Spatial Optimal Model of Ecological Mitigation Measures to Support Decision-Making for Mitigate Environment Impact

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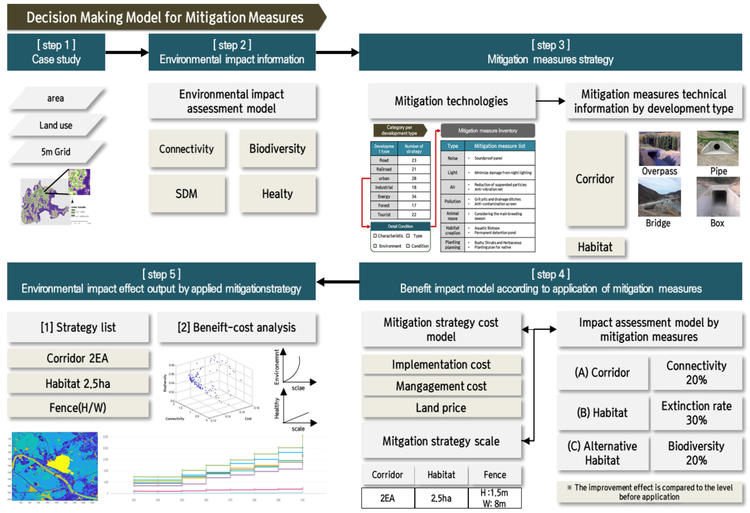
INTRODUCTION

- Decision-makers are faced with the challenge of planning efficient urban ecological planning that considers the trade-off between economic and environmental aspects to enhance biodiversity.
- However, tools to support a integrated mitigation measures strategy that considers the ecological response to urban development are lacking.
- In this study, we introduce a spatial decision-making model for ecological response that simulates mitigation measures using a multi-objective optimization algorithm.
- The model evaluates ecological benefits, such as the probability of connectivity and edge density, as landscape structural and functional factors that respond to urban development.
- It aims to minimize the ecological benefits and implementation cost to explore the optimal space for mitigation measures, such as ecological corridor (EC) and habitat creation (HC).

METHODS



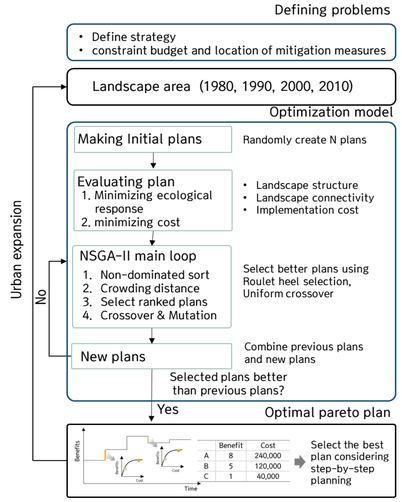
[Step 1]
The stage of inputting information about the target site where development is being carried out.

[Step 2]
The stage of selecting which environmental factors to evaluate for their impact on the development.

[Step 3]
The stage of selecting mitigation measures to minimize the environmental impact of the development project.

[Step 4]
Applying models to evaluate the effectiveness of mitigation measures and estimate costs associated with their implementation.

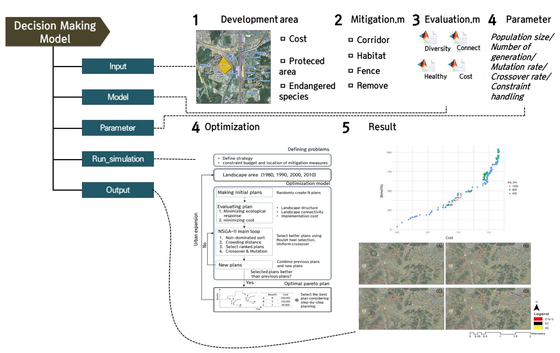
[Step 5]
The stage of deriving and visualizing results through evaluation models and spatial optimization models

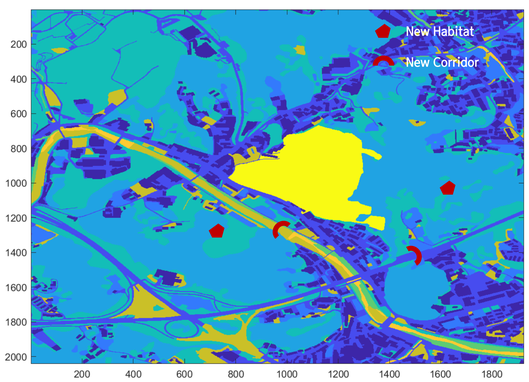


- The strategies of ecological corridors and habitat creation are frequently used to mitigate the impact of urban development on species and promote ecological benefits
- we used landscape composition and configuration factors as ecological benefits variables to assess the effectiveness of ecological corridors and habitat creation in maximizing ecological benefits

