Assessment of Habitat Quality in the Western Region of Mongolia Using the InVEST-Based Model

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ABSTRACT

The western region of Mongolia is the homeland of a number of endangered species, among them saiga and snow leopard. This region supports healthy populations of threatened wildlife. Therefore, this investigation is significant in detecting the quality and degradation of habitat for this region. The aim of this study is to assess habitat quality using a tool to support the decision-making process. We applied two widely used models: the Integrated Valuation of Ecosystem Services and Trade-offs (InVEST)-based habitat quality model and the Analytical Hierarchy Process (AHP). A geographic information systems (GIS)-based AHP model was used to estimate the weight of each threat. The InVEST-based habitat quality model was used to integrate information on land use and land cover (LULC) and threats to biodiversity to assess habitat quality for the given area. For the data analysis, eight threats were prepared (urban land, mining areas, paved and unpaved roads, cropland, location of herders, and nighttime light). The raster data were obtained from Landsat Operational Land Imager (OLI) imagery, Google Earth, and a Mongolian geodatabase. These raster files of the distribution and intensity of each threat were assigned values between 0 and 1. After estimation of the weighted value of each threat, we assessed the threat impact on specific LULC types. The weighted value was created by applying the Eigen vector, which determined each threat's impact on the habitat. Finally, we generated two spatial distribution maps: habitat quality and habitat degradation. The results showed that high-quality habitats were detected in the special protected areas and low-density herder camp areas. Most low-quality habitats were detected in the areas that overlapped with human activity. A large portion of the study area was highly affected by unpaved road impacts. The resulting habitat quality and habitat degradation maps are a source of valuable information that will contribute to developing nature conservation planning and improving ecosystem services.

Keywords: Habitat quality, habitat degradation, threats, biodiversity conservation, InVEST software

1. INTRODUCTION

Habitat quality is a concept widely applied in ecology, biology, and natural conservation. The habitat, being resources and conditions in an area, produces occupancy-including survival and reproduction by a given organism [1]. Habitat quality refers to the ability of the ecosystem to provide conditions appropriate for individual and population persistence [1]. The loss, fragmentation, and degradation of habitat are the greatest threats to biodiversity [2], and these processes contribute to landscape change [3]. The loss, fragmentation, and degradation of habitat are determined to be: loss of habitat for a given species from an area, division of

large areas into several small areas, and reduction in quality of area for a given species, respectively [4]. Growing levels of human activity around the world can negatively affect wildlife movement, distribution, and biodiversity. In other words, increasing human activity threatens wildlife population by increasing mortality, loss, and fragmentation of the habitat [5]. Moreover, land use and land cover (LULC) change have a significant effect on habitat quality.

Valuation of habitat quality requires complex integration of many properties of the ecosystem [6]. Where the data collection process as a traditional method for habitat quality has been extremely time-consuming, and its accuracy is questioned, considering inter-subjective differences [7]. This

problem generates the need for methods to create repeatable results over a large-scale with quantified precision [8]. To solve the challenge of assessing habitat quality at different levels of information processing, Zlinszky et al. [6] suggested implementing three stages. The first stage is identifying the location of habitats for a given area. The second stage is to create maps of the environment, ecophysiology, or biometric variables of a habitat for identifying habitat quality in a given area. The third stage is to develop a model based on ecological knowledge that represents how environmental variables impact habitat quality, and applying remote sensing (RS) to measure those variables as well as geographic information systems (GIS) to combine them into a final quality map.

The western region of Mongolia, with the Altai Mountains in the west, the Gobi desert in the east and south, and a mix of lakes, forests, steppes, and desert in the north and center, is the homeland of many endangered species; saiga and snow leopard, for instance [9]. Moreover, the region has a large number of fresh and salt lakes, which are a globally important habitat for birds. In other words, the region is a habitat that supports healthy populations of threatened wildlife species. Therefore, habitat quality assessment of this region is significant for detecting habitat quality and degradation, which will contribute to developing nature conservation planning and improving ecosystem services.

