Ph.D. Dissertation of Engineering

Identifying trade-offs and opportunities for forest carbon storage and endangered species habitat in South Korea

February 2023

Graduate School of Seoul National University
Interdisciplinary Program in Landscape Architecture

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Submitting a Ph.D. Dissertation of Public Administration

February 2023

Graduate School of Seoul National University
Interdisciplinary Doctoral Program in Landscape Architecture

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Confirming the Ph.D. Dissertation written by Jing Rong Zhu
February 2023

Chair ____(Seal)

Vice Chair ____(Seal)

Examiner ____(Seal)

Examiner ____(Seal)

Examiner ____(Seal)

Abstract

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Protecting the endangered species habitat while attempting to limit climate change, for example by storing carbon in forests, is a major problem for managers of natural resources on a warming globe. With advantages for endangered species and decreases in atmospheric carbon, carbon offset funds provide important prospects for the preservation and restoration of natural ecosystems. endangered species, Nevertheless, may suffer if locations with rich carbon stores do not spatially correspond with the priority habitat needs of endangered species. Although species diversity and carbon stocks are generally consistent, effective conservation calls for the inclusion of more precise measurements of habitat for endangered species. Based on recent data and the Zonation Prioritizing Program, this

research examined the geographical trade-off between carbon and habitat priority for endangered species in South Korea. For five sample endangered species, priority sites for potential carbon sequestration (maximum potential biomass) were identified by iteratively weighing the carbon in the endangered species' habitat. Nevertheless, considerable areas crucial for endangered species habitat would be lost if prioritization was based only on carbon sequestration capacity. It is necessary to enhance policy frameworks to eliminate obstacles to landowner involvement in carbon storage projects that boost endangered species habitat and to mandate that both the carbon captured and the endangered species habitat be extra. It will be very beneficial for both the endangered species habitat and carbon storage if the endangered species habitat is properly taken into account when determining the region's priority for land-based carbon sequestration and storage. Nevertheless, in certain ecosystems, maximizing carbon storage and safeguarding endangered species' habitats may not be mutually exclusive. In contrast to persistently supporting a high stocking rate or mature forest conditions that eliminate species that prefer open or young stands as a result of promoting early successional forest conditions, promoting early successional forest conditions does not increase carbon storage at the stand level. The research on the trade-offs between carbon dioxide emissions and preserving the habitats of endangeredspecies in South Korean woods is briefly summarized here. In

each instance, activities of human beings have greatly reduced the impact of natural disturbances; thus, it is usually necessary to restore or imitate these disturbances in order to conserve the habitat, even if it means less carbon is stored at the stand level. We propose that managers and planners can discuss these trade-offs and steer clear of unfavorable behaviors that could eventually reduce adaptive capacity by using the region to maximize carbon storage and endangered species habitat. Instead, planning for landscape-scale adaptation to climate that supports a diversity of habitats and maximizes forest carbon storage can be facilitated by a critical assessment of the effects of stand-level management actions for both carbon and conservation of endangered species.

Keywords: Carbon storage; Endangered species habitat; Distribution; Trade-off; Synergies; Invest; Maxent.

Student Number: 2019-38865

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I. Introduction

1. Study Background

A crucial tactic for reducing emissions of carbon dioxide and adapting to climate change is maintaining and restoring natural ecosystems (i.e., Paris Agreement, 2015). Priorities for carbon as well as endangered species habitat may not, Nevertheless, coincide in time or place (Anderson et al., 2009; Strasburg et al., 2010; Venter et al., 2009). (Martin et al., 2013). This is especially true for areas with a high concentration of narrowly dispersed endemic species: nearby areas with high carbon values may have very diverse species assemblages and hence have differing conservation values. To maximize long-term conservation benefits, it is also vital to consider how climate change could modify future priorities for carbon and endangered species habitat. For this reason, metrics for endangered species' habitat should be carefully chosen and verified.

The leading worldwide cause of species extinction, habitat loss for endangered species, is occurring at an alarming pace (Forrest et al., 2015). (Dirzo and Raven, 2003). In addition, the second-largest source of human greenhouse gas emissions is deforestation (Gullison et al., 2007). In order to reduce emissions of carbon dioxide and save biodiversity, it is essential to preserve forests and natural ecosystems, both now (by preserving present habitats) and in the future (by preventing climate change) (Houghton et al., 2015). There is a chance to reduce deforestation rates and safeguard or improve carbon storage via mechanisms like the UN's REDD+ (Reducing Emissions from Deforestation and Forest Degradation) (Harvey et al., 2010) and different local carbon markets (Polglase et al., 2013). According to Houghton et al. (2015), these processes may also help with extensive restoration, which might have positive effects on biodiversity and emissions of carbon dioxide (Alexander et al., 2011; Martin et al., 2013). Nevertheless, in order to secure actual benefits for both, especially where endemism is significant, site-based studies are required to confirm global evaluations of spatial priority for carbon and endangered species habitat (Anderson et al., 2009; Magnago et al., 2015).

The extensive corpus of research looking at carbon and the endangered species habitat preferences shows an understanding of the risk that climate change poses to systems, this risk would persist even if land-based carbon storage increased substantially (Gullison et al., 2007; Metz et al., 2007). In spite of this acknowledgement, the majority of research fails to take into account the importance of endangered species' habitats. Regardless of whether these regions are now top priorities for biodiversity conservation, ongoing conservation of endangered species' habitats will need the preservation or restoration of areas that will endure or become suitable under anticipated climate change. In order to avoid less-than-ideal conservation results, analyses of trade-offs between endangered species habitat and carbon storage should include the present needs of the species (Kujala et al., 2013).

Planning for the future is essential for assessing carbon storage since it may assist identify both areas with a high potential for sequestration and those with a high concentration of carbon storage already. A crucial step in protecting the endangered species habitat is the restoration of damaged and deforested ecosystems, which also provides considerable chances to trap carbon and draw in money for carbon offset projects. Where species are anticipated to need to spread into presently unvegetated regions in order to retain their appropriate range, restoration is especially advantageous. This calls for estimations of the potential habitat value for endangered species as well as assessments of the potential value of carbon sequestration and storage (hereinafter "carbon storage") at a location.

Considerable progress has been achieved in accounting for potential climate change when planning conservation efforts, from developing basic ideas to finding workable solutions (Jones et al., 2016; Mawdsley et al., 2009; Schmitz et al., 2015). In order to help animals monitor their climatic niche and create new habitat, several studies have identified priority locations for conservation and restoration (Jones et al., 2016; Williams et al., 2005). Planning for numerous advantages is what is lacking (in this case, endangered species habitat as well as carbon storage). In addition to enabling climate change mitigation, taking numerous benefits into account opens up the potential for a conservation sector that is badly underfunded to profit from the carbon offset markets.

2. Purpose of Research

Local species variety, ecosystem health, and regional habitat conditions across a larger area with a comparable natural assemblage of endangered species are all examples of markers of endangered species.

In this study, our goals were to (1) characterize the broad linkages between production possibilities for combinations of carbon storage, wood, and endangered species habitat, and (2) pinpoint the management factors that have the most impact on joint production relationships. To help with forest planning, identify synergies and trade-offs between these parameters.

This informational synthesis could help operationalize spatial goals, guide spatially explicit national forest evaluations of possible co-benefits, and help decide whether conservation efforts should be reactive or proactive.

II. Literature review

1. Relationship between carbon dioxide and the endangered species habitat

It is encouraging to see the importance of intact forests being recognized more and more as a natural climate solution. Fortunately, a large number of restoration and forest management techniques that aim to increase carbon storage and sequestration can also help many forests endangered species, for whom increased in situ carbon directly translates to increasingly improved habitat circumstances. For instance, carbon is stored in large quantities in old, structurally complicated, hardwood stands with a lot of snags and felled timber (Ford & Keeton, 2017), while also serving as a crucial habitat for animals like the yellow-throated marten, the leopard cat, and H. interims (Martes flavigula koreana). Many other, frequently fragile, endangered species, on the other hand, rely on habitat types, like early successional forests or open woods, that are frequently maintained by disturbance and thus naturally store less carbon, which naturally store less carbon.

What happens when disturbance-focused measures to increase critical habitat for endangered forest endangered animals clash with initiatives to maximize carbon in the soil? As public pressure grows to avoid any forest management that is perceived to compromise the storage of carbon, many managers are acutely aware of this question, this study have heard these worries over and over again from people all over the region, both in targeted conversations with natural resource managers and in more formal listening sessions (Janowiak et al., 2020) and surveys (Schattman et al., 2021). The significance of preserving varied habitat conditions is often overlooked, even in the expanding number of studies addressing the link between carbon storage as well as forest endangered habitat or biodiversity. Before suggesting it could assist us in managing these possible trade-offs between carbon and habitat for endangered species, we quickly explore this research in this article. In our local South Korea forest area, there is not yet a lot of literature on this link.

2. Research on carbon storage and endangered species

In addition to functioning as habitat elements that some species respond to, certain carbon pools (such as living trees or dead wood) have the capacity to swing the carbon equation one way or the other. This trade-off between carbon storage and endangered species habitat may be most evident at the stand size, which is generally on the order of one to 100 hectares (Crosby et al., 2020; Hunter, 2005). With few significant exceptions, most studies that have looked at the connection between carbon and endangered species, or biodiversity more broadly, have done so at wide scales or have not addressed how different species react to these "microfilter" habitat components (Hunter, 2005). Therefore, without careful scientific evidence, the link between carbon storage and the results of the distribution of habitat for endangered species is often assumed and generalized as being favorable. Nevertheless, other research has issued a warning that this apparent association might be significantly influenced by the geographical scale of the investigation (e.g., Blumstein & Thompson, 2015).

Numerous studies explore the relationship between measures for carbon sequestration and endangered species (such as habitat appropriateness indices) and forest management. One study, for instance, used a forest growth and yield model to simulate harvest scenarios in Vermont with varied levels of tree retention and then compared the results to occupancy models for more than 50 bird species. More extensive prescriptions were shown to increase biodiversity results but diminish in situ carbon storage because of the variety of habitat needs (Schwenk et al., 2012). Simulation research carried out in Missouri found that there was uncertainty regarding the relationship between changes in bird populations and management-driven carbon storage (carbon storage was inferred, not quantified; LeBrun et al., 2017). Most of these studies fail to explain how small variations in carbon storage effect small variations in habitat, however a few mentions structural components (such snags) as significant modulators (e.g., Kline et al., 2016). The carbon dynamics linked to leakage or the movement of harvesting operations to other locations when harvesting is curtailed in one place are conspicuously lacking from this research on forest management. The carbon results of forest management studies should not neglect the larger carbon dynamics that are eventually, if indirectly, influenced by management choices, even if management prescriptions alone cannot resolve this market problem.

Others have looked at regions with high habitat quality, abundance of species, as well as carbon storage concentrations, sometimes known as "hotspots," across a wide range of geographic scales. Perhaps not unexpectedly, these hotspots often exist in the most intact natural landscapes or officially protected regions (Blumstein & Thompson, 2015; Hanna et al., 2020; Lecina-Diaz et al., 2018), albeit the advantages for endangered species differ by taxonomic and species guild (Polasky et al., 2011). These findings may aid in the determination of conservation priorities at large geographic scales, but they may not be as important for stand-level management.

In other instances, a closer look at a single species uncovers more complex patterns of interactions between endangered species. In comparison to non-tribal regions, Ojibwe and Menominee tribe forests maintain better carbon storage due in part to lower densities of white-tailed deer (Odocoileus virginianus) (Waller & Reo, 2018). Low-density longleaf pine (Pinus palustris), which is maintained by periodic fire in the southeast of the United States, is a need for red-cockaded woodpeckers (Picoides borealis). It was found that, on a stand-level, continuing carbon sequestration would not be consistent with the restoration of woodpecker habitat because of a simulation of thinning and managed fire. (2015) Martin et al. Bird diversity and abundance in central California fell three decades following riparian forest restoration, whereas tree biomass (carbon) both above and below ground increased. This was the only research we could find that explicitly assessed management impacts on both tree carbon and animal populations. Most of the research extrapolates advantages to endangered species from habitat components, intactness, or suitability indices, except for this instance (Dybala et al., 2019). While many species may be represented by these fair proxies, equating, for instance, increased aboveground tree biomass with higher advantages for endangered species ignores the possibility that it is possible that some species will benefit, and others will not.

