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A GIS-Assisted Assessment and Attribute-Based Clustering of Forest Wetland Utility in South Korea

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Abstract: The aim of this study was to determine the characteristics of forest wetlands by developing factors for site suitability and applying these factors to 107 sites in South Korea. We developed a forest wetland assessment in a Geographic Information Systems (GIS) environment to assess site suitability. We considered 16 factors including slope, elevation, visibility, land ownership, distance to city, and so on. We conducted an expert survey with experts to analyze the relative importance by using the Analytic Hierarchy Process (AHP). We found that the order of importance of the 5 criteria applied in this study was: (1) Natural Ecology, (2) Land Use, (3) Natural Landscape, (4) Tourist Attraction, and (5) Accessibility. We then analyzed the spatial characteristics of each site based on the AHP result and divided the 107 forest wetlands into three categories by cluster analysis. Sites with high scores on the assessment were primarily the landscape ecology or land use criterion. Our differentiation of these forest wetland characteristics could help enable policymakers to develop sustainable management with the aim of balancing conservation with utilization in ecotourism destinations.

Keywords: AHP; cluster analysis; efficient land use; environmental capacity; forest recreation; GIS

1. Introduction

In a forest wetland, marsh plants grow naturally in forests or marshlands and peatlands connected with forests, providing various public service functions. Wetlands are characterized by generally nutrient-rich soils and high moisture availability, enabling smallholder farmers to produce crops all year round [1]. Previous studies regarding forest wetlands have dealt with their ecological, social, economic, and recreational functions worldwide [2–5].

According to the Korean Forest Service's investigation regarding forest wetlands in South Korea since 2006, the average area of 1264 forest wetlands is approximately 0.31 ha, of which 0.49 ha is nationally owned, and approximately 0.26 ha is publicly and privately owned [6]. Due to the fact that most of the forest wetlands in South Korea are located in mountains with limited accessibility, visitation is declining and therefore these wetlands have become neglected.

There are two main reasons for conserving and utilizing these forest wetlands. Firstly, to reduce the decline of plant succession, caused by an absence of landscape management [7,8] and secondly, to enhance their public utilization for social, health, educational, and recreational benefits [9–12]. Notably, forest recreation has gained increasing societal importance in the last decades [13]. Considering the importance and utility of forest wetlands, it is necessary to consider both their ecological and sociocultural characteristics.

This study aims to determine the value of forest wetlands so that they can be utilized wisely in the future. Specifically, we analyze the status of forest wetlands scattered in various areas and develop an attribute-based index to evaluate their utility. Our findings provide important implications for forest wetland planning and management.

1.1. Forest Wetland Conservation and Use

According to Campbell (2009) [14], forestry is increasingly important for both wildlife conservation and human use, although frequent conflicts occur between these uses. Wetlands in forests have particular potential to be highly valued in terms of their conservation and use. Wetlands, which include mangroves, forests, carr, pocosin, and floodplains [15] are of great conservation value due to their rich biodiversity and function as land and water transition zones, including mitigating climate change impacts [5,16], wetland ecosystems have irreplaceable and important functions in protecting water resources and both globally and locally, the water cycle relies on wetlands [17].

Despite an increasing number of studies regarding the ecological significance of wetland biodiversity [16] including studies highlighting potential conflicts between conservation and utilization [18–20], few studies have incorporated human presence in wetland management. The conservation aspects of wetlands to date have been the focus rather than the management of human presence in wetlands. Considering the public value of wetlands to many people, it is crucial to use and manage them wisely, to mitigate ecological disturbance from ecological succession, reckless destruction and loss of ecosystem function [21–23]. Despite the significant negative impacts of 'humidity' on preference for forest recreation [24] or its importance as an object of conservation, recreational activities derived from wetlands have been relatively underestimated [20,25].

The use and management of forest wetlands need to be more highlighted because they are directly connected to peoples' quality of life [26,27], public health [28], management strategies [29,30], and even crop production [23,31]. Moreover, a substantial body of evidence demonstrates that wetlands can deliver a great variety of benefits to human society [32]. Therefore, the sociocultural functions of wetlands should be explored so that public activities for people are balanced with conservation and the natural development of wetlands.

We believe that due to their conservation importance, wetlands should not be used carte blanche. Instead, evaluation and good management are needed to balance their conservation values with human needs using land use suitability analysis [33–35]. Forest wetlands worldwide have been significantly neglected and highly used and therefore need to be studied and managed appropriately.

1.2. Evaluation of Forest Wetlands

Evaluation can serve as a support tool in the decision-making process for conserving and using forest wetlands appropriately [26,31] so that better management and protection of wetlands resources can be achieved.

Despite major difficulties in quantitatively assessing the current state and economic value of wetlands due to the lack of an efficient market for these wetland services [23,36], there have been many attempts (e.g., [23,37]) to evaluate the value of forests that surround wetlands at the landscape level. The US Environmental Protection Agency (US EPA, 2006) [38] refers to the three-tiered monitoring and assessment program for wetlands. The Level 1, landscape assessment, relies entirely on Geographic Information Systems (GIS) data, utilizing landscape disturbance indices to assess wetland condition. The Level 2 assessment (rapid assessment) uses relatively simple metrics to assess wetland condition. The Level 3, intensive site assessment, provides a more thorough and rigorous measure of wetland condition by gathering direct and detailed measurements of biological taxa and/or hydrogeomorphic functions. Although this monitoring and assessment system at each stage is critical for wetland management, we focused on the Level 1 stage, which evaluates the characteristics of land at a landscape level for comparing sites overall.