In more recent years, several new approaches for ecosystem services have been developed by various schools. For instance, an open-source Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) software was developed at Stanford University by Sharp et al. [10] in 2018. The InVEST-based habitat quality model evaluates biodiversity status in a landscape and creates habitat quality maps by applying data from LULC change and biodiversity threats [11]. The InVEST-based habitat quality model provides easy access to data, significant analytical capabilities with several factors, a simple operation, and data processing [12]. The InVEST-based habitat quality model has been employed for maintenance of biodiversity [10]. The aim of this study is to assess habitat quality using the InVEST-based habitat quality model as a tool to support the decision-making process.

2. STUDY AREA

We selected the western economic region of Mongolia as the study area. The study area covers a total area of 415.3 thousand km², comprising 5

aimags and 91 soums. According to the Regional Development Concept adopted by the Parliament of Mongolia in 2001, the western economic region of Mongolia includes Bayan-Ulgii, Govi-Altai, Zavkhan, Uvs, and Khovd aimags. In 2020, the western region had a population of 415 thousand persons. This population comprised 106.8 thousand households, 66.8% of which were classified as herder households [13]. In addition, the Regional Development Concept states that pasturing livestock, irrigated agriculture, and the manufacturing sector should be developed as priorities in the western economic region, considering this region's nature, raw material, and intellectual potential [14]. In the western region, the annual mean temperature is 0.1°C, the average temperature in January ranges from -18.2°C to -31.8°C, and in July from +15.6°C to +21.0°C over the last 20 years. The total annual mean precipitation is approximately 150.4 mm, which ranges from 126.3 mm to 170.7 mm.

3. METHOD AND DATA

3.1. Method

In this study, we used the InVEST-based habitat quality model, and the Analytical Hierarchy Process (AHP) model. InVEST is a tool for geographic, economic, and ecological accounting for ecosystem services, according to specific types of LULC. The software includes 17 models that evaluate ecosystems, both biophysical processes, and processes related to economic value. The InVEST-based habitat quality model is a novel tool used for assessing habitat quality under anthropogenic threats [15]. The InVEST habitat quality model uses habitat quality and rarity as proxies to represent the biodiversity of a landscape, estimating the extent of habitat and vegetation types across a landscape, and their state of degradation [10]. This model integrates maps of LULC with data on threats to habitats and habitat response. In addition, the model, alongside ecosystem services, enables users to compare spatial patterns and identify areas where threatened species can be protected. The InVEST habitat model will produce two results: habitat quality and habitat degradation (equations are found in Morrone [16]). The AHP model is commonly used to estimate the weight of each threat. Therefore, the GIS-based AHP model was used. The AHP model is expressed with the following equations (1-3) [17].

$$W_{ij} = \frac{\sum X_{ij}}{n} \tag{1}$$

Where Xij- the normalized value of a pair comparison matrix, n- the order of the matrix and Wij- the weight of the criteria. The consistency ratio (CR) indicates the probability. The consistency of the pairwise comparison matrix is expressed by the consistency ratio index. When the CR exceeds 0.1 (10%), the weighting value is disagreeable, and when the index value is estimated below 0.1, the weighting value is agreeable.

$$CR = \frac{CI}{RI} \qquad (2)$$

Where CI-consistency index, RI- random index and CR-consistency ratio, calculation of the consistency index uses the following equation.

$$CI = \frac{\lambda_{max} - n}{n - 1} \qquad (3)$$

Where CI- consistency index, λ_{max} - maximum eigenvalue, and n is the order of the matrix.