Others have investigated the possible effects of forest carbon storage programs on the endangered species habitat more widely. Researchers in the Pacific Northwest linked an econometric model with models of species distribution for 35 vertebrates that depend on forests, and they concluded that the availability of carbon markets is likely to amplify habitat loss predicted under climate change, primarily as a result of modifications to landowner planting techniques (Hashida et al., 2020). Others have demonstrated how funding from forest carbon offsets may cut the price of purchasing property for habitat protection, having a positive effect on biodiversity (Schuster et al., 2014). Importantly, several studies have looked at the ecological and social effects of international carbon programs (like REDD+), noting how the advantages for endangered species may be restricted or, at best, unequally distributed (Beaudrot et al., 2016; Phelps et al., 2012; Seddon et al., 2020). Nevertheless, trade-offs and possible synergies are undoubtedly not restricted to South Korea. In this article, we concentrate on carbon storage and habitat concerns for endangered species in the South Korean area.

Above all, this short assessment of the literature demonstrates how nuanced the relationship between carbon and endangered species is and how it is important to not lose sight of the subtleties of species-specific habitat needs. We need direct characterizations of trade-offs that span several scales, are species-specific, and are empirical (not inferred). This is especially true when new programs continue to emerge that, in the name of carbon, constantly promote increased stocking and mature conditions across all forest and woodland types. Instead, the carbon calculus should consider the effects on individual stands, where management actions are implemented, as well as the wider landscape in which these stands are located, where planning for conservation and climate adaption must be performed.

III. Materials and methods

1. Study flow

There are two parts to this research. Predicting the distribution of carbon storage as well as habitats for endangered species is the goal of the first session in order to identify any disparities between them. For upcoming national conservation and management plans, the second session will uncover trade-offs and synergies between carbon storage and habitat distribution for endangered species. The findings will help identify high-priority conservation sites that provide several advantages.

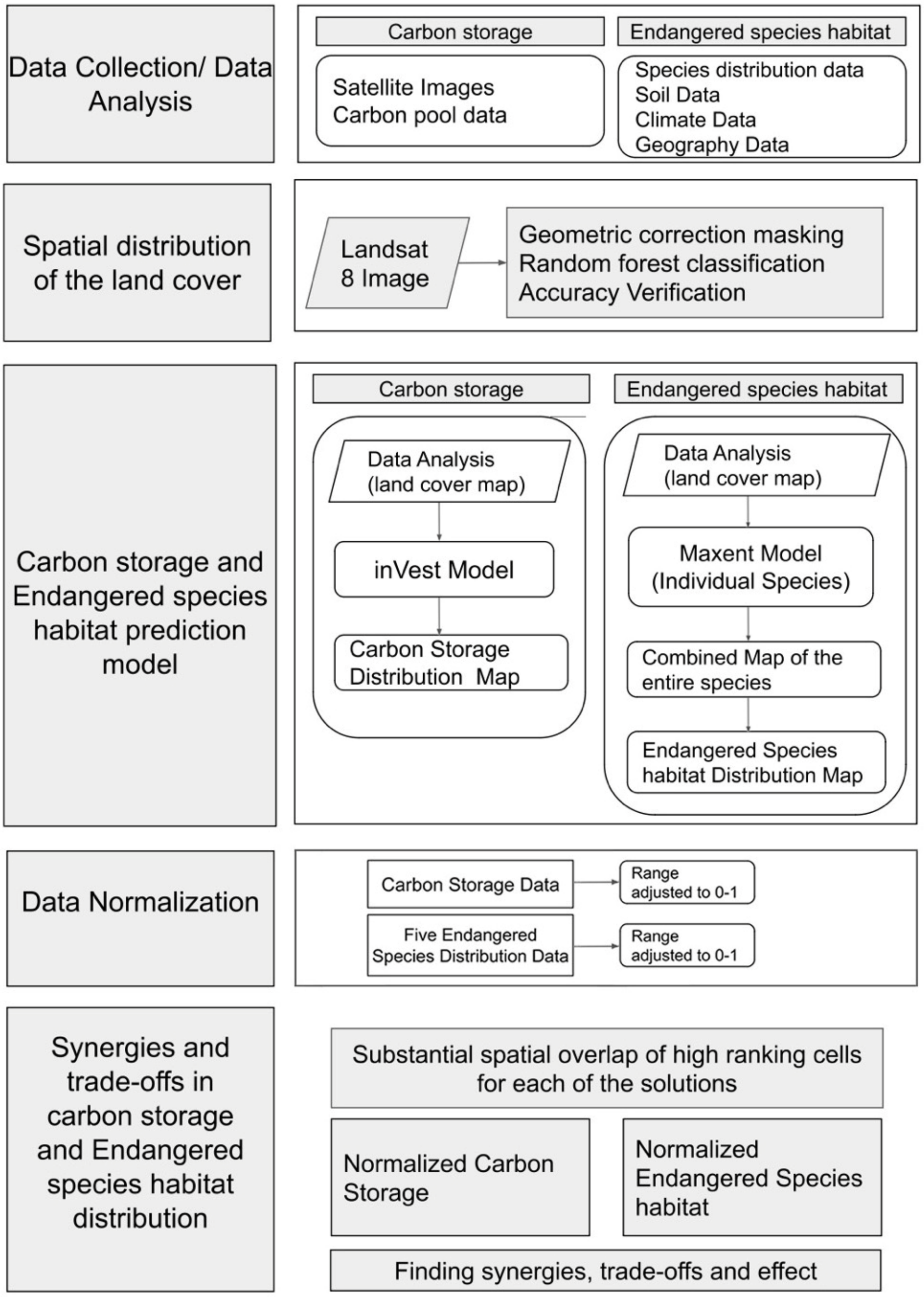

Fig 1 Study flow

2. Study sites and the datasets

2.1. Study sites

South Korea, often referred to as the Republic of Korea, is a country in East Asia that is located on the southernmost point of the Korean Peninsula, which extends from the far eastern region of the Asian continent. The sole country that shares a land border with South Korea is North Korea, and their 238-kilometer border follows the Korean Demilitarized Zone (DMZ). South Korea is mostly ringed by water and has a 2,413-kilometer coastline along three seas. Ulleung Island and Dokdo Island lie in the East Sea, which is bordered by the Yellow Sea to the west, the East China Sea to the south, and the Yellow Sea to the east. The general location is around 37° North and 127° 30' East.

It is estimated that 41,500 species make up the Republic of Korea's biota, of which 8,150 have been evaluated (Table 2). These species include fish, vascular plants, birds, reptiles and amphibians, mammals, and fish. One thousand two hundred twenty-one of these species (8.7%) are listed on the Red List. The Japanese sea lion (Zalophus japonicus), the only species, was considered extinct (EX). The IUCN Red List also classified this species as extinct. Five mammal species are among the ten species that are regarded in the Republic of Korea as regionally extinct.

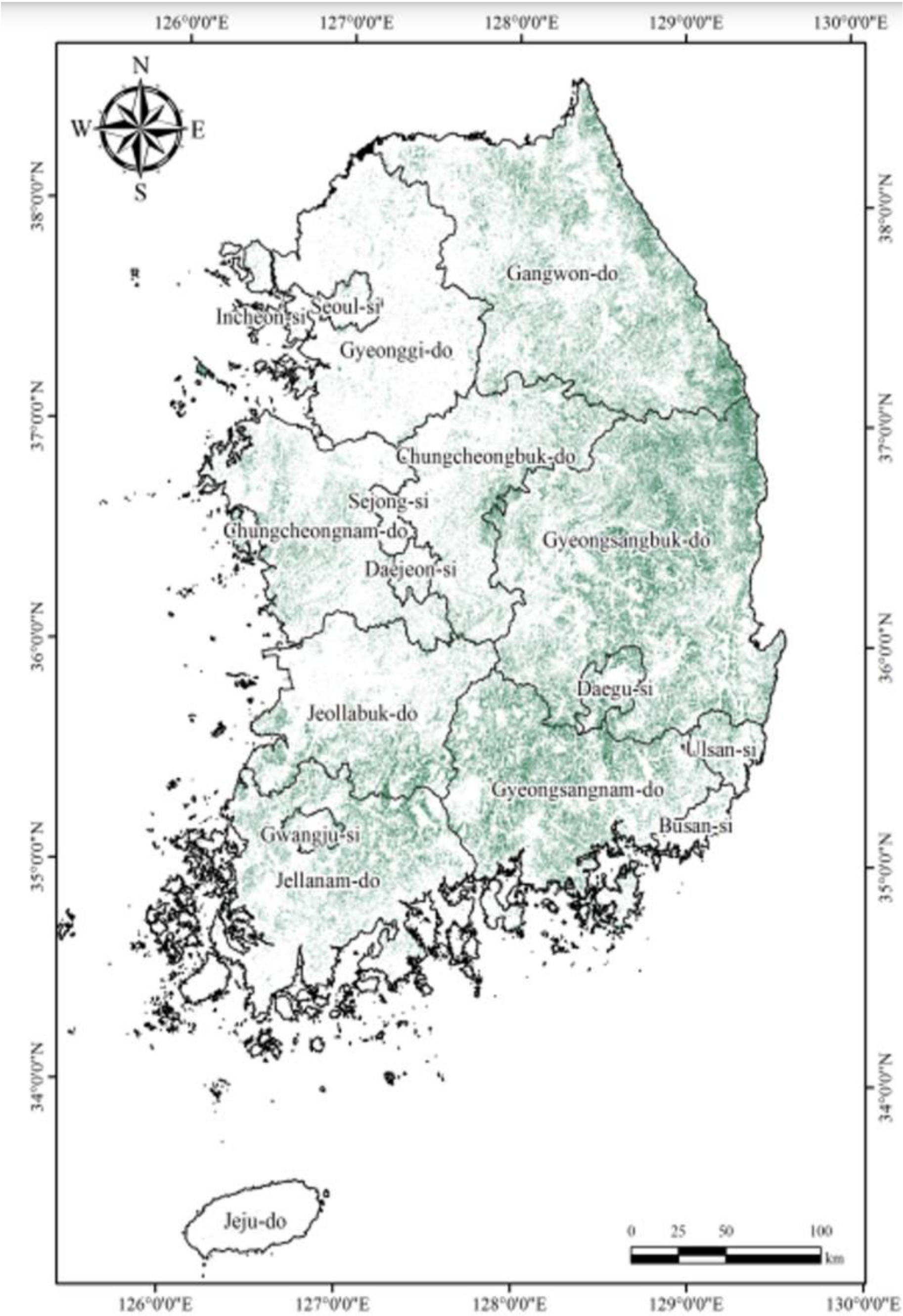

Fig 2 Study sites

2.2. Estimation of the Carbon Storage

The InVEST carbon storage and sequestration model program, developed by the Natural Capital Project (www.naturalcapitalproject.org), was used to determine carbon stocks in the study area. By aggregating the carbon pool values given to every land cover type, the overall amount of carbon stored in the study region is calculated based on the carbon cycle via the InVEST carbon model (Sharp et al. 2018). According to the model (1), the carbon density of every form of land cover (i) is indicated in Eq (1).

$$C_i = C_{i(above)} + C_{i(below)} + C_{i(dead)} + C_{i(soil)} \quad (1)$$

In this formula, $C_{i(above)}$ represents the carbon density of biomass above ground in the ith Land cover type (tons/ha), $C_{i(below)}$ represents the carbon density of belowground biomass in the ith Land cover type (tons/ ha), $C_{i(dead)}$ represents the carbon density of dead organic materials in the ith Land cover type (tons/ha), and $C_{i(soil)}$ represents the carbon density of soil in the ith Land cover type (tons/ha). Based on Eq. 2, the model software calculates the sum of carbon sequestered in the research area.

$$C_{total} = \sum_i^n \quad C_i + A_i \quad (2)$$

In this formula, C_{total} represents the total carbon storage within the study region (tons), n represents the amount of Land cover types within the study region, and A_i represents the area of every Land cover type (ha).