The US EPA's monitoring and evaluation system focuses primarily on the ecological status and value of wetlands, but it is also required to evaluate the sociocultural values of forest wetlands for public use. To consider public use, site suitability based on a forest wetland's ecological and sociocultural attributes is necessary, regardless of whether it can be utilized. Previous studies [39–41] that determined site suitability have commonly used GIS programs, which enable the analysis of site characteristics and compare and validate their condition effectively with other sites. In site suitability studies using GIS on forest sites, several attributes, which are standard for evaluation, have been developed for formulating reliable utilization models. Some examples of these attributes on forest sites include land cover type, wild animal zones, distance to roads, distance to facilities, distance to residences, landscape openness, landscape diversity, and forested area [42–44].

Because the results of these GIS-based evaluation systems rely on which attributes are selected and weighted, further scientific selection or weighting processes are required. For example, weighting or prioritizing attributes have often been conducted using expert elicitation [45,46] or using a GIS-Analytic Hierarchy Process (AHP) combination method [47–50]. Attribute-based evaluation studies using AHP on forest sites have been developed to decide whether forests should be for conservation only or for recreational use only. However, forest wetlands need to be considered not only from a conservation perspective, but also from a public use perspective.

Therefore, one approach for ameliorating this problem is to develop several attributes regarding a forest's ecological characteristics and recreational characteristics, in addition to weighting the values using AHP. We aim to develop attributes and evaluate forest wetlands in South Korea using AHP to determine site suitability for their recreational opportunities, without jeopardizing social acceptance or the achievement of conservation goals.

2. Methodology

2.1. Study Sites

The study area was limited to Chungcheongbuk-do and Gyeongsangbuk-do Provinces in South Korea. These sites were determined by verifying redundancy and validity information from the Korea Forest Service (2017) [51]. Finally, 107 from 111 forest wetlands in the two provinces were selected for the study (Figure 1). In Chungcheongbuk-do Province, 35 sites were selected (32.7%) and in Gyeongsangbuk-do Province, 72 sites were selected (67.3%). Among the major plant communities in the forest wetlands, the proportion of willow communities was the highest with an average of 67.3%. The average area of the forest wetlands was 6404.3 m^2 in the core area, with Chungcheongbuk-do Province comprising 6907.4 m^2 and Gyeongsangbuk-do Province comprising 6159.8 m^2. This area is quite large considering that the average area of 1264 total forest wetlands in South Korea is approximately 3100 m^2 [52].

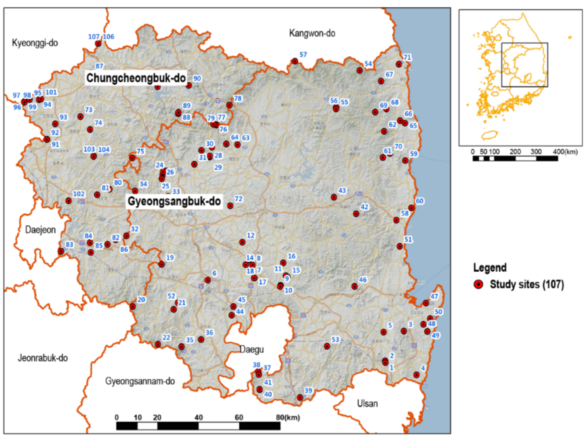


Figure 1. Distribution of the study sites.

2.2. Assessment Factors

To assess the suitability of the forest wetlands for ecosystem conservation and recreational use, variables such as slope, elevation, visibility, vegetation, and tourist attraction were selected based on previous studies [6,40,44,47,52–54]. We also chose land ownership, development feasibility and distance to city (considering the practical applicability) [33,55]. The final factors determined were divided into 16 assessment factors in 5 criteria, which were Natural Landscape, Natural Ecology, Land Use, Accessibility, and Tourist Attraction (Table 1).

Table 1. Assessment factors and their sources in this study.

Criteria	Factors	Sign	Source
Natural landscape	Slope	Negative	Korea Forest Service (DEM)
	Elevation	Negative	Korea Forest Service (DEM)
	Visibility	Positive	Korea Forest Service (DEM)
Natural ecology	Ecological zoning map	Positive	Ministry of Environment, Korea
	Vegetation (Age Class)	Positive	Forest type map by Korea Forest Service (1:25,000)
	Water system	Positive	National Information Society Agency
	Species diversity	Negative	Korea Forest Service
Land use	Forest wetland area	Positive	Korea Forest Service
	Land ownership	Nominal Scale	Korea Forest Service (Basic map of nation-owned property), Korea National Arboretum
	Development feasibility	Nominal Scale	Ministry of Environment, Korea (Land use regulations information system)
Accessibility	Distance to city	Negative	Ministry of Land, Infrastructure, and Transport (Traffic map)
	Distance to access road	Negative	Korea Transport Database
Tourist attraction	Number of nearby tourists	Positive	Tourism Knowledge Information System
	Number of nearby tourist destination	Positive	Ministry of Culture and Tourism
	Number of nearby cultural heritage	Positive	Cultural Heritage Administration, Korea
	Proximity to national park	Negative	Korea National Park Service