3.2. Data

In order to assess habitat quality, we used five different datasets, namely LULC, threats/human activities (e.g., paved road, unpaved road, mining areas, urban land, cropland, night light and location of herders), habitat types, and sensitivity of each habitat. In 2020 we generated an LULC map for the entirety of Mongolia using Landsat OLI imagery from May to September 2019 with a spatial resolution of 30 m [18]. The LULC map was extracted from this (Figure 1a). For the data analysis, eight threats were prepared (urban land, mining areas, road (paved and unpaved), cropland, location of herders, and night light). The raster data were obtained from Landsat OLI imagery, Google Earth, and a geodatabase from the Agency for Land Administration and Management, Geodesy and Cartography (ALAMGG). These raster files of the distribution and intensity of each threat had values between 0 and 1 (Figure 1b-i). distribution and intensity of each threat had values between 0 and 1 (Figure 1b-i).
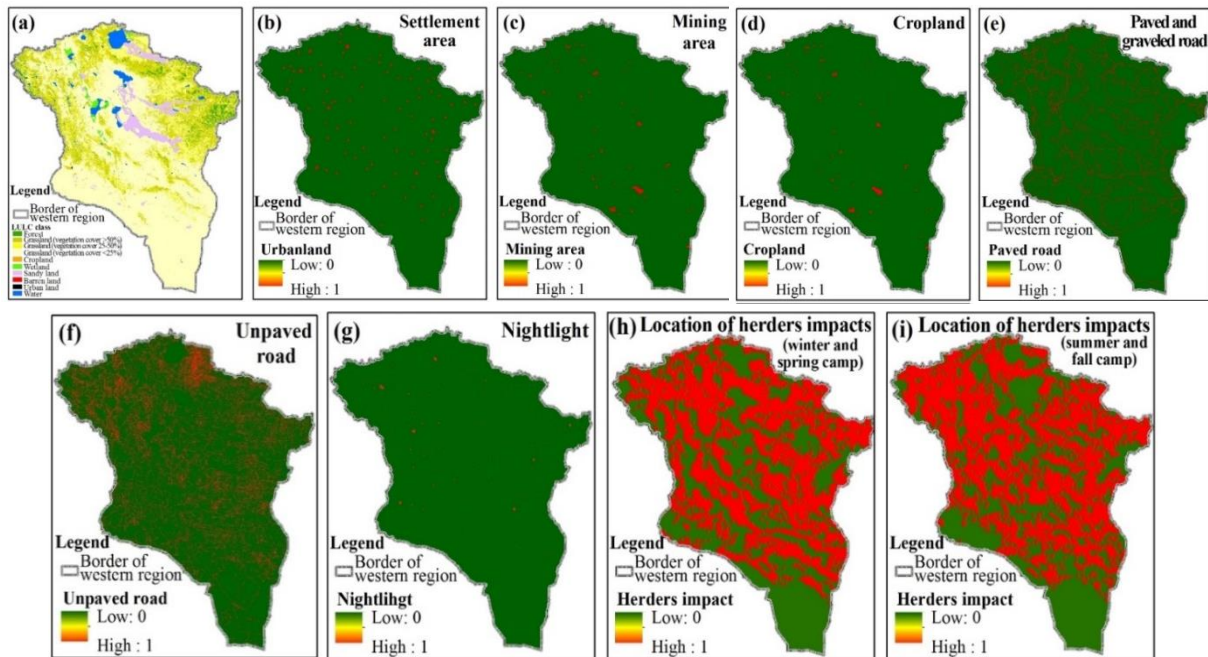

Figure 1(a) Spatial distribution map of LULC in 2019. The map generated from Landsat OLI imagery using Random Forest classifier with 303 training samples; (b) Spatial distribution map settlement area extracted from ALAMGG geodatabase; (c) Spatial distribution map of mining areas (with licenses) extracted from a Mongolian geodatabase (MMHI, 2017); (d) . Spatial distribution map of the sown area obtained from Landsat OLI in 2019; (e) Spatial distribution map of paved and improved roads obtained from Google Earth and the ALAMGG geodatabase; (f) Spatial distribution map of unpaved road obtained from Google Earth and the ALAMGG geodatabase; (g) Spatial distribution map of night light impact extracted from the ALAMGG geodatabase; (h) Location of herders' impact (winter and spring camps), obtained from the ALAMGG geodatabase; (i) Location of herders' impact (summer and fall camps), obtained from the ALAMGG geodatabase.