The initial information needed to run the InVEST carbon storage as well as sequestration model were land cover information for the research region and carbon density information for every kind of land cover in the study region, as stated by Sharp et al. (2018).

The land cover information was saved as a land cover raster map in accordance with the specifications of the InVEST carbon storage modelling program. The mapping program ArcGIS 10.8 was used to process the land cover raster map. The Survey Department of the Ministry of Environment originally provided the South Korean Ministry of Environment with its digital land cover data. To extract the land cover of South Korea in the ArcGIS environment, the land cover polygon shapefile of South Korea was cut. The Feature to Raster tool in ArcGIS was then used to turn the clipped polygon map into a raster dataset. In the carbon pools table, carbon information should be included. The input was added at the time of conversion and is therefore necessary to run the model, as further detailed by Sharp et al. (2018), and every land cover type in the attribute table was given a unique land cover code. Carbon pool table: A comma-separated values table (CSV file) containing carbon pool values was created in accordance with the specifications of the InVEST carbon modelling program. Values for each of the four carbon pools (the aboveground, belowground, dead organic matter, and soil carbon pools) for every kind of land cover were included in this table. For every kind of land cover, the carbon pool values were taken from previously published literature. According to Brown (1997), quantifying aboveground carbon storage is difficult, labor-intensive, and time-consuming. As one of the most trustworthy sources of carbon information globally, the Intergovernmental Panel on Climate Change (IPCC) 2006 report was used to collect aboveground carbon information (Hiraishi et al. 2014; Sharp et al. 2018). In addition, a variety of different information sources were utilised to gather and contrast information on aboveground carbon storage (Coomes et al., 2002; Grace et al., 2006; Malhi, 2006; Socolow and Pacala, 2006). The IPCC 2006 report included the carbon storage estimates for the below-ground carbon pools of various land cover types (Hiraishi et al., 2014; Sharp et al., 2018). According to Sharp et al. (2018), the "root to shoot" ratio approach was used to determine the below-ground carbon storage values of the land cover type comprising woody biomass (Cairns et al., 1997; Grace et al., 2006). Additionally, information on soil carbon as well as dead matter carbon densities was gathered from research published before (Chacko et al. 2019; Paquit 2017). In accordance with the needle, it was divided into seven categories. InVEST 3.7 software was then used to run the model while integrating the land cover raster dataset and the CSV file that contains carbon pool data. There was a user-defined workspace folder in which the final maps and information tables were placed for this model run.

2.3. Endangered species habitat model

2.3.1 Habitat Distribution Prediction Map

The 5th National Survey, for which location information was gathered, provided the species data. information from the 5th National Natural Environment Survey (2019) and the Annual Environmental Survey (2019–2023) were utilized. The 5th National Natural Environment Survey separated areas into categories based on their water systems and forest cover, then studied representative mountains within every category. In contrast, the survey unit for the fifth survey was a 1:25,000 topographic map that was split into 9 grids of 2′30″ in accordance with latitude and longitude. every grid was then transformed into a map unit survey that investigates Simply plant a 1:25,000 topographic map in the area where there are terrestrial insects. As with the 5th National Natural Environment Survey, the survey is conducted on a unit basis, and vegetation is assessed regionally (Ministry of the Environment, 2022). The whole nation will be surveyed during the fifth National Natural Environment Survey. It is presently being implemented and should be finished in 2023. The south and the north are the two geographically distinct sections of the nation, and every is inspected annually.

2.3.2 Target species

Five species that might serve as a good representation of the diversity of species found in native forests were chosen using the following criteria.

First, creatures in the top echelon of the food chain with a vast range were taken into consideration, including umbrella species. Umbrella species are those with the greatest habitat requirements, allowing for the conservation of several species with varying habitat needs even if just one of those species is protected, which is particularly beneficial for protecting an ecosystem or a particular habitat (Roberge and Angelstam, 2004). As a result, martens at the top of the food chain in domestic forests were chosen for this investigation with preference. The marten is particularly significant in domestic ecosystem studies because it fulfils the functions of umbrella species and spore, and its home range, which ranges from 22.3 to 59.1 km2, is several times bigger than that of other comparable medium-sized animals. The marten was likewise selected for the same reasons as Martes flavigula koreana.

Second, species that might potentially be sensitive to development initiatives at the border of the forest were chosen because they can live both within and outside the forest. As a result, Ninoxscutulata and Accipitersoloensis were chosen.These species use forest margins (such as arable land, lowland forests, thickets) as refuges, resting spots, and food sources in addition to being in the top echelon of the food chain. The lutra was chosen as a medium- to large-sized animal in addition to the forest edge birds.The following five species were then studied: Felis Bengalensis, Euptilura, Lutra, Martes flavigula koreana, Accipitersoloensis, as well as Ninoxscutulata.

Finally, the following five species were then studied: Felis Bengalensis, Euptilura, Lutra, Martes flavigula koreana, Accipitersoloensis, as well as Ninoxscutulata. To determine the species distribution, a species distribution model was applied.

2.3.3 Environmental factor

By using the species distribution model (SDM) on the five species mentioned above—Felis Bengalensis Euptilura, Lutra, Martes flavigula koreana, Accipitersoloensis, as well as Ninoxscutulata—and determining potential habitats, as well as averaging and standardising them—the species richness map was created.

The MaxENT model (Phillips et al. 2006; Seo et al. 2008; Song and Kim, 2012; Kim et al., 2013) was chosen from among the several species distribution models (SDM). Species habitat-related environmental parameters need to be chosen in order to utilise MaxENT. The following variables were chosen: soil (sand, silt, CaCO3, clay) geography (digital elevation model, slope, aspect) and climatic (bio1, bio2, bio3, bio4, bio5, bio6, bio7, bio8, bio9, bio10, bio11, bio12, bio13, bio14, bio15, bio16, bio17, bio18, bio19) data (Wordclim- https://www.worldclim.org). The study team's most current access to national information was used to analyze the variables, which were then built with an 800 m spatial resolution. The AUC area under the ROC curves was used to assess the model accuracy of the MaxENT findings using at least 7 occurrence information (Franklin, 2009). At this point, the prediction accuracy increases as the AUC number gets closer to 1.0.

The five species' potential occurrence probabilities from using MaxENT are based on the "maximum training sensitivity plus specificity" value, where the sum of sensitivity (prediction rate of occurrence area) and specificity (prediction rate of non-occurrence area) is maximum (inhabited area, 1) and non-occurrence (inhabited area, 0). (Hu and Jiang, 2011; Heibl and Renner, 2012; Jeon et al., 2014; Kim Ji-yeon et al., 2014). The five species' binomial information were overlapped, added, and standardized to a value between 0 and 1 before being combined into a single number.

2.3.4 Accuracy Assessment

The MaxENT model, which has a greater prediction accuracy and has been shown in several prior studies, was utilized in this investigation to predict just the appearance information, eliminating the non-appearance information about the species (Phillips et al., 2006; Elith et al., 2006). Based on information regarding the target species' appearance, the MaxENT model, which is based on regression analysis, predicts the distribution of wildlife using a maximum entropy technique. As a consequence, findings with the greater predictive ability may be obtained by using solely species appearance information as the dependent variable (Phillips et al., 2004). The independent variable needs variables that describe the properties of the environment, whereas the dependent variable needs information on species' appearance (specifics about the location of the target organism).

MaxENT is a model that only uses appearance data and has greater predictive accuracy when just appearance information is used than other models; hence, it is often employed lately (Pearson et al., 2007; Chang-Wan Seo et al., 2008). The analysis utilised MaxENT 3.3.2. The ROC measures every model's accuracy (Receiver Operating Characteristic). It was calculated using the cross-validation AUC (Area Under Cover) value after ten iterations (Thuiller, 2003).

The habitat potential was evaluated in this research by using environmental factors as independent variables and the occurrence information of five endangered species that are also natural monuments as dependent variables. The receiver operating characteristics (ROC) curve's area under the curve (AUC) was used to assess the model's capacity for explanation. Based on the appearance information supplied to the model, reliability was confirmed. Additionally, the interpretation of the variable response curve created as a consequence of the investigation and an estimation of habitat features was used to evaluate the link between animals and certain environmental factors.

According to Ekness and Randhir, the degree of disturbance based on the intermediate land cover categorization was identified and scored to indicate land use disturbance (2007). Industrial and transportation regions, which are thought to have a high degree of land use disturbance, received high ratings, while wetlands and wooded areas, which are thought to have a low degree of disturbance, had low scores (Ekness and Randhir, 2007). The primary land cover categorization used by the Ministry of the Environment is the basis for land use status.

2.4. Trade-off and Synergies

This research used a variety of techniques to examine the degree to which carbon priorities were geographically linked with habitats for endangered species. First, we tested whether carbon was related to the species richness of all endangered avian and birds and mammals using linear least squares regression. The distribution models were combined to get the model species richness.

In this research, the possible geographical overlap of habitat priority for endangered species and carbon was examined using the land use prioritization program Zonation (Moilanen et al., 2014). The Zonation algorithm, which considers connection requirements and endangered species habitat priority at various points in time, repeatedly eliminates the least desirable cells from the landscape while minimizing the marginal loss of conservation score.

Although there were five species in the study area, their ranges were too narrow to fit precise distribution models at this resolution. These five species' occurrence locations were therefore hidden (Moilanen et al., 2014). The integration of the uncertainty analysis utilized the distribution discounting function (Moilanen et al., 2006). The standard deviation of the Maxent result for 2022 used as the basis for the uncertainty maps for the habitat of the model species. The default value of the distribution discounting rate (α) was set to 1.0, which resulted in a one-standard-deviation reduction in the mean estimate for each species in each grid cell. Therefore, cells with greater expected suitability uncertainty were given less weight (Kujala et al., 2013).

The performance curves were used to assess the marginal loss of habitat for endangered species and carbon storage for each zonation run. The key conservation measures needed for this area are to rehabilitate destroyed and degraded regions and safeguard ecosystems from logging and other human-caused changes. As a result, The study did not restrict the sites with priority to those with native vegetation already in place., allowing for the prioritization of locations for restoration work that could be crucial for the endangered species habitat or for carbon sequestration. The research is meant to assist NRM investment plans when combined with thorough on-the-ground evaluation and stakeholder involvement, but it does not identify the conservation measures needed in each priority region. By superimposing the ideal zonation solutions over the mapped forest regions (Accad and Neldner, 2015), investigations were carried out on the possibility of restoration in priority areas. The degree to which endangered species habitats and carbon storage priorities reside outside of current protected areas was also looked at to examine the feasibility of developing additional protected areas (DSEWPaC, 2010).

Therefore, opportunities to stop more deforestation should be investigated, especially in the high-priority regions. Strong regulatory frameworks must be combined with opportunities and incentives to minimize vegetation loss in order to prevent large-scale clearance. Both regulations and incentives are required to prevent additional habitat loss for endangered species (Evans, 2016).

IV. Results

1. Description of the components that make up the InVEST carbon storage and sequestration model

1.1 Spatial distribution of the land cover

Fig. 3 displays the developed Land cover raster map of the research region. The research region was mostly made up of 22 different types of land cover, according to the generated Land cover raster map, namely, Residential, Industrial, Commercial, Communication, Transportation, Public Utilities, Paddy Field, Non-Irrigated Land, Protected Cultivation, Orchard, Other Cropland, Deciduous Forest Land, Coniferous Forest Land, Mixed Forest Land, Natural Grassland, Non-Natural Grassland, Inland Wetland, Coastal Wetland, Natural Barren Land, Non-Natural Barren Land, Inland Water and Seawater. As a result, the research site may be considered one of the provinces that is most suited for examining the carbon storing capabilities of various Land cover types. With the help of the Tabulate Area Tool of the Spatial Analyst extension in the ArcGIS environment, the area percentages of each Land cover category were determined. The natural forests took up the biggest area, accounting for 61.7% (6,098,000 hectares) of the research sites, among the 22 Land cover categories.