2.3. Data Collection and Units of Analysis

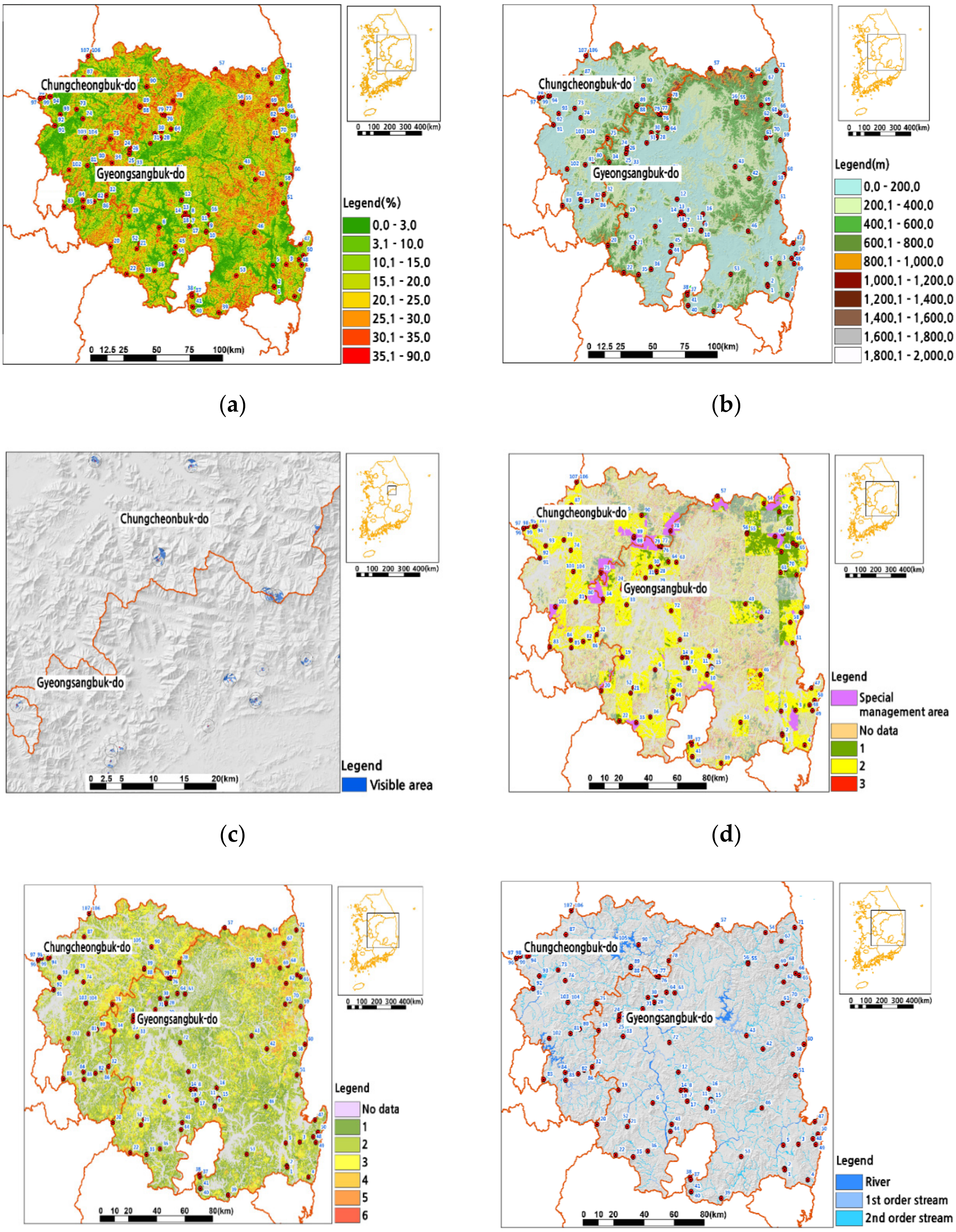
The 16 assessment factors were based on spatial data and analyzed primarily through ArcGIS 10.1. In the Natural Landscape criteria, slope, elevation, and visibility data were collected, with slope and elevation determined using a 30 m resolution Digital Elevation Model (DEM) provided by the Korea Forest Service. To determine the exact degree of slope on each forest wetland, we used the 'extract values to points' plugin in ArcGIS using extracted slope raster data from the DEM. Similarly, accurate elevation data for each forest wetland location was constructed using the DEM. The DEM was also used for the visibility analysis by measuring the sensibility and openness from the forest wetland locations. This data was obtained by using the 'viewshed' plugin in ArcGIS and setting the observation height to 2 m from the surface and the analysis radius to 1 km. A data table was then created by calculating the area in m^2 of a 1 km boundary for each forest wetland.

The ecological zoning map refers to a comprehensive and graded Ministry of Environment, Korea map of features such as mountains, rivers, wetlands, rural areas, and urban areas, related to their ecological value, naturalness and landscape value. The map is classified into 1 grade (conservation), 2 grade (minimization of damage), 3 grade (development area) and separate management areas based on the environmental information of the land. The existing ecological zoning map was overlapped with each forest wetland location and the grade for each location identified. For vegetation (age class), we used the six-level classification used in the forest type map (1: 25,000) from the Korea Forest Service. The age classification data for the forests were entered as an integer between 1 and 6, and zero was entered if there were no age class data (e.g., residences and cultivation areas). These six grades are classified according to the degree of forest age in Korea (e.g., 1 class from 1 to 10 years, 2 class from 11 to 20 years, 3 class from 21 to 30 years, 4 class from 31 to 40 years, 5 class from 41 to 50 years, 6 class from 51 to 60 years). In accord with data provided by the National Information Society Agency (NIA) and the Ministry of Public Administration and Security (MOPAS), the water systems were classified into first, second, and third-grade local stream data of the river geographical information system. The distances between streams and each forest wetland were measured as the shortest distance using the 'near' plugin in ArcGIS. The number of wetland species measured species diversity. That is, the more the wetland species, the higher the score (1 to 4) and when rare plants were found in forest wetlands, the highest score of 5 was given.