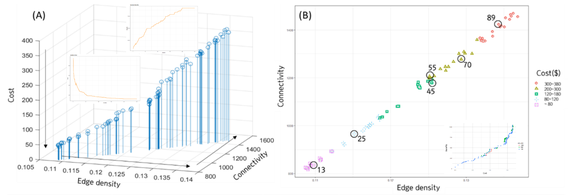
Sectors	Factors	Formula	Reference
Landscape structural factors	Edge Density (ED)	$\frac{Total\ length\ of\ habitat\ edge}{Total\ area\ of\ habitat}$	(Bologna and Heck, 2002; Gosens et al., 2022; Rosa et al., 2017)
Landscape Functional Factor	Probability of connectivity (PC)	$\left(\sum_{i=1}^{n}\sum_{j=1}^{n} a_{ij}e^{-\alpha d_{ij}}\right)/A_L^2$	(Harris et al., 2014; Manuel et al., 2016)
Constraint	Location of mitigation measures	Specific location for creating new mitigation measures strategies	(Wang et al., 2022)
Cost	Implementation cost	Implementation cost * area of the planning lot	(Hyun et al., 2021; Marcel P et al., 2009; Yoon et al., 2019)

HIGHLIGHT

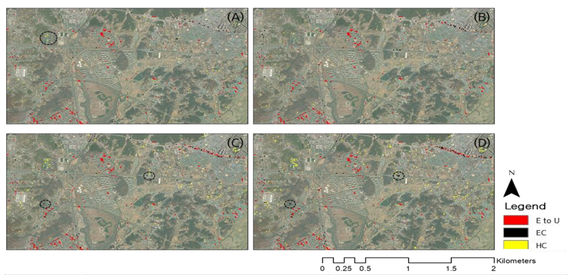




RESULT



Planning	13th plan	25th plan	45th plan	55th plan	70th plan	89th plan
Edge density	0.109789	0.117463	0.125444	0.125149	0.131839	0.1345
Connectivity	835.4231	1007.348	1196.57	1214.54	1365.071	1412.898
Cost (million$)	5	114	179	201	307	337
EC area (m^2)	150	180	360	300	420	480
HC area (m^2)	90	210	240	330	450	480

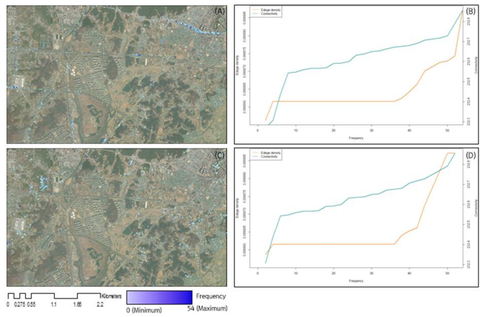


Plan	Area (m^2)			Benefits		Cost
	E to U	EC	HC	ED	Con	(10^8)
25th plan	7,260	270	110	0.156857	1776.17	590
50 th plan	7,820	350	140	0.159568	1844.63	780
75 th plan	8,276	450	480	0.168521	2037.928	9900
95 th plan	8,276	510	480	0.171386	2119.706	1110

- As the number of mitigation measures increased, the implementation costs increased, while the benefits of mitigation measures improved.
- we observed differences in performance between the two objectives within similar cost boundaries.
- The performance of these objectives can vary within similar cost boundaries

- This study presents the results of spatial visualization of four optimal mitigation plans (25th, 50th, 75th, and 95th) generated through a series of actions
- The 25th plan exhibited the lowest performance for all three objectives, while the 95th plan showed the highest performance.
- Although the edge density of the 25th plan was similar to that of the 50th plan, the distribution pattern of the mitigation measures differed
- The study suggests that in future urban planning, it is crucial to consider the edge effect of the existing forest areas as the mitigation measures were installed around the edges of these areas.

DISCUSSION



- The frequencies of EC and HC were analyzed for 100 plans generated through a series of actions, ranging from 0 to 54
- The installation of EC was more frequent in the residential area located in the northeast
- HC was found that they were mainly concentrated in the forest area located in the northwest, created in the edge area of the fragmented forest due to urban development

- This study aims to provide various alternatives for decision-makers who have different goals and design constraints. To satisfy multiple objectives, a Pareto of multiple objectives (benefit and cost) was provided. Decision-makers can choose an option that reflects their preferences, such as ecological benefits and low cost. decision-makers considering minimum costs can choose low benefit and cost plans.

- We found that HC and EC contribute differently to improving ecological functions such as connectivity and edge density. This suggests that a combination of various strategies and technologies is important to enhance biodiversity.

CONCLUSION

- The purpose of this study was to focus on the effectiveness of phased mitigation measures in minimizing ecological responses and cost caused by urban development. Our model can support collaborative design by providing spatially explicit options that consider the balance between competing issues.

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