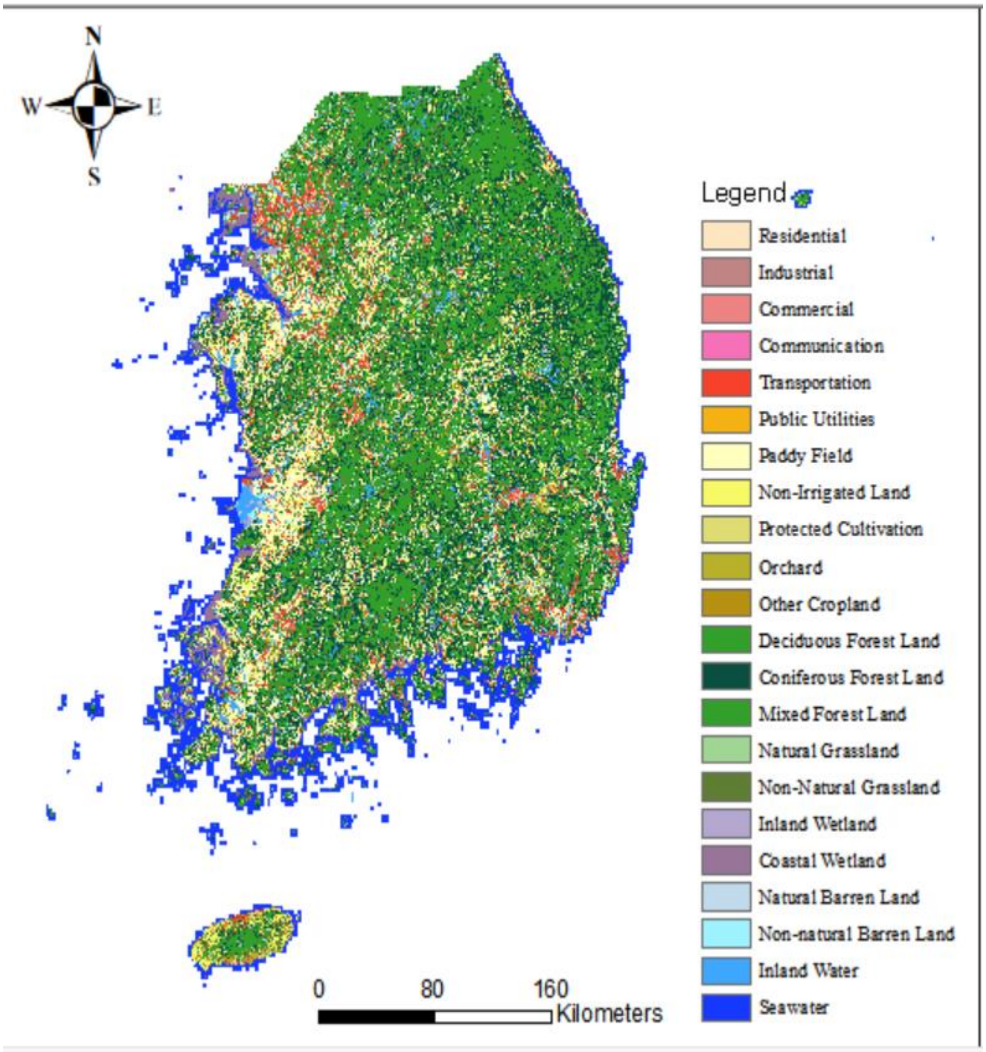

Fig 3 Spatial distribution of the land cover using Satellite Image in 2022

1.2. Carbon Pools Table

The model's second main input is the carbon pool table. Table 1 displays the formed carbon pool table. The results table shows that Mixed Forest Land (140 tons/ha) had the highest predicted values for above-ground carbon pools, followed by Deciduous Forest Land (130 tons/ha), Coniferous Forest Land (120 tons/ha), Natural Grassland (15 tons/ha), Orchard (15 tons/ha), and Rice Field (10 tons/ha). Additionally, non-natural grassland had an estimated aboveground carbon pool value of 5 tons per hectare, compared to 3 tons per hectare for other crops and other cultivations. According to the data for the aboveground carbon pool, there is an exact correlation between the amount of woody material and the amount of carbon stored aboveground in the study region. Wetlands (both inland and coastal), barren land (both natural and non-natural), populated regions, and land cover types with water bodies all had a value of 0 for aboveground carbon storage. Additionally, similar to above-ground carbon storage, the below-ground carbon values of various land cover types vary greatly. Broadleaved forest (75 tons/ha) and coniferous and mixed woodland (70 tons/ha), natural grassland (35 tons/ha), orchard (30 tons/ha), paddy (5 tons/ha), and non-natural grassland (5 tons/ha) had the greatest estimated belowground carbon pool values. The estimated above-ground carbon values for non-irrigated land were 4 tons/ha, whereas the values for each protected crop were 3 tons/ha and the values for other crops were 2 tons/ha. In this research, soil carbon storage values varied less noticeably across land cover types than above- and below-ground carbon storage values. According to Paquit (2017), since it is difficult to measure carbon data in dead wood in the field, when evaluating the carbon density in dead matter, only litter carbon data were often taken into account. This challenge is brought on by uncertainties in carbon emissions to the environment, deadwood and soil, and litter.

Table 1 Carbon pools table

No	LUCODE	LULC	C_above	C_below	C_soil	C_dead
1	110	Residential	0	0	0	0
2	120	Industrial	0	0	0	0
3	130	Commercial	0	0	0	0
4	140	Communication	0	0	0	0
5	150	Transportation	0	0	0	0
6	160	Public Utilities	0	0	0	0
7	210	Paddy Field	10	5	20	0
8	220	Non-Irrigated Land	8	4	16	0
9	230	Protected Cultivation	6	3	15	0
10	240	Orchard	15	30	20	0
11	250	Other Cropland	3	2	8	1
12	310	Deciduous Forest Land	130	75	35	12
13	320	Coniferous Forest Land	120	70	35	12
14	330	Mixed Forest Land	140	70	35	12
15	410	Natural Grassland	15	35	30	4
16	420	Non-Natural Grassland	5	5	15	2
17	510	Inland Wetland	0	0	0	0
18	520	Coastal Wetland	0	0	0	0
19	610	Natural Barren Land	0	0	0	0
20	620	Non-Natural Barren Land	0	0	0	0
21	710	Inland Water	0	0	0	0
22	720	Seawater	0	0	0	0

1.3. InVEST carbon storage and sequestration model outputs

The geographical distribution of carbon storage in the research region was compiled using the InVEST carbon storage and sequestration model as a raster output (Fig. 4). The findings also demonstrated that various forms of land cover had variable carbon storage capacities. In general, compared to other land cover types, vegetative land cover types retain comparatively more carbon (Chacko et al. 2019; Kumarasiri et al. 2021). However, as Paquit (2017) explains, agricultural land cover types' capacity to store carbon is often disregarded or even overestimated. However, by storing more soil carbon, agricultural land also makes a major contribution to overall carbon storage.

The regional distribution of carbon storage throughout the nation is seen in Figure 4. According to calculations, South Korea's forests can store between 3,927 and 900,427 kg of carbon per tree. The carbon storage capacity of Korea's forests was estimated to range from 3.73 to 880.4 kg/tree. In the instance of the carbon storage function, altitude-dependent spatial variations were shown. In general, it was discovered that forests in urban regions had a relatively poor carbon storage function, whereas forests in natural settings with high forest ages, centered on the Baekdudaegan, had a high carbon storage function. This study analysis also supported earlier findings (Yoo Seong-jin et al., 2012) that the carbon storage function is more controlled by tree features, such as forest age, than by site factors, such as latitude.

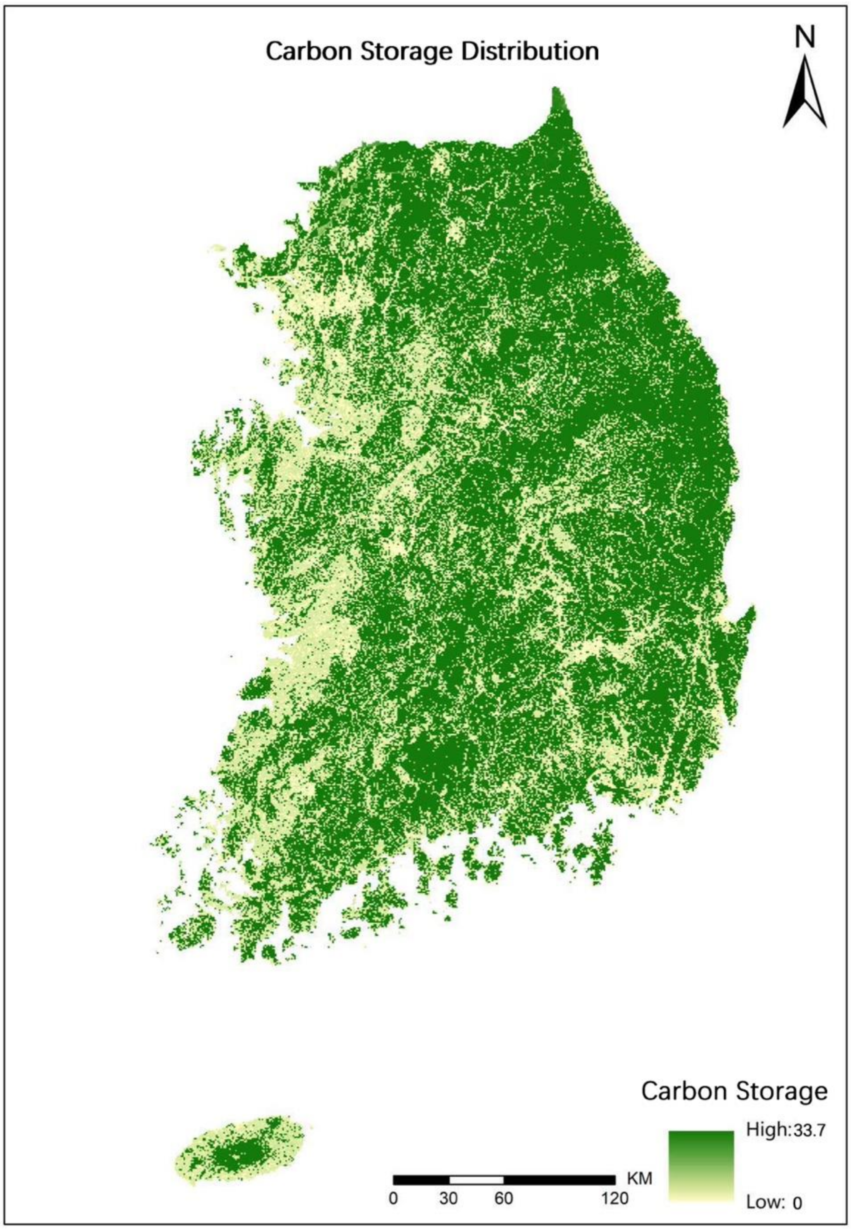

Fig 4 Carbon storage map of South Korea using InVEST model.

Table 1 demonstrates that in comparison to other land cover categories, deciduous forest land, coniferous forest land, mixed forest land, non-irrigated land, and natural grassland all had considerably greater carbon storage rates per hectare. Mixed Forest Land had the largest carbon storage out of the 22 land cover groups, with 6863.6 million tons, or around 27% of the total carbon storage in the research locations.