The forest wetland area of land use criteria was calculated using a shape file with the areas determined by calculations conducted by the Korea Forest Service. Land ownership of forest wetlands was determined by comparing forest wetland location data to a basic map of nation-owned property provided by the Korea Forest Service. These data are composed of a framework that distinguishes between national/public sector ownership and private sector ownership. A development feasibility map was extracted based on development regulations using a land use regulation information system obtained from the Ministry of Environment, Korea website. Development feasibility was classified as impossible if it prohibited the construction of, or designation as, a national park/provincial park.

The distance to city factor was calculated by measuring the distance from the center of the city to the location of the forest wetland. The city center was nominated to be a municipal office and distance was measured by physical shortest distance (Euclidian distance) rather than a road map. For distance to access roads, network data for traffic data information from the Korea Transport Database were used. From this data, paved roads of more than two lanes were extracted and the distance between each forest wetland and nearby access road were calculated using the used 'near' plug-in of ArcGIS.

For the number of nearby tourists, the boundary of the city was defined as the administrative area (Si, Gun, and Gu) where the forest wetland was located. The number of official tourists in the city was obtained from the Tourism Knowledge Information System. Data for the annual number of tourists were interrogated and the data were analyzed one year before the investigation. Based on information from the Tourism Promotion Act of Korea (2017) [56], the number of tourist destinations was calculated by combining the number of tourist sites, tourist complexes, and special tourist zones officially designated within the city boundary. The number of cultural heritage sites was calculated by combining the number of cultural heritage sites designated as national treasures such as historic sites, places of natural beauty, historical interest and natural monuments within the city boundary. For the proximity to national parks, the shortest distance from the forest wetlands was measured using the 'near' plug-in of ArcGIS to the boundary data on national parks, provincial parks, and county parks. If the forest wetland was within one of the three park types listed above, the data value input was zero (Figure 2).

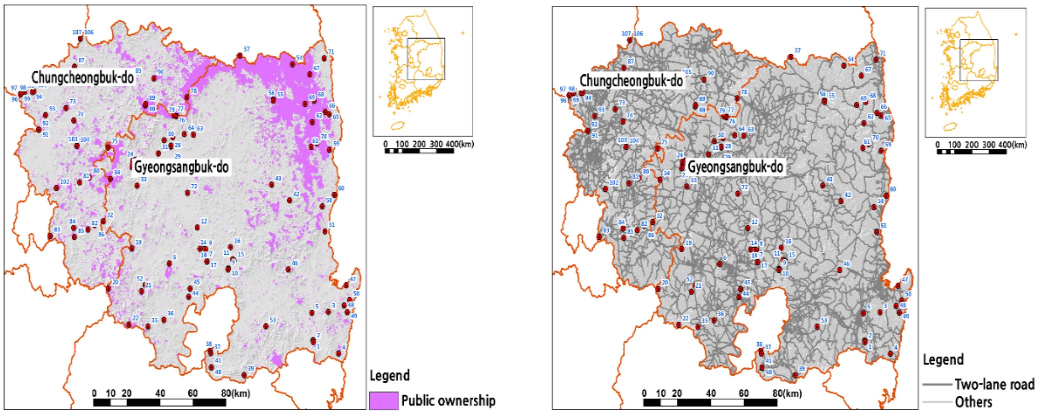


(**a**) (**b**)

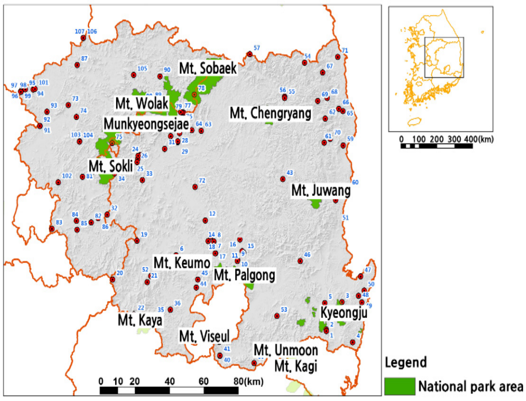
(**c**) (**d**)

(**e**) (**f**)

Figure 2. *Cont.*



(**g**) (**h**)



(**i**)

Figure 2. Spatial analysis for each forest wetland factor using GIS. (**a**) Slope analysis, (**b**) Elevation analysis, (**c**) Visibility analysis, (**d**) Ecological zoning map division, (**e**) Vegetation division, (**f**) Water system division, (**g**) Land ownership division, (**h**) Distance to access road analysis, (**i**) Proximity to national park analysis.

2.4. Data Analysis Methods

AHP is a decision-making methodology developed by Saaty (1980, 1982) [57,58] to improve inefficiencies in the decision-making process. The AHP method is one of the multi-criteria decision-making approaches that are commonly used in agricultural land use suitability analysis [59]. Furthermore, AHP can deal with multi-criteria evaluation and can be integrated with GIS spatial analysis for site selection [49]. It takes a structured approach using expert judgement that comprises of six steps [49,57]. These steps are: (i) the problem definition, (ii) the hierarchical construction and development of the problem into component factors related to the objectives and outcomes of the problem, (iii) the specification of numerical values using pair-wise comparison scales, (iv) the calculation of normalized principal eigen vectors, maximum eigenvalue, consistency index, consistency ratio and random consistency index for each criteria, (v) the revision of the process until consensus is reached if inconsistencies in the decision process exist, and (vi) the integration of weight values to reach an optimum decision.

The AHP measurement scale is generally known to have the highest reliability rating of 9 points [60], and it is commonly interpreted as a ratio scale rather than an ordinal scale. Experts typically conduct the AHP; however, it is difficult to evaluate the pair comparison between factors. In this study, the experts evaluated the forest wetlands using the 9-point scale. The expert survey was conducted for two months from August to September 2017, with 33 samples collected and analyzed by 66 experts. The response rate was 50.5% (Table 2).

