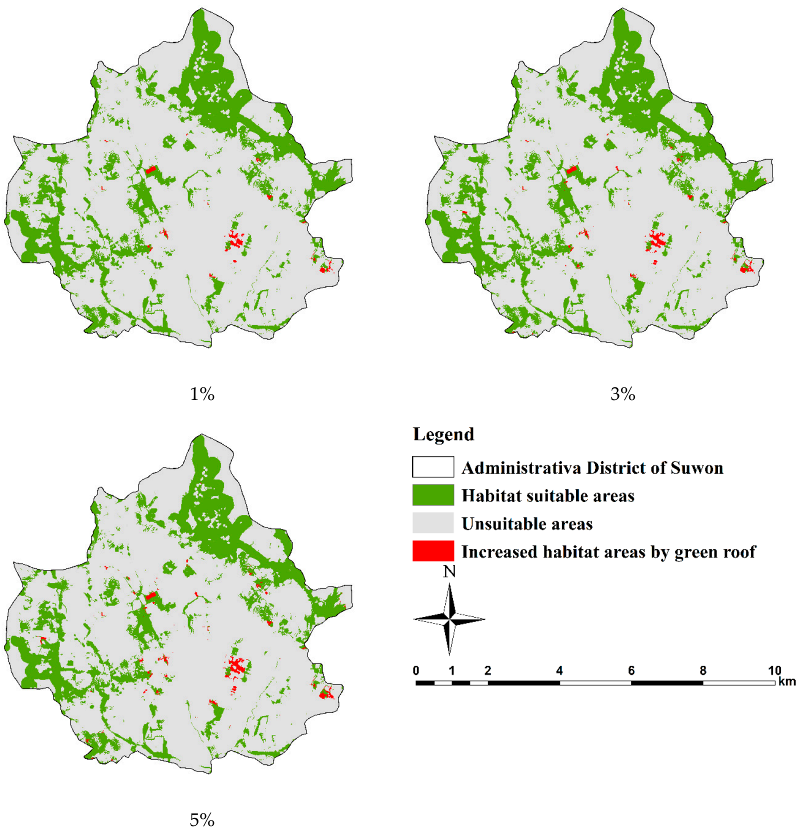

Figure 9. Application result of rooftop greening scenario in the commercial area (CS below commercial area rooftop greening scenario).

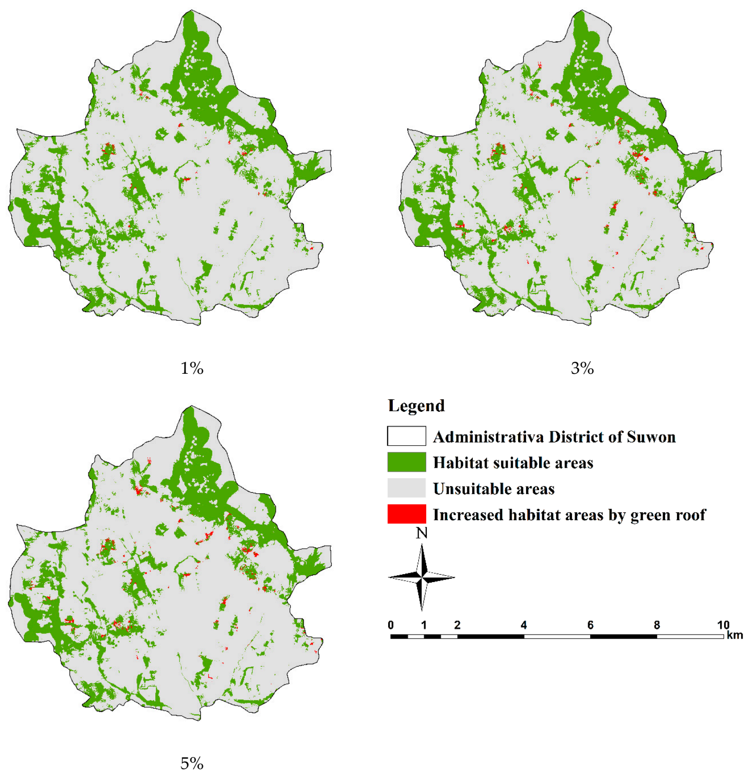

Figure 10. Application result of rooftop greening scenario in the public area (PS below public area rooftop greening scenario).