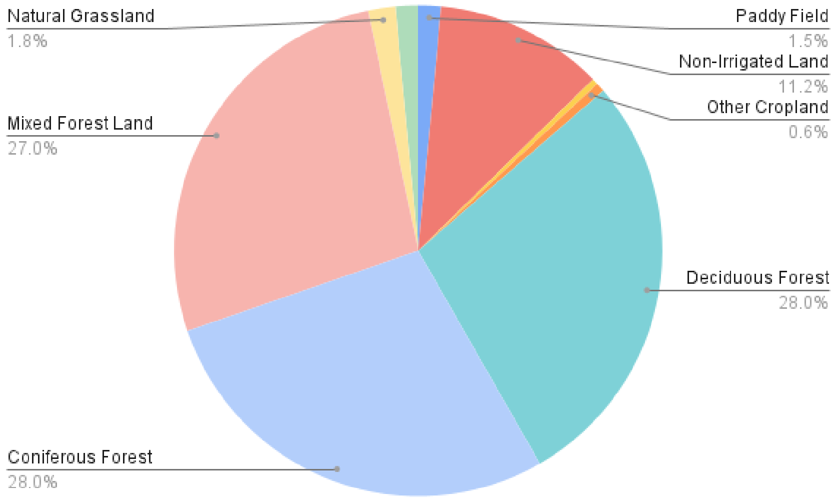

Fig 5 Pie chart showing the percentages of Carbon pools in each Land cover class in the study sites

Additionally, it demonstrates that deciduous forest area has absorbed much more carbon than coniferous forest land (6523.7 million metric tons), coming in second (5900.2 million metric tons). Additionally, 112.4 and 108.9 million metric tons of carbon are stored in natural and artificial grasslands, respectively.

The findings of the present study may be contrasted with those of the research conducted by Kumarasiri et al. (2021). In this work, carbon storage in the Samanalawewa watershed in Sri Lanka was evaluated using the InVEST carbon storage and sequestration model (version 3.7). Similar to the present work, they estimated the total carbon storage of the study region using the carbon data from four carbon pools: above-ground biomass, below-ground biomass, soil organic matter, and dead organic matter. The findings indicated that there were 17 different land cover classifications in the Samanalawewa watershed, with natural trees having significantly larger carbon storage values contained inside them while grasslands and scrublands had more moderate carbon storage values. Additionally, exceptionally low carbon concentrations from various land cover types, including industrial zones, agricultural zones, and grasslands, were noted (Kumarasiri et al. 2021). As a result, the research done by Kumarasiri et al. (2021) also demonstrates how the capacity for carbon storage is influenced by the kind of land cover and how natural vegetation has a positive correlation with carbon storage. The maximum carbon storage is among natural forests, according to Chacko et al. (2019), whereas semi-evergreen and deciduous forests have relatively low carbon storage. Furthermore, while the various tree species in forest plantations grow quickly, research by Lasco and Pulhin (2003) notes that natural forests have a far better capacity to store carbon than do forest plantations. Natural shrublands and forests often retain a larger proportion of carbon because they have the capacity to constantly absorb carbon over a long growth cycle (Sedjo 2001). This shows that, in comparison to other forms of land cover, natural forests are capable of sequestering and storing large quantities of carbon.

Numerous researchers from across the globe have used the same modelling strategy to calculate the geographical distribution of carbon storage and forecast the overall amount of carbon storage in a certain study region (Babbar et al., 2021; Chacko et al., 2019; He et al., 2016; Jiang et al., 2017; Kumarasiri et al., 2021; Lyu et al., 2019; Zhao et al., 2019). A forest's quality and significance in terms of carbon storage and sequestration may be determined using the InVEST carbon storage and sequestration modelling approach, according to Kumarasiri et al. (2021). Additionally, by using this modelling technique, it is possible to evaluate how proposed conservation priority areas may affect natural forests and the capacity for total carbon storage (He et al., 2016; Lyu et al., 2019). Scenario analysis requires the creation of future land cover data and the determination of carbon pool values for each kind of land cover since these two fundamental data inputs serve as the foundation for the whole model (Sharp et al. 2018). According to Wu et al. (2015), mapping out conservation priority areas in terms of their ability to store carbon in natural forests using the CLUE-S (conversion of land use and its effects at a small regional extent) model may be helpful.

2. Habitat prediction model and accuracy verification

2.1 Endangered species distribution

In this research, Accipitersoloensis, Lutra, Martes flavigula koreana, Ninoxscutulata, and Prionailurus, five endangered species in South Korea, were evaluated for appropriate habitat regions using the environmental factors and species distribution model MaxENT. From this model, the richness maps for the five national species were created.

The AUC value of the ROC curve was employed to validate the correctness of the MaxEnt model of these species prior to analyzing the species richness maps. Because of this, the target species' AUC values varied from 0.760 to 0.890, showing that all models had a respectably high degree of accuracy.

2.1.1 Distribution of Accipiter soloensis (Accipitersoloensis)

According to the Accipitersoloensis species distribution model, the AUC value was 0.863, demonstrating great accuracy. High habitat appropriateness for Accipitersoloensis was mostly found in mild terrain with modest slopes, while in places with slopes larger than 30 degrees, suitability steadily dropped. However, it was not discovered that altitude made a substantial difference. High light levels are often preferred by forests, particularly towards their borders. (Figure 6).

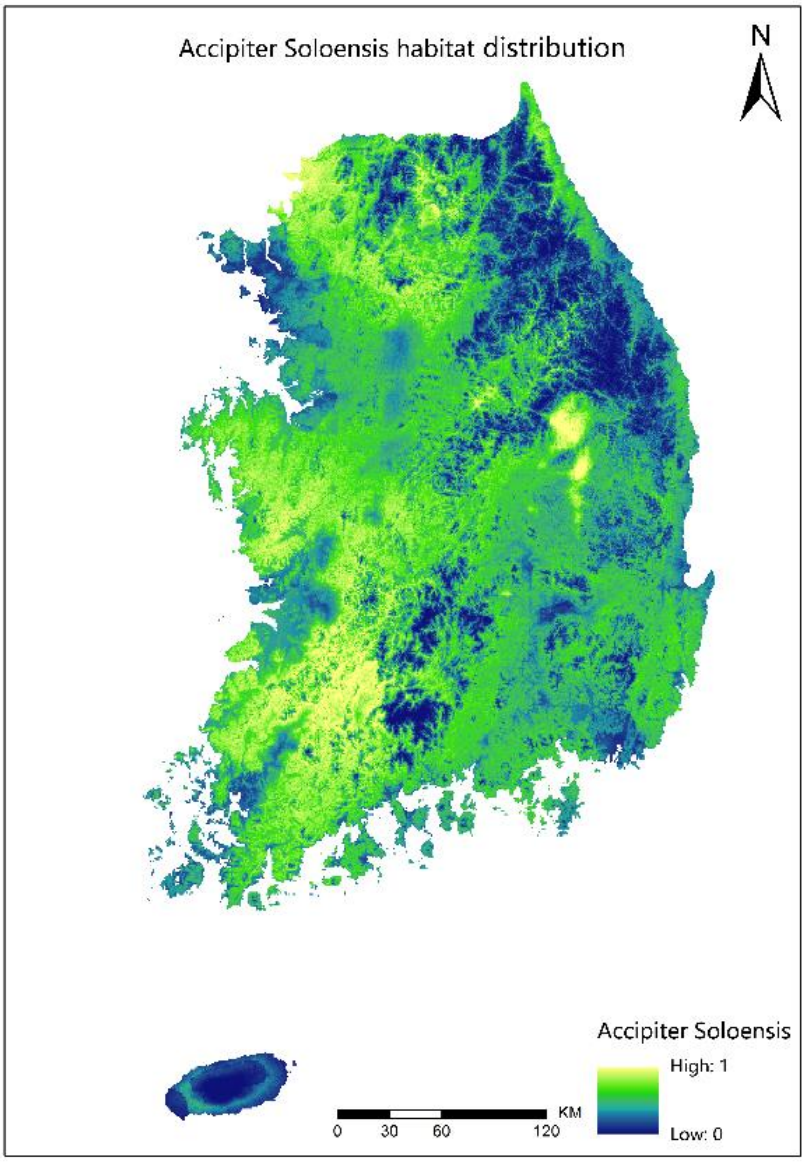

Fig 6 Habitat prediction of Accipitersoloensis

2.1.2 Distribution of Lutra (Lutra)

Looking at the median distribution model findings for the species of Lutra, the

AUC value in this instance was 0.760, which was the model accuracy among the 5 species chosen for this research but demonstrated a respectable level of accuracy. Most of the habitat-suitable regions for wildcats were found to be those near inland water and forests at lower elevations, suggesting that they were the land cover classes most susceptible to water source areas (Figure 7).

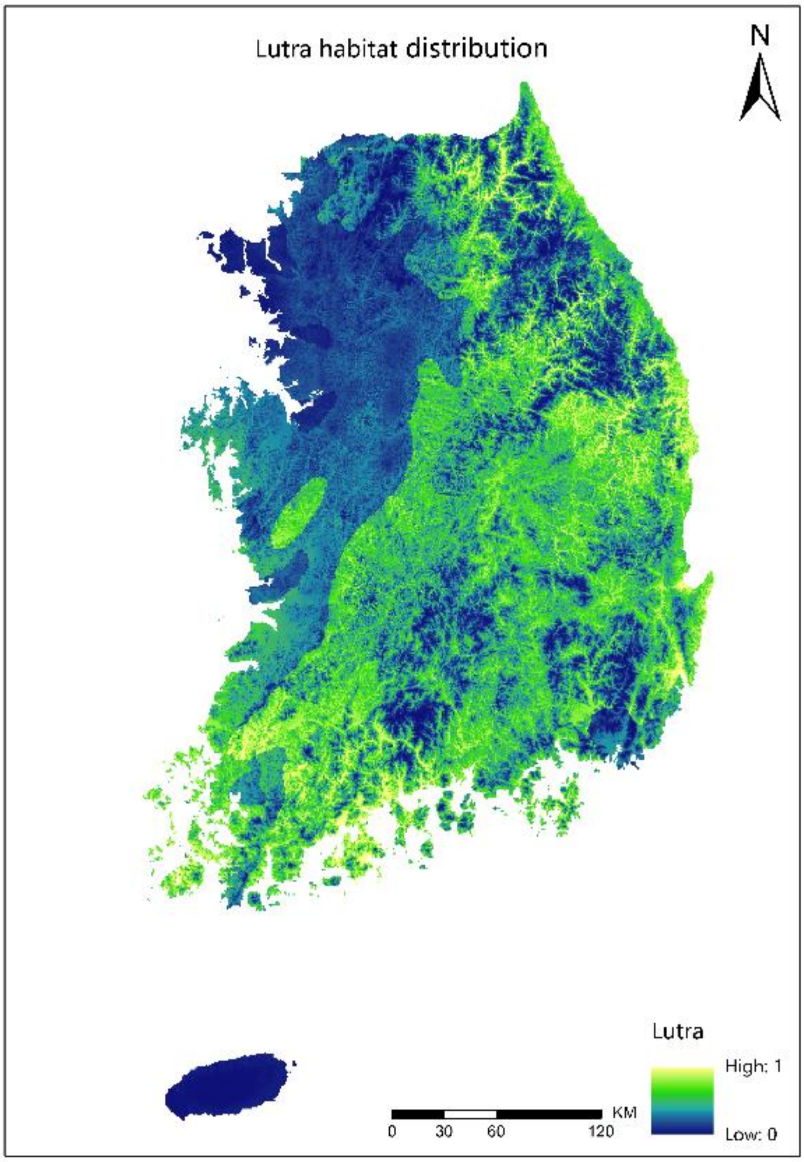

Fig 7 Habitat prediction of Lutra

2.1.3 Distribution of Martes Flavigulakoreana (Martes flavigula koreana)

According to the Martes flavigula koreana species distribution model, the AUC value was 0.799, indicating a comparatively high level of accuracy. Martens need more challenging environments than wildcats and moose, and most of the places with good habitat appropriateness for martens were forested regions with high elevations and steep slopes. In addition, it was discovered that Jeju Island's mid-mountain regions provided martens with a decent habitat. They were mostly found in the Baekdudaegan area, which has extensive forests and extremely undulating terrain. Coniferous forests were favored above other kinds of forests (Figure 8).