Table 2. The Expert characteristics for Analytic Hierarchy Process (AHP).

Division		Frequency (Percent) or Average
Occupation	Faculty	16 (48.5%)
	Researcher	10 (30.3%)
	Related Industry	5 (15.2%)
	Doctoral candidate	2 (6.1%)
Major	Tourism management	14 (42.4%)
	Landscape architecture	13 (39.4%)
	Forestry	4 (12.1%)
	Rural Planning	2 (6.1%)
Period of related research experience	-	13.3 year

Note: Period of related research experience was calculated based on career experience in the related field after obtaining a master's degree.

AHP also measures the Consistency Index (CI) and the Consistency Rate (CR) for each assessment item in order to solve the error due to difficulties encountered in AHP surveys. Although using less than 0.1 CR is recommended to improve the reliability of the data [61], we set the CR value to 0.2 according to existing studies [62,63]. These authors assert that less than 0.2 is acceptable for AHP. Therefore, all response data with a CR of 0.2 or more were deleted from the weight analysis. The expert-weighted data and CR scores were analyzed in Excel 2010.

The data of these extracted factors were graded into 5 stages (Table 3). Based on previous studies [64,65], we utilized the mean and standard deviation of each factor to divide into 5 grades. The scores between grades were coded from 0.2 to 1.0 at interval scale. The value of each forest wetland derived from this stage was multiplied by the weight value of each factor from the AHP analysis and was used as the final data for assessing forest wetland suitability.

Table 3. Data normalization.

Division	5 Grade	4 Grade	3 Grade	2 Grade	1 Grade
Dispersion	$X \leq m - \sigma$	$m - \sigma < X \leq m - \frac{1}{3}\sigma$	$m - \frac{1}{3}\sigma < X \leq m + \frac{1}{3}\sigma$	$m + \frac{1}{3}\sigma < X \leq m + \sigma$	$m + \sigma < X$
Evaluation score	0.2	0.4	0.6	0.8	1.0

Note: m = mean, σ = standard deviation.

2.5. Cluster Analysis

The final stage of this study was the clustering of forest wetland to analyze the forest wetland characteristics relatively and suggest forest wetland management. Cluster analysis has been developing for several decades, and many clustering algorithms have been published (e.g., [66]). This method defines the similarity between data and combines them in order from the closest similarity. It is a robust method for characterizing data by group and furthermore, it can provide the references for classifying the management of forest [67].

We performed the hierarchical agglomeration algorithm for clustering. The forest wetland was gathered into one cluster depending on 16 factors, which is different from another cluster in the process of cluster analysis. In addition to this, the ANOVA test was conducted to confirm which forest wetland criteria is critical in dividing the groups in the cluster analysis. A statistical analysis was performed using the R programming language [68] and visualized using Tableau software (2018. 3).

Figure 3 indicates the conceptual flowchart of methodologies and summarizes the research contents used in this study.

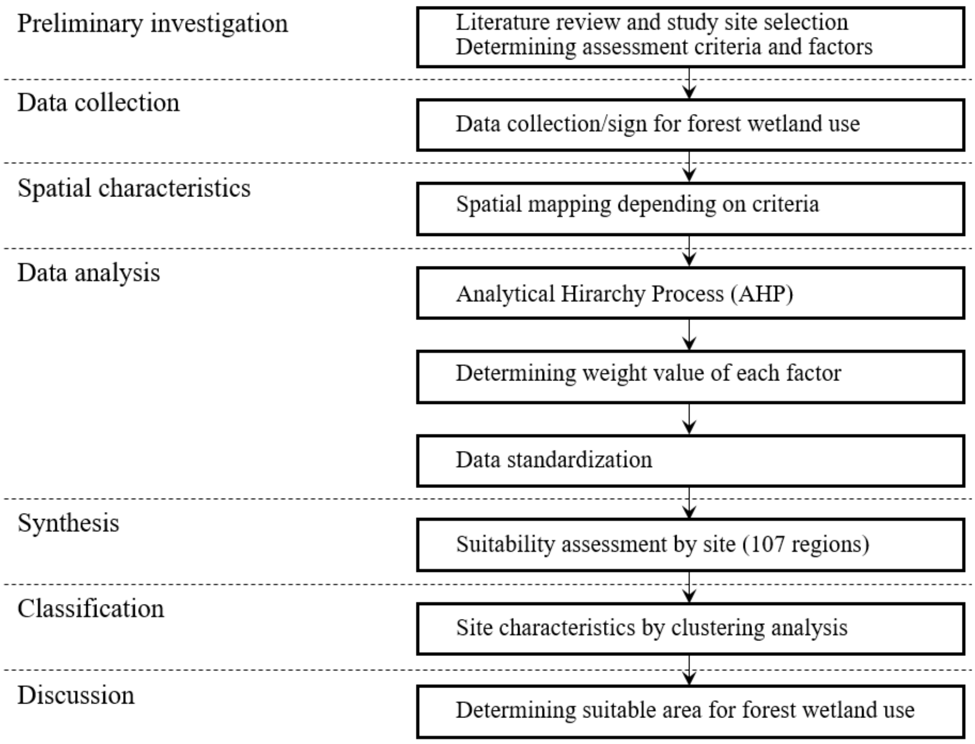


Figure 3. Conceptual flowchart of the methodology.

3. Results

3.1. AHP Result by Forest Wetland Factors

The AHP result of the 5 criteria and 16 factors analyzed by 33 experts are shown in Table 4. Here, only the result with a CR value of 0.2 was extracted, and the local weight method, in which the sum of the criteria and factors as well is 1, was used. The score used in this study was calculated by dividing the sum of all criteria by a factor of 1000 and dividing the converted value of the subclassification by the importance.