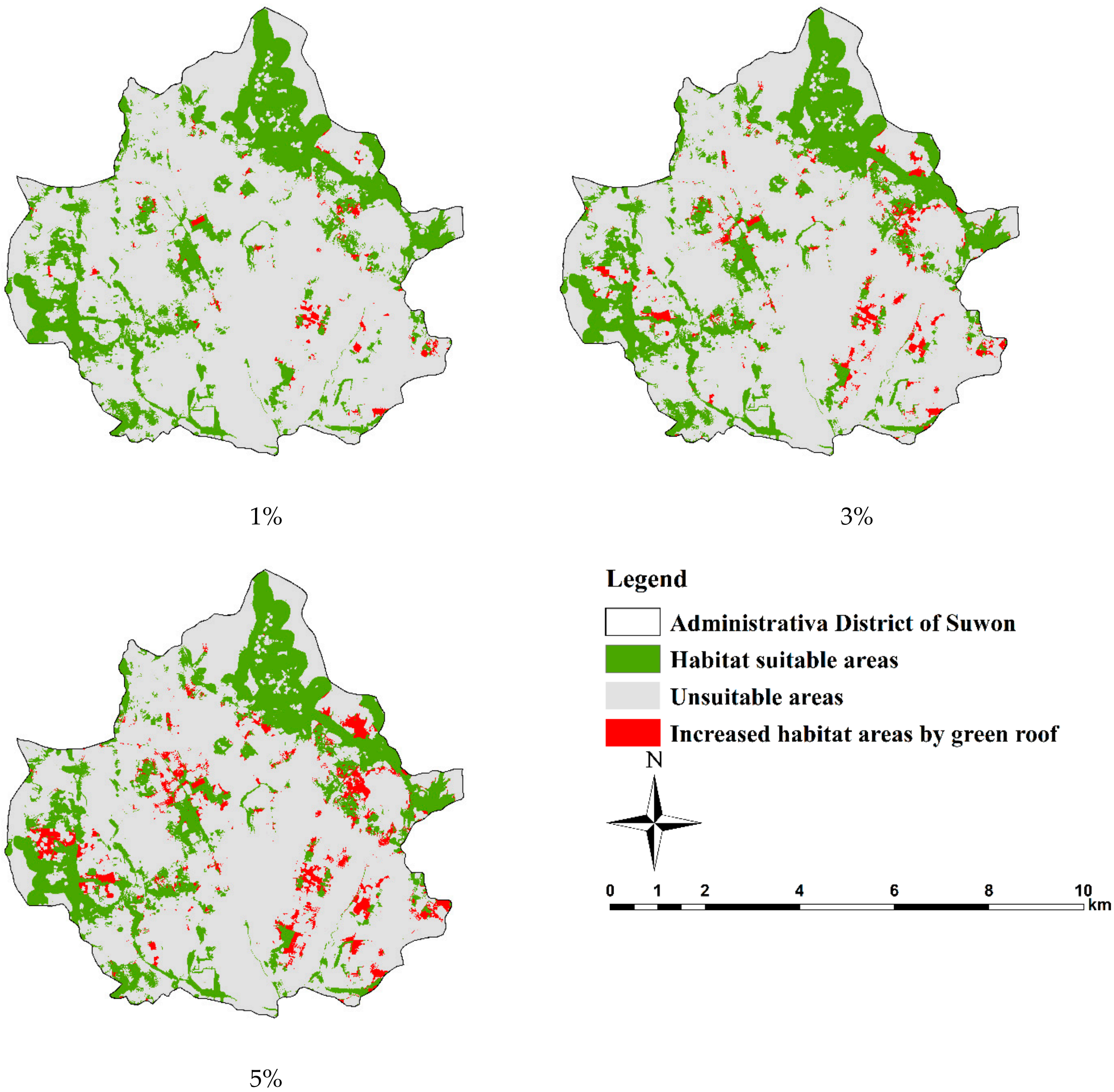

Figure 11. Application result of rooftop greening scenario in total areas (TS below total area rooftop greening scenario).