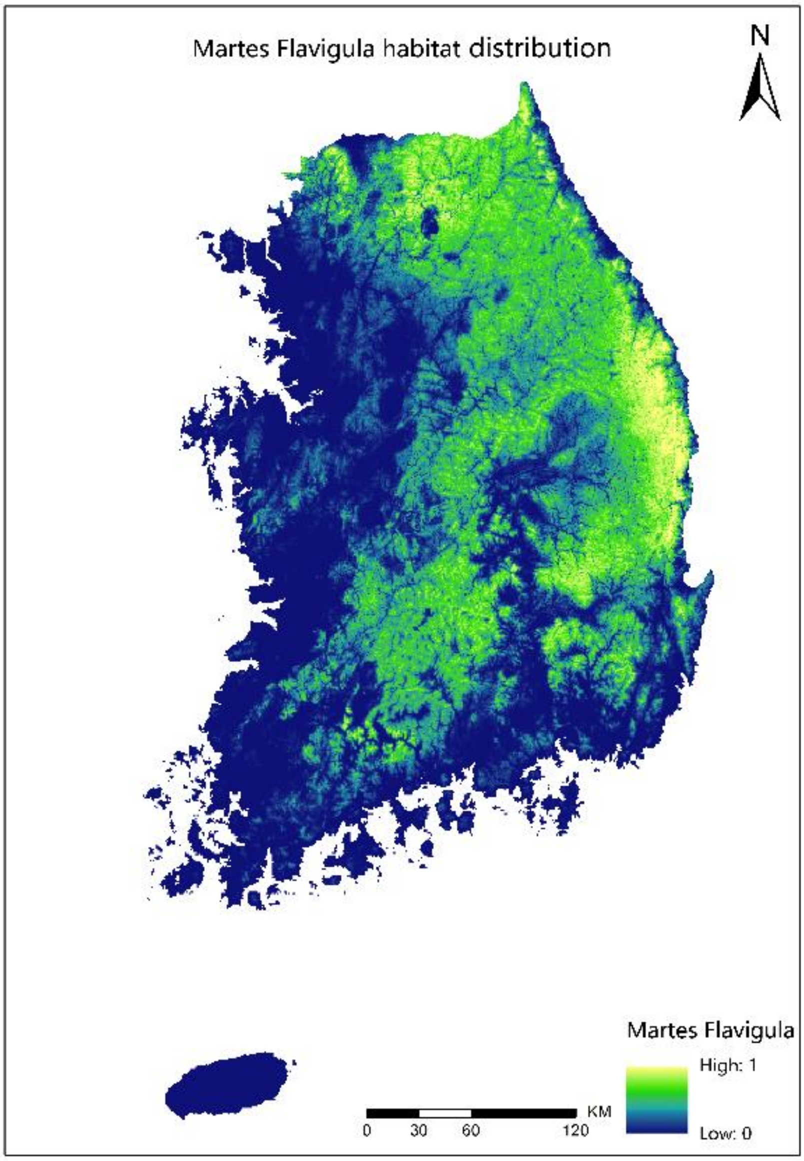

Fig 8 Habitat prediction of Martes Flavigula

2.1.4 Distribution of Ninox Scutulat (Ninoxscutulata)

According to the Ninox Scutulata species distribution model's output, which demonstrated great accuracy, the AUC value was 0.856. The majority of the grasslands and woodland borders at relatively low elevations were places with excellent habitat appropriateness for Ninox Scutulata. The same applied to different vegetation kinds (Figure 9).

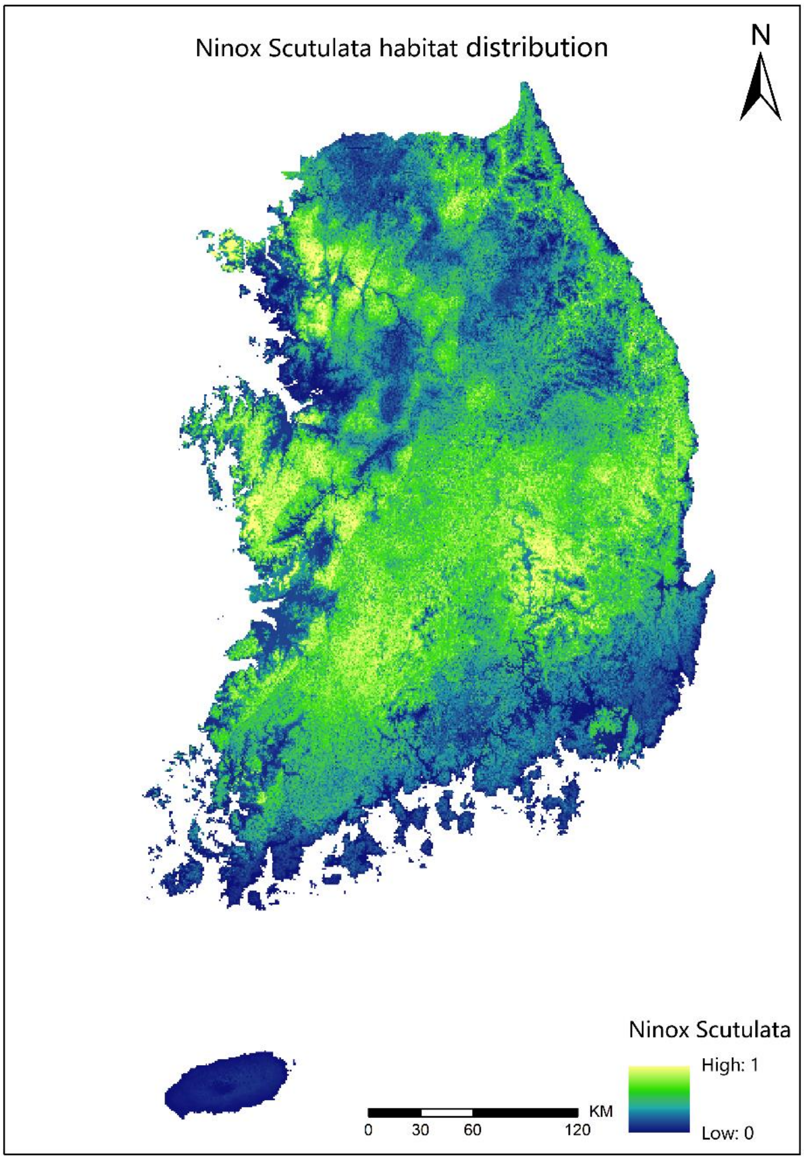

Fig 9 Habitat prediction of Ninox Scutulat

2.1.5 Distribution of Prionailurus (Felis Bengalensis Euptilura)

The AUC score was 0.890 and has a good level of accuracy based on the Prionailurus species distribution model. The land cover categorization for regions with a high habitat appropriateness for cats, such as coniferous forest areas, is forest areas (Figure 10).

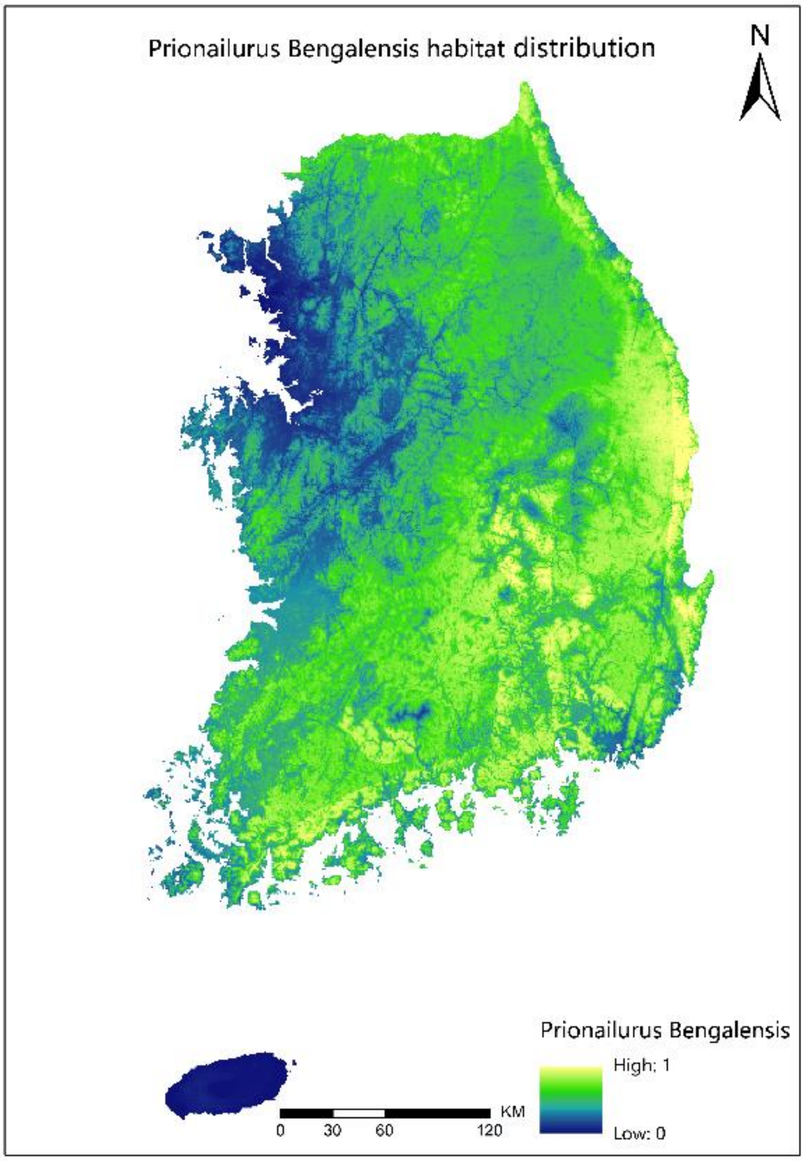

Fig 10 Habitat prediction of Prionailurus Bengalensis

2.2 Normalization

2.2.1 Normalized endangered species diversity prediction model

Species diversity was used as the dependent variable in a stepwise regression analysis with 20 habitat factors acting as the independent variables in the species diversity prediction model stage. Prior to doing the regression analysis, the multicollinearity issue must be resolved. In general, multicollinearity is thought to occur when the tolerance limit is less than 0.1 or the variance inflation factor (VIF) exceeds 10. (Seung Jang et al., 2009). Therefore, it was determined that there was no multicollinearity issue in this research since the maximum variance inflation factor was 2.205 and the lowest value of the system was 0.454.

Through the processes of overlapping, summarizing, and standardizing, the habitat appropriateness of the five species mentioned above was constructed as a species richness map in the range of 0 to 1 (with 0 being the minimum and 1 being the maximum), and the computed values were dispersed at 0.2 intervals. A region with a value of 0 has no species among the five typical species, a value of 0.2 has one species, a value of 0.4 has two species, a value of 0.6 has three species, and a value of 0.8 has four species. The area where all five species are found is referred to as Species 1.0. The research revealed that 78.16% of the nation had values of 0.2 or above, suggesting that at least one species (Felis bengalensis Euptilura, Lutra, Martes flavigula koreana, Accipiter Soloensis, and Ninox Scutulata) would be present. When examining the overall pattern of species richness distribution, it can be seen that species richness was highest in lowland forests and portions of forest borders at low altitudes, as well as in deep forests at high elevations, such as Mt. Seorak, Mt. Odae, and Mt. Backdudaegan.