The results of the classification of criteria showed that Natural Ecology was the highest (521.977) followed by Land Use (150.267), Natural Landscape (127.628), Tourist Attraction (105.473), and Accessibility (94.655). These results suggest that the natural ecology criteria is very critical when determining the site suitability for forest wetlands, inferring that adequate conservation and effective utilization should be considered at the same time.

As a result of the scoring of factors, the relative importance (conversion value by weight) of 'species diversity' in the natural ecology criteria was the highest with 239.306 points, followed by 118.918 points for 'ecological zoning map', 99.942 points for vegetation (age class), 69.222 points for 'forest wetland area', and 63.811 points for 'water system'.

The lowest weight value when comparing between factors was 'number of nearby tourist destinations' in the tourist attraction criteria with the second- lowest factors as follows: 'number of nearby cultural heritage' (21.333), 'proximity to national park' (27.684), 'slope' (31.375), and 'land ownership' (33.241). These results suggest that the factors of characteristics near the forest wetlands such as 'number of nearby tourist destinations', 'number of nearby cultural heritage sites' and 'proximity to national parks' were relatively lower than those directly representative of the site characteristics (Table 4).

Table 4. AHP results by forest wetland factors.

Criteria	Weight	Conversion Value	Factors	Weight	Conversion Value
Natural landscape	0.128	127.628	Slope Elevation Visibility	0.246 0.298 0.456	31.375 37.991 58.261
Natural ecology	0.522	521.977	Ecological zoning map Vegetation (Age Class) Water system Species diversity	0.228 0.191 0.122 0.458	118.918 99.942 63.811 239.306
Land use	0.150	150.267	Forest wetland area Land ownership Development feasibility	0.461 0.221 0.318	69.222 33.241 47.804
Accessibility	0.095	94.655	Distance to city Distance to access road	0.463 0.537	43.870 50.784
Tourist attraction	0.105	105.473	Number of nearby tourists Number of nearby tourist destination Number of nearby cultural heritage Proximity to national park	0.362 0.148 0.202 0.262	38.224 15.558 21.333 27.684
Total	1.000	1000.000	-	4.975	997.325

3.2. Forest Wetland Site Suitability

The total average score and standard deviation results of the feasibility evaluation of 107 forest wetland sites are as follows: Natural Landscape (m = 76.629/std. = 17.908), Natural Ecology (m = 388.863, std. = 33.626), Land Use (m= 96.987, std. = 19.371), Accessibility (m = 59.429, std. = 17.774), Tourist Attraction' (m = 60.519, std. = 18.502), and Total Score (m = 682.417, std. = 44.964). Table 5 provides the top 15 scores of 107 study sites that were scored by 16 forest wetland assessment factors in the 5 criteria. The region classification means the administrative area and serial number assigned at the time of the investigation, and the final score (synthesis) was calculated by multiplying the weighted results by the 5 criteria and the regional characteristic score. As a result of grading, the most suitable area for future use of forest wetland was 'Chungbuk 2017_05', with Natural Landscape of 90.959, Natural Ecology of 389.709, Land Use' of 131.145, Accessibility of 68.332 and Tourism Attraction of 94.266.

Table 5. Top 15 regions for forest wetland suitability assessment.

Region (Serial Number)	Assessment Criteria					Synthesis	Ranking
	Natural Landscape	Natural Ecology	Land Use	Accessibility	Tourist Attraction		
Gyeongbuk 2017_04	104.323	430.344	76.316	58.175	97.262	766.420	2
Gyeongbuk 2017_06	85.496	450.332	76.316	84.497	66.530	763.173	3
Gyeongbuk 2017_12	86.395	485.431	90.160	65.566	32.471	760.024	5
Gyeongbuk 2017_38	88.228	450.332	76.313	66.949	70.328	752.153	6
Gyeongbuk 2017_44	127.627	376.947	108.734	94.654	54.301	762.263	4
Gyeongbuk 2017_52	101.204	402.471	103.457	75.723	47.811	730.666	15
Gyeongbuk 2018_07	85.072	450.332	76.316	68.332	61.629	741.681	9
Gyeongbuk 2018_13	67.145	441.365	117.301	48.018	64.791	738.621	10
Gyeongbuk 2018_18	93.180	437.570	131.145	18.931	53.717	734.544	11
Chungbuk 2017_05	90.959	389.709	131.145	68.332	94.266	774.411	1
Chungbuk 2017_06	90.959	376.947	117.301	68.332	94.266	747.805	8
Chungbuk 2017_19	106.156	393.504	117.849	48.018	86.621	752.148	7
Chungbuk 2017_20	91.773	389.709	136.971	75.723	38.008	732.183	14
Chungbuk 2017_32	64.026	465.443	95.437	48.018	60.993	733.918	12
Chungbuk 2017_34	106.156	356.958	150.267	46.636	73.439	733.456	13

3.3. Comparison of Forest Wetlands Between Clusters

According to the cluster result (Table 6, Figure 4) of the application of each forest wetland total score, 107 forest wetlands in this study could be categorized into 3 clusters. Of the 107 sites, 40.86% belonged to cluster 2. The average values of each criteria for cluster 2 were: 73.8 for Natural Landscape, 322.1 for Natural Ecology, 118.0 for Land Use, 57.5 for Accessibility, and 65.5 for Tourism Attraction. Cluster 1 accounted for 37.63% of the total, with the following results: Natural Landscape (73.4), Natural Ecology (387.1), Land Use (97.0), Accessibility (61.8) and Tourist Attraction (54.8). The average value of cluster 3 by each criterion were: 88.9 for Natural Landscape, 259.7 for Natural Ecology, 113.1 for Land Use, 59.2 for Accessibility, and 54.4 for Tourist Attraction'.