5. Discussion

The characteristics of the rooftop greening scenario reflection result for each type of space are analyzed in more depth. First, the residential area is characterized by being evenly distributed throughout Suwon, unlike other use areas. In addition, when looking at a residential area's surrounding environment in recent years, most green spaces have been created abundantly through landscaping. Therefore, if rooftop greening is created in residential areas, it is believed that it will significantly increase the connectivity with the surrounding green areas. In this study, it is judged that due to this reason, the rate of increase in the habitat-suitable areas of the Paridae family in the rooftop rehabilitation scenario in residential areas is higher than that of other use areas (Table 4).

Second, when looking at the distribution of Suwon-si as a whole, it can be seen that the industrial zone is mainly located outside Suwon-si. If one checks Suwon-si's topography, one can see that green areas and forests are distributed outside the city (Figure 6). However, considering the characteristics of the location of the industrial area in Suwon, it can be seen that the location of the industrial area in the southeastern part is located in the downtown area rather than in the green area compared to the area where the particular industrial area is located. Although the habitat area has increased due to these factors and there are many rooftop greening industrial areas in the southeast, it can serve as a stepping stone connecting green areas and green areas. As such, the result did not rise significantly (Table 4).

Third, if one checks the distribution in Suwon-si, the distribution of commercial areas can be confirmed to be similar to that of residential areas, but only the locational factor is not an essential factor of the suitable habitat. For example, if there are many roads in the area where vehicles mostly travel, various factors such as the presence of parks and artificial green spaces in the vicinity of the aging building or the presence of the river, and the accessibility of rivers affect the habitat suitability, which is less than 1%. When the 3% and 5% rooftop greening scenarios are reflected, the efficiency is lowered (Table 4).

Fourth, as public areas are relatively far apart from other public areas in Suwon-si, there are not as many residential areas, but the efficiency of the area of increased habitat area compared to the rooftop greening area is relatively high. If the reason is interpreted by looking at maps and tables, as in residential areas when checking the characteristics of distribution and locational properties of use areas, public areas and residential areas have secured a number of landscape areas in recent cases. It was judged that the green area network was well-formed, and this result came out (Table 4).

On the other hand, the efficiency was evaluated when the rooftop greening scenario was reflected with 1, 3, 5% of the total public, residential, commercial, and industrial areas, not by scenario comparison. The 5% technology-applied area scenario was the most efficient, followed by the 3% scenario and the 1% scenario, showing higher efficiency compared to the technology-applied area (Table 5). The higher the rooftop greening area, the higher the efficiency of increasing the area suitable for habitation. As the area increased, the spacing between the stepping stone patch connecting the green area and the green area narrowed, and the connectivity increased. Therefore, the more rooftop greening spaces there are, the more efficiently the Paridae family's habitat can be expanded.

Table 5. Habitat area and efficiency by technology reflection scenario.

Species	**Scenario**	**Before Technology Reflection**	**Area of Technology Reflection 1% (1.6 km^2)**	**Area of Technology Reflection 3% (3.3 km^2)**	**Area of Technology Reflection 5% (4.5 km^2)**
Paridae	Habitat increase area (km^2)	27.87	29.26 (1.39 increased)	31.51 (3.64 increased)	34.39 (6.52 increased)
	Efficiency compared to the area of technology reflected (%)	-	86.87	110.3	144.88

Previous studies confirmed that algae are primarily engaged in three activities in the rooftop greening space. First, feeding activity; second, habitat (nest); third, rest. However, the three types of bird activity are behaviors due to complex factors. If one thinks about birds' habitats, one can think of rooftop greening and other essential factors in bird habitats. For example, there are heights of buildings or artificial bird nests. If these environmental variables are collected and edited, it is thought that a rooftop greening scenario with higher habitat increase efficiency can emerge.