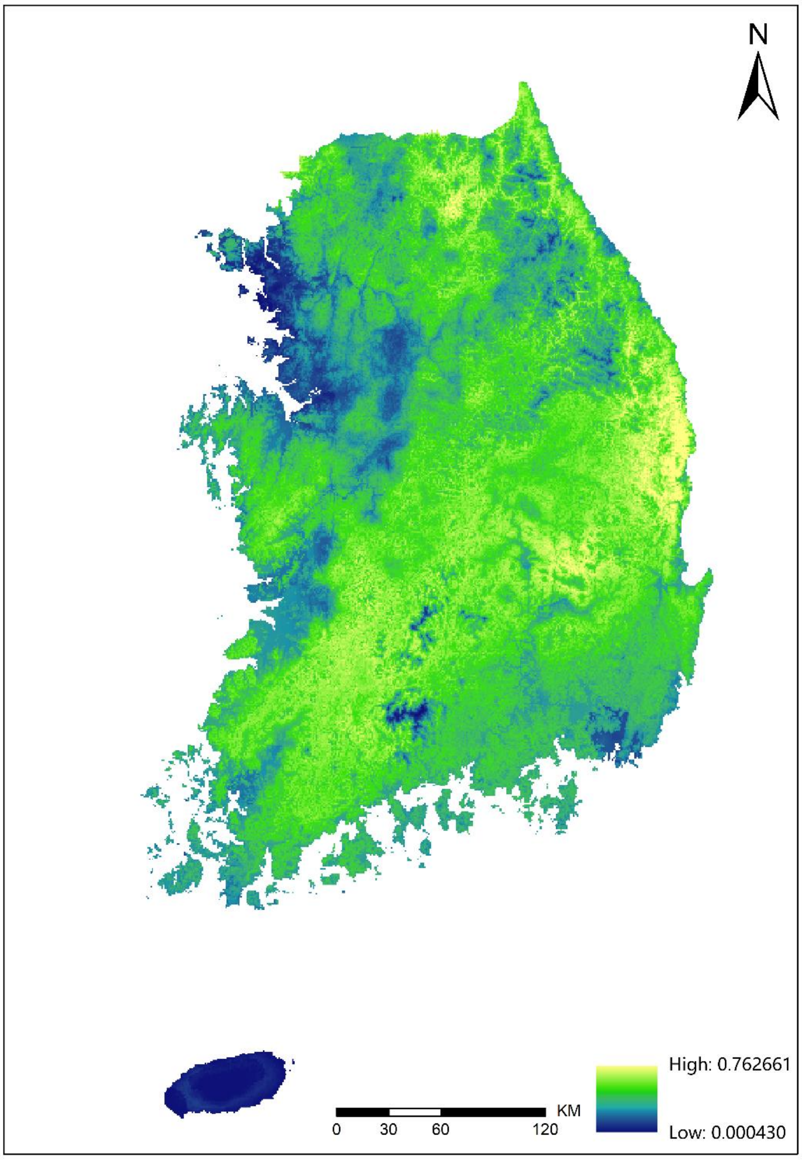

Fig 11 Normalized endangered species diversity prediction model

According to the research, at least one species (Accipitersoloensis, Lutra, Martes flavigula koreana, Ninoxscutulata, and Prionailurus) with values of 0.2 or above would exist in??% of the nation. When examining the overall trend of species richness distribution pattern, it can be seen that species richness was high in lowland forests, part of the forest borders at low altitudes, and deep forests at high elevations, such as Mt. Seorak, Mt. Odae, and Mt. Backdudaegan.

On the other hand, the number of bird species was negatively correlated with both the distance from the valley and the distance from mixed forests. Accordingly, the more space there is between a location and a valley or mixed forest, the more forest algae there will be. The aquatic ecosystem that thrives within of forests depends on valleys. In valleys, water flows and weeds and plants develop around them, providing a favourable environment for birds to survive or breed. The larger the species variety, the closer the distance is to the valley. Additionally, the biodiversity is larger the closer the distance is to the mixed forest since mixed forests provide more food and shelter than simple forests like deciduous and coniferous forests.

2.2.2 Normalized carbon storage

The geographical distribution of carbon storage in the research region was compiled into a raster output according to the InVEST model for carbon storage and sequestration. The results also revealed that carbon storage differed amongst various kinds of land cover. In comparison to other land cover types, vegetative land cover types often store more carbon (Chacko et al. 2019; Kumarasiri et al. 2021). Nevertheless, as Paquit (2017) explains, agricultural land cover types' capacity to store carbon has been disregarded and could even be overestimated. By retaining more soil carbon, agricultural land also made a substantial contribution to overall carbon storage.

The regional distribution of carbon storage throughout the nation is seen in Figure 12. In South Korea, forests are estimated to store carbon at a rate ranging from 3,927 kg per tree to 900,427 kg per tree. In South Korea, the projected carbon storage value of forests varies from 3.73 kg per tree to 880.4 kg per tree at its highest. The spatial differences according to altitude were shown for the carbon storage function. In general, forests around Baekdudaegan had a high capacity to store carbon, compared to those in developed areas, which had a relatively low capacity. The study analysis also supported the findings of earlier studies (Yoo Seong-jin et al., 2012), which found that site factors like latitude have less of an impact on carbon storage function than do tree features like forest age.

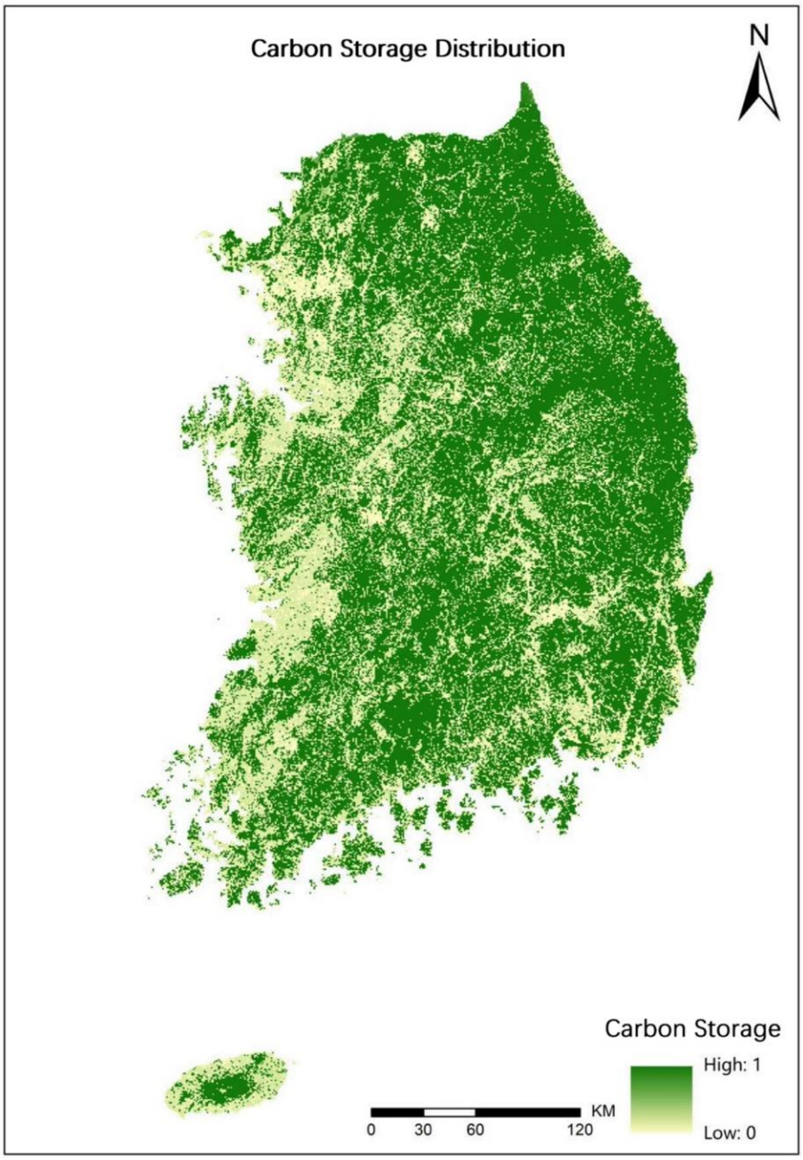

Fig 12 Carbon storage map of South Korea using InVEST model

The soil layer, which made up 82.86% of the total carbon storage across the four layers at the research sites, had the highest value for carbon storage, as shown in Figure 13. Furthermore, the soil layer supplied more than 60% of the carbon storage for each land cover, showing that soil is the most significant carbon sink for each ecosystem.

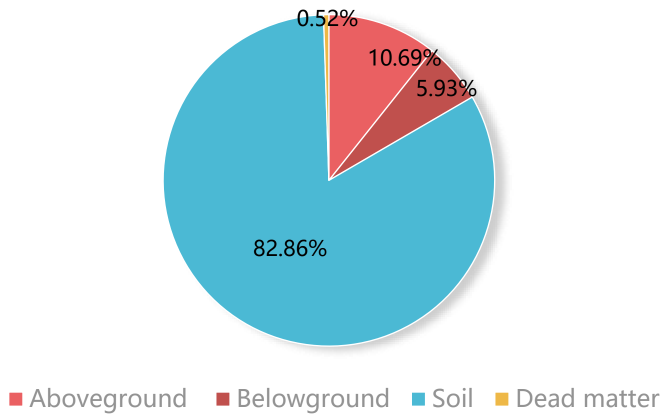

Fig 13 Pie chart showing the percentages of Carbon storage in each

As seen in Figure 14, compared to the other land cover categories, Forest Land and Agricultural Land had a comparatively larger quantity of carbon storage per hectare. The biggest carbon storage was found on mixed forest land, which made up 52.87% of the total carbon stored in the research sites.

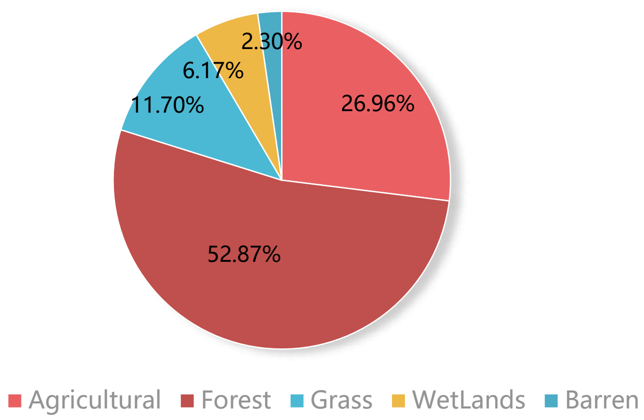

Fig 14 Pie chart showing the percentages of Carbon storage in each Land cover in the study sites

Additionally, Table 2 below demonstrates that broadleaved forests store much more carbon than coniferous forests, coming in second with 5900.2 million tons, followed by 6523.7 million tons. Additionally, 112.4 and 108.9 million tons of carbon are stored in natural and man-made grasslands, respectively.

Table 2 Carbon storage in each Landcover type

LULC type	Mean C (t/ha)	Total C (million t)	C in each LULC(%)
Residential	0	0	0
Industrial	0	0	0
Commercial	0	0	0
Communication	0	0	0
Transportation	0	0	0
Public Utilities	0	0	0
Paddy Field	35	151.8	1.5
Non-Irrigated Land	105.3	1938.8	11.2
Protected Cultivation	15	39.5	0.4
Orchard	65	0.5	0
Other Cropland	14	62.8	0.6
Deciduous Forest Land	256.3	6523.7	28
Coniferous Forest Land	250.8	5900.2	28
Mixed Forest Land	257.1	6863.6	27
Natural Grassland	86	112.4	1.8
Non-Natural Grassland	85.6	108.9	1.5
Inland Wetland	0	0	0
Coastal Wetland	0	0	0
Natural Barren Land	0	0	0
Non-Natural Barren Land	0	0	0
Inland Water	0	0	0
Seawater	0	0	0

2.3 Trade-off and Synergies

This research used a variety of techniques to examine the degree to which carbon priority were geographically linked with habitats for endangered species. First, we tested whether carbon was related to the model species richness of all endangered avian and animal species using linear least squares regression. By adding the distribution models, it was possible to determine the endangered species' model habitat distribution.