Table 6. The mean of criteria by cluster and ANOVA test results.

Criteria	Cluster Type (Percent Occupied)			ANOVA Test	
	1 Cluster (37.6%)	2 Cluster (40.9%)	3 Cluster (21.51%)	F	Sig
Natural landscape	73.4	73.8	88.9	4.917	0.009 **
Natural ecology	387.1	322.1	259.7	151.055	0.000 **
Land use	97.0	118.0	113.1	11.340	0.000 **
Accessibility	61.8	57.5	59.2	0.943	0.393
Tourist attraction	54.8	65.5	54.4	3.957	0.023 *

* $p < 0.05$. ** $p < 0.01$.

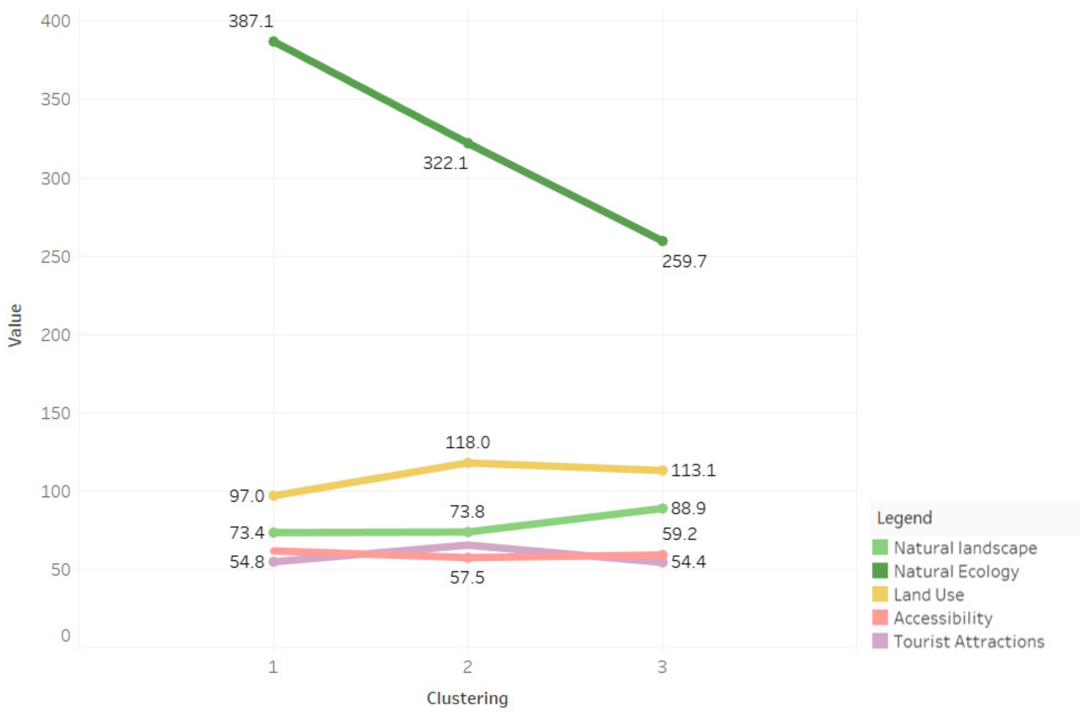


Figure 4. Comparing cluster-specific characteristics.

As a result of analyzing the difference between clusters by each criteria, it was found that Natural Ecology and Land Use have the highest determinants in grouping clusters ($p = 0.000$). Natural Landscape ($p = 0.009$) and Tourist Attraction ($p = 0.023$) also had a statistically significant difference between clusters. Conversely, few differences were found and the statistical difference between clusters was insignificant in the mean scores for Accessibility. When the totals of the clusters were compared, cluster 1 was found to be the most suitable for forest wetland use, and 12 (86.7%) of the top 15 study sites were in cluster 1. Cluster 1 is characterized by a high value of natural ecology and a low score of land use relatively compared with other clusters. In other words, it has high natural ecological value to protect, but it has low relative value in terms of forest wetland area or a land use ownership perspective.

4. Discussion

4.1. Is Balancing Forest Wetland Conservation with Development Possible?

In recent years, not only the ecological value of forest wetlands [16,69], but also the utilization value of activities such as recreation and education have been highlighted [32]. In this context, this study has developed the indicators, which can assess the conservation value and also utilization value of forest wetlands. The factors we have developed assessed the conservation value and utilization value of forest wetlands. These forest wetland assessment factors were applied to 107 forest wetlands, and it was suggested that the zones for conservation and utilization can be established through this process. An interesting aspect of this study is that the score for Natural Ecology, which includes 'ecological zoning map', 'vegetation', and 'water system' was the highest in the relative importance of the 5 criteria for the efficient use of forest wetlands. Furthermore, the Land Use criteria was also relatively critical for practicality. This suggests that forest wetlands for utilization should also be managed with some degree of ecological value, which is highly related to the tendency for people to visit places with high ecological value and high attractions [70]. However, it is necessary to pay close attention to conservation and management that can include accessibility for people and their various recreational uses. As noted by Lee (2009) [71], once a wetland is destroyed by ecological disturbance, it is difficult to rehabilitate.