Studies on Paridae and rooftop greening have been verified through monitoring rather than conformity analysis. According to monitoring, the range of action and ecological characteristics of the typical tit family is, on average, a horizontal radius of 250 to 500 m, and the vertical movement distance is 6 to 30 m [13]. Coniferous forests are preferred, and artificial structures are sometimes used as shelters. According to previous studies' monitoring results, the excretion of birds was confirmed in the rooftop afforestation space, confirming that the rooftop afforestation space is utilized [45]. However, studies related to rooftop rehabilitation's ecological role and the contribution to the promotion of biodiversity are insufficient compared to studies on reducing urban environmental damage, saving energy, and providing green space. In the urban planning stage, if the expansion of the habitats for birds that inhabit the city is spatially predicted based on rooftop greening creation, efficient rooftop greening will be possible.

On the other hand, increasing green space within an urbanized area is desirable, but considering the economic point of view in creating a natural rooftop greening, building a rooftop greening requires considerable economic power for building owners. However, as the Korean government has declared carbon neutrality in 2050, many projects to secure green space in urban areas are underway. Seoul, Korea's capital city, is already operating a policy that provides 100% support for public facilities, 70% for private facilities, and 90% for urban regeneration projects in private facilities in creating rooftop greening. If studies that quantitatively analyze the effects of rooftop greening are continuously carried out, as in this study, it is expected that more subsidies and budgets will be allocated for urban greening projects in the future. In particular, since there are many cities with similar conditions to Korea, a policy that significantly reduces the burden on building owners is expected to be realized due to increased awareness of the importance of rooftop greening.

Since this study deals only with rooftop greening, there is a limit to reflecting scenarios only in the use area: the buildings. In future studies, if many variables are added, such as securing roadside green spaces and connectivity of natural green spaces, which will positively contribute to future research, the efficiency of rooftop greening is expected to be better, and the data can be used as useful reference and evidence. Furthermore, it is considered necessary to study how technologies such as rooftop greening and greening on the walls of buildings and artificial habitats will correlate with the species living in the city. In this study, there is a limitation in that a feasibility evaluation to determine whether rooftop greening is possible in selected buildings and areas of use could not be conducted. Due to the large scale of the site, it is difficult to collect detailed information (year of construction, allowable load, and the likes). Therefore, this limitation is improved by constructing detailed building information for more detailed target sites in future studies and conducting a feasibility evaluation.

6. Conclusions

In this study, the species distribution model in Suwon-si was used to identify suitable areas for habitats and to examine the changes in habitats when the scenarios for rooftop rehabilitation for various usage areas were applied and used efficiently for the expansion of habitats. Four usage areas representing Suwon-si were selected, and a scenario for creating rooftop greening in the top 1, 3, and 5% of the building area by usage area was developed and applied. As a result of applying the rooftop rehabilitation scenario, the overall increase in the area suitable for habitat was obtained, but the efficiency of increasing the habitation area was different in the four areas. When the rooftop greening area increased, the areas where the habitat area increased significantly were residential areas and public areas.

On the other hand, the increased habitat area was relatively low compared to the increased rooftop area in commercial areas. According to the rooftop greening composition, the rankings are as follows based on the efficiency of increasing habitat sites. The priority is a residential area that is evenly distributed throughout the city of Suwon, and the locational characteristics are relatively close to the green area. The second priority is a public area where artificial green areas and landscaping areas are actively secured. The third priority is a natural forest and grassland located outside the downtown area. The industrial area closes to the 4th and last priority, and was derived as a commercial area. It is expected that the result that the rooftop rehabilitation in urban areas derived in this study will help to increase the area of the habitat suitable for species and can be used as a methodology for promoting biodiversity in cities.

This study analyzes the change of habitat suitability of the Paridae according to the rooftop greening composition scenario and proposes an effective rooftop greening composition plan. As a result of the study, it was found that the increase of the rooftop greening area affected the increase of the area suitable for the habitation of the Paridae family. In particular, it was confirmed that the efficiency of increasing the suitability of the form varied according to the type of use area of the building to which rooftop greening was applied. It is believed that installing rooftop greening in residential and public areas will improve the suitability of the Paridae family, considering the derived efficiency. This study's results can be used as primary data for determining priority when Suwon-si is creating rooftop greening to improve biodiversity. In addition, the system of this study can be applied when establishing policies for promoting biodiversity in cities developed with high density in foreign countries.

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