All habitats for endangered species showed a strong correlation with carbon (Fig. 2, adjusted R^2 = 0.53, $p < 0.001$). Although it was significant, the link was less strong for mammals (adjusted R^2 = 0.42, $p < 0.001$), than it was for birds (adjusted R^2 = 0.58, $p < 0.001$). High value endangered species habitat is typically found in high elevation forests, such as Mt. Seorak, Mt. Odae, and Mt. Backdudaegan. As shown in Figure 15, however, there was significant overlap between high-ranking cells for each of the solutions, suggesting that these areas may also have high carbon storage potential. According to the carbon-only weighting, the western boundary of the rainforest zones was given priority, suggesting that this region may be of high value for sequestering carbon, but not for protecting endangered species.

For each of the solutions, there was a significant geographical overlap of high-ranking cells (Fig. 15), showing that places with high value as endangered species habitat, typically the eastern sections of Mt. Backdudaegan, also had high potential for carbon storage. As a result of the carbon-only weighting, a priority was given to the western boundary of the rainforest zones, suggesting such these regions may be of high value for sequestering carbon but not for endangered species habitat.

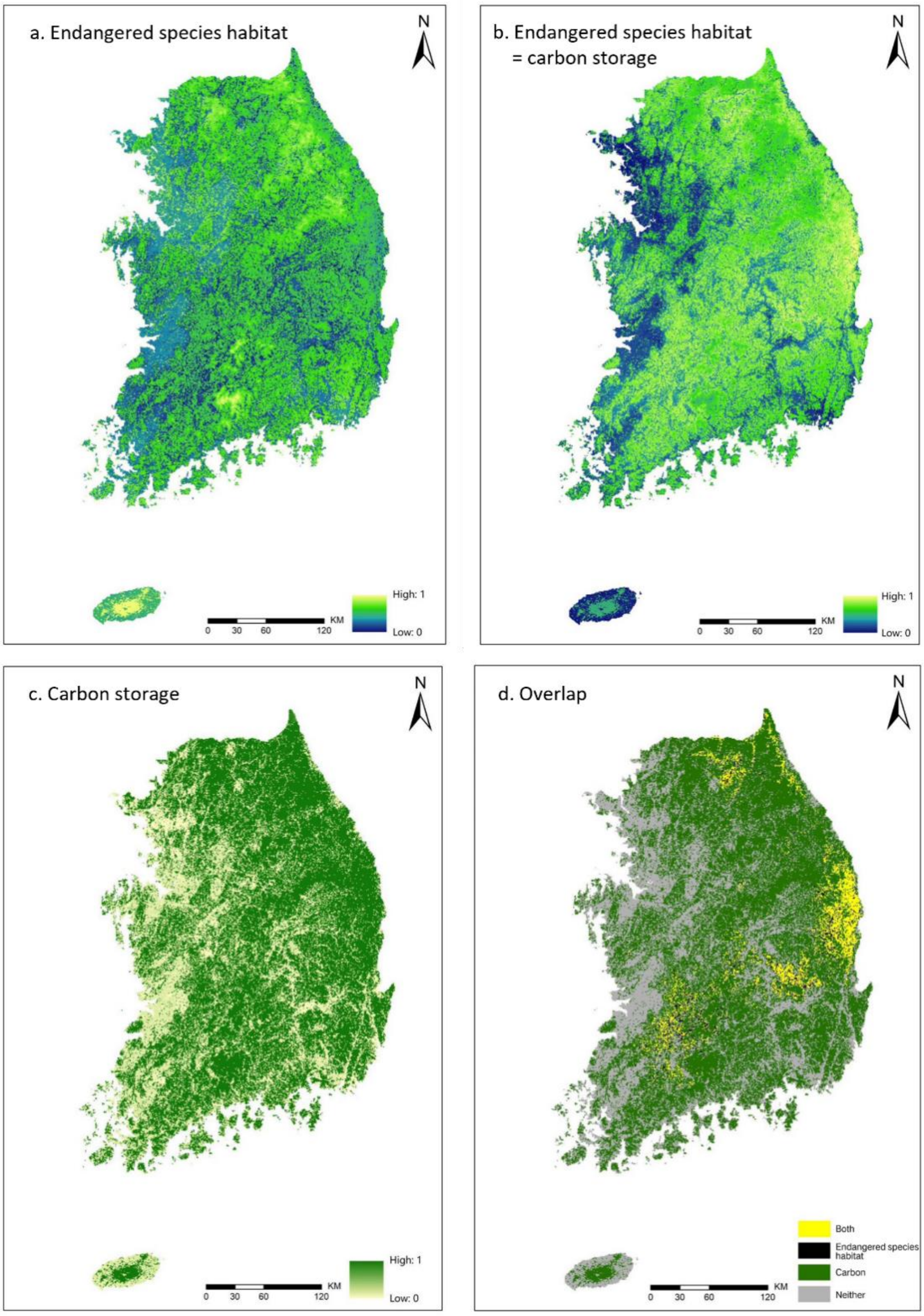

Fig 15 The priority areas in the region of South korea. Left to right: a) Endangered species habitat ; b) Endangered species habitat and carbon are weighted equally; and c) carbon storage only. The far right map d) shows the distribution of the area above the overlapping

Ⅵ. Discussion

In this area, the priorities weighted by either carbon or habitat for endangered species were very congruent. Some endemic species may not be protected as well if they are not taken into account specifically. In this research, the importance of looking beyond simply maximizing carbon gains or focusing solely on species diversity is highlighted. It might cause significant species to be missed.

There is an advantage to living in this area in that if habitat for endangered species is prioritized, there is only a small trade-off with carbon. The Mt. Backdudaegan areas have the largest biomass and concentration of narrow-range endemics, resulting in high spatial congruence for habitat priority for endangered species and carbon. Although not the only place in this circumstance, many regions face a considerable trade-off (Venter et al., 2013). (Thomas et al., 2013). Considering cost, this trade-off becomes even more problematic, yet if regions are prioritized for preservation merely based on the least expensive means of lowering emissions, many significant biodiversity hotspots might be missed (Venter et al., 2009). At a broad scale, the association between carbon biomass and habitat for endangered species is positive and larger than that seen in this area (Strassburg et al., 2010). Nevertheless, throughout history, it has been recognized that protecting biodiversity through planning must take into account complementarity and irreplaceability in addition to species richness (Margules and Pressey, 2000). This research has shown that, while simultaneously boosting the capacity for carbon storage, planned conservation action might have a large positive impact on the habitat of endangered species in this area.

A never-ending task is to develop regulatory frameworks that enhance the financial viability of carbon offset initiatives and habitat improvements for endangered species. More research is needed in Australia to determine the viability and implementation of carbon farming initiatives in order to conserve the habitat of species facing extinction as well as to mitigate the effects of climate change (van Oosterzee, 2012). The difficulty and expense of the project creation process, Nevertheless, restrict the adoption of carbon offset initiatives (van Oosterzee, 2012). Since non-additional projects may sell carbon at a cheaper price during the reverse auction process, these variables also favor projects that would have occurred otherwise.

The findings of this study offer suggestions for the targeted preservation of habitats for endangered species as well as for the targeted conservation and regeneration of vegetation in areas with high carbon storage potential. Particularly atop Mt. Backdu daegan, the area has unspoiled regions with significant biological value that are not officially protected. Due to South Korea's present development policy, all of the study's bioregions have seen considerable losses in the amount of existing and regrowing vegetation, and further losses are probably on the way.

As a result, chances to stop more clearance should be looked into, especially in the high-priority regions. Strong regulatory frameworks must be combined with opportunities and incentives to minimize vegetation loss in order to prevent large-scale clearance. A combination of incentives and regulation is necessary to prevent further loss of biodiversity (Evans, 2016).

Restoration efforts should be prioritized in areas of high biodiversity value that have previously undergone severe deforestation and fragmentation. This research emphasizes the importance of these areas for vertebrate conservation since they have high levels of endemism. Sustainable long-term possibilities, like carbon storage, that have a considerable potential to offer triple bottom line benefits need to be investigated in light of continuous deforestation and development (Hatfield-Dodds et al., 2015; Russell-Smith et al., 2015).

By recovering cleared areas in this area, significant carbon and habitat advantages for endangered species might be attained. And a high-priority activity, especially for the region's sparsely dispersed endemic species, has been identified: restoring important refugia for species under climate change (Shoo et al., 2011).

Even while the endangered species habitat has been taken into consideration when calculating carbon offsets, other possible ecological and social effects of carbon pricing systems have also drawn attention. For instance, it has been proposed that reforestation for carbon sequestration may have a detrimental impact on displacement of hydrological flows or displacement of food production on marginal agricultural land (Jackson et al., 2005). Fortunately, the majority of these won't likely cause problems in the area. There is evidence that afforestation in South Korea is expected to reduce environmental hazards, especially hydrological risks, to agricultural output.

Another major issue is the improper administration of forest management, which puts forest people in danger of being evicted and marginalized (Sikor et al., 2010). Nevertheless, in South Korea, "carbon farming" is seen as having a considerable potential to provide indigenous people with economically worthwhile labor on the land via the application of traditional burning techniques.

The management of biological processes that result in carbon sequestration is another issue with carbon markets in other regions of the globe, since it reduces the value of endangered species' habitats. Outside of the black and green are areas with lingering vegetation (Accad and Neldner, 2015). Managers who allow natural processes to achieve better results for the endangered species habitat would receive less compensation from carbon payments under certain carbon pricing arrangements than those who only focus on carbon (Galatowitsch, 2009).Fortunately, the Carbon Farming Initiative and its successor, the Emissions Reduction Fund, have particular techniques that take into account these natural processes, and there is space for other countries to adopt comparable approaches (van Oosterzee, 2012). Carbon markets should be modified wherever feasible to prevent encouraging undesirable results. Designing policies to prevent projects from being too narrowly focused (such as concentrating on a specific ecosystem function like carbon) is one possibility. Another is investigating ecological uncertainty and the political, economic, and social environment in which the policy could be implemented (Lindenmayer et al., 2012). Future carbon storage prospects should undergo thorough analyses of biodiversity protection; this might be encouraged by rewards for better results for the endangered species habitat. Additional efforts should be done in the South Korean context to guarantee the additionality of carbon storage operations and the protection of endangered species habitat.

This analysis shows how to prioritize the many advantages of carbon and endangered species habitat while taking into consideration both of their futures. The identification of significant areas that are now degraded and should be prioritized for restoration efforts is made possible using data on carbon storage capacity paired with future priorities for endangered species habitat. Valuable but vulnerable sites might be given priority for conservation efforts in intact regions. In an era of fast global change, this kind of conservation planning, which considers numerous advantages and future concerns, is essential for effective conservation results.

VI. Conclusion

Endangered species habitat comprises regional habitat conditions across a greater area having a comparable natural assemblage of endangered species, as well as local species diversity and carbon storage.

This research set out to (1) characterize the broad linkages between production possibilities for combinations of carbon storage and habitat for endangered species and (2) pinpoint the management factors that have the greatest impact on joint production relationships. We have identified local stand characteristics associated with carbon storage, as well as endangered species diversity, in order to maximize opportunities for carbon storage and endangered species habitat conservation.

The study took place in South Korea, which has a lot of endangered species habitat. Additionally, this area has a lot of potential for sequestering carbon. The prioritization of restoration and preservation in places with high endangered species habitat value and carbon storage potential will be influenced by the identification of priority locations for endangered species habitat conservation and carbon storage. With the existing distribution of species in mind, this analysis considered the endangered species' habitat as well as the potential for carbon sequestration. Priorities for spatial conservation were determined for the present and two future time periods using the systematic conservation planning tool Zonation (Moilanen et al., 2014) (2055, 2085). We next evaluated changes in spatial priority when various benefits were taken into account by incrementally increasing the weighting of carbon in relation to endangered species habitat. This was done to determine the best course of action for all priorities.

The findings pinpoint conservation goals for space that are resilient to numerous advantages.

This informational synthesis may direct spatially explicit national forest evaluations of possible co-benefits, operationalize spatial goals, and inspire reactive or proactive conservation activities.

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