In addition to the development and application of forest wetland utility derived from this study, it is also important to ascertain the types and characteristics of forest wetlands for detailed management. To date, the types of forest wetlands in South Korea that were investigated in the Korea National Arboretum (2009, 2014) [72,73] have been divided into 'abandoned rice paddy type', 'mountain valley type', 'mountain slope type', 'basin type', and 'special type'. These types of formations are the most important characteristics of the basic form of the space and the ecological differentiation in the development of the utilization model of a forest wetland. In addition, the spatial form of forest wetlands can be classified into four types: (1) small form type, (2) rectangular type, (3) large area type, and (4) mixed type. This spatial form of forest wetlands can be a significant factor influencing the planning direction, proper capacity, community involvement, and sustainability of using the area. For example, Mei et al., (2018) [36] suggested that small, broken, and isolated wetlands cannot benefit from the same protection that larger wetlands connected to navigable waterways receive. Furthermore, Feghhi et al., (2017) [40] presented the characteristics of forest area suitable for recreation by, for example, slope and soil type. Existing research has suggested the characteristics and conditions of forest area for conservation and utilization. From the results of this study, we can macroscopically determine which areas are suitable for forest wetland utility. The next step would be to investigate the forest wetland characteristics of each site such as vegetation type, water quality, wildlife conservation, and utilization. In some cases, it may help to improve the sustainability of the forest wetland by distinguishing conservation and utilization zones according to ecological value or the purpose of use [74].

4.2. The Application of This Assessment System and Policy Implications

Land suitability analysis is used for site selection, impact studies and land use planning [75]. Moreover, many studies using GIS [40,43,44,76,77] have been carried out to evaluate the value of forests. In particular, the AHP method has been used effectively in factor-based GIS research to derive the weight by factors [47,78]. Although such land suitability evaluation can be an optimal alternative to efficiently use the site [79,80], it is required to minimize the moral dilemmas using GIS considering 'accuracy', 'accessibility (public access to information and facilitating public participation)', and 'accountability and shared responsibility' [33]. In particular, if the 'accuracy' is not secured due to an error in the unit or location of the analysis, the case of forest wetland, which may be a critical subject of conservation, could be fatal.

The GIS-assisted forest wetland suitability results of this study demonstrate that the richness of a site can also be expressed through its ecological, visual, land use, and touristic characteristics. This study is novel because it developed space-based factors and introduced not only the ecological characteristics of forest wetlands, but also the land use ownership or distance from the city for land feasibility. As reported by Eggers et al. (2018) [19], such an assessment tool as that developed in this study can be useful for local government forest wetland management as well as for determining the characteristics of an individual forest wetland. As a result of this assessment system that was composed of 5 criteria and 16 factors in 107 study sites, 3 types were statistically classified depending on their spatial characteristics. These clustering results showed remarkable differences in the Natural Ecology criteria, implying that natural ecology characteristics were a crucial factor in distinguishing the categories. Conversely, forest wetlands with high natural ecology value were relatively poor in terms of land use utilization. These clustering results by site characteristics can be effective not only in identifying the characteristics of the regions but may also have implications for different management strategies according to regions.

Based on the findings derived from this study, the suggestions that can be used in the area of policy are as follows: The management authority of wetlands in South Korea depends on whether the site is in forest or inland. The former is administered by the Korea National Arboretum, and the latter is administered by the Ministry of Environment, Korea. Since the national investigation of existing inland wetlands has been more prevalent than forest wetland, there is a lack of research on forest wetlands. Furthermore, evaluation of the value of forest wetlands is insufficiently reflected in policy. There is a need to differentiate between wetland assessment factors managed by Ministry of Environment and forest wetland assessment factors. Moreover, the policy for conserving and utilizing the forest wetland should be developed based on the assessment factors and assessment results derived from this study.

With regard to sustainable planning and related policy for forest wetlands, there is a need to plan for demand and supply. This study was limited to an investigation based on the spatial characteristics in terms of supply, but it is necessary to use the comprehensive utilization model and related policies, which are the combination of the supply resources and the needs of the users for detailed planning and maintenance by site. Therefore, it should be supported by an approach to conserving resources such as the introduction of capacity [81,82] to restricting the use density or the use zoning system like FROS (Forest Recreation Opportunity System) introduction [83,84]. Although the small number of survey participants (experts) may be a limitation of this study, it is necessary to be compared with the current result through the following studies.

Finally, in order to develop a sustainability model of forest wetlands, it is necessary to develop the sustainability evaluation factors for forest wetlands nationwide. This will identify long-lasting forest wetlands and determine their management. This evaluation is critical because the transition process of forest wetlands is very rapid and tends to be terrestrial. This can limit basic research on the forest wetlands in terms of investigating and recording the temporal or spatial aspects. Therefore, it would be desirable to establish a policy to assess and conserve the value of forest wetlands in terms of sustainability by conducting monitoring [85,86] based on the initial investigation and evaluation in this study. In terms of using forest wetlands efficiently, it is an improvement to extend the GIS-based assessment system to the public in an open user-oriented technology way [33]. Furthermore, this study can be applied to other countries based on the evaluation results and policy proposal regarding Korean forest wetlands.

5. Conclusions

This paper provides a novel contribution in response to the current demand for site suitability assessments for forest wetlands. To achieve this, forest wetland assessment factors were developed, applied, and classified in 107 sites. The results of this study can be applied not only to the primary goal of analyzing the characteristics of the forest wetlands in South Korea, but also to the utilization model of local individual forests such as ecological tourism and community space. Furthermore, this study can contribute to the diversification of the forest welfare service and activation and local regeneration of underdeveloped or abandoned areas. However, this study was limited to a landscape-based analysis. Site surveys should accompany this analysis to confirm vegetation condition, wild animals, water systems, and the surrounding infrastructure. In a future study, we aim to establish sustainable forest wetlands by applying the concept of the ROS system (Recreation Opportunity System) to divide zones on the sites and their capacity for efficient use of forest wetlands.

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