4. RESULTS

Examination of each threat's potential impact on the habitat was done by applying a pairwise comparison matrix with a 0 to 1 preference. Table 1 shows the ranking of 7 threats, based on literature reviews and expert knowledge, followed by the calculated weighting of the value of each threat using GIS-based AHP. We evaluated a CR=0.025, suggesting that there was a reasonable level of consistency in judgment. After estimation of the weighted value of each threat, we assessed threat impact on specific LULC types (forest, mountain steppe, steppe, dry steppe, cultivated land, wetland, sandy land, barren land, urban land, and lakes). The weighted value was created by applying the eigen vector, which determined each threat impact on the habitat. Finally, we generated two spatial distribution maps of habitat quality and habitat degradation

(Figure 2). Three habitat quality classes (high, medium, low) were determined to estimate the coverage. Habitat quality assessment shows that 90.7% of the total territory was high-quality, 6.8% medium-quality, and 2.5% low-quality (Figure 2 (left)). Habitat degradation assessment shows that 65.1% of the total territory was un-degraded, 27.7% medium-degraded, and 7.2% strongly degraded (Figure 2 (right)).

Table 1. Defined ranking and weights of each threat

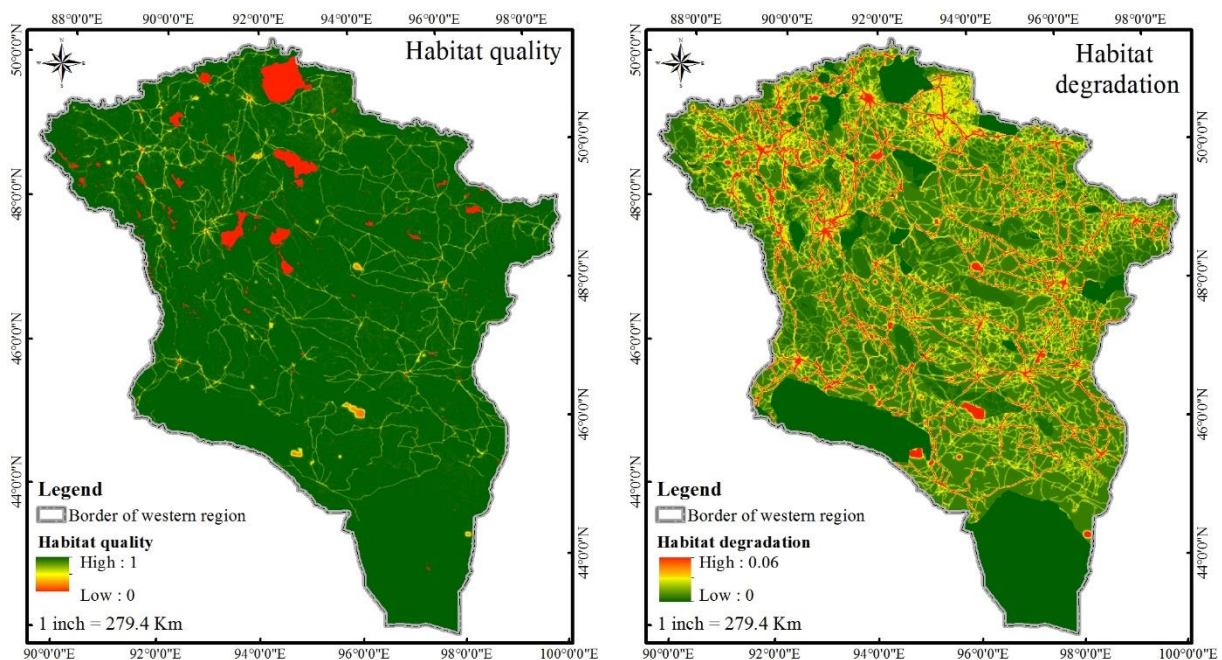| Threats	Ranking	Weight
Paved road	3	0.16
Unpaved road	4	0.10
Mining areas	2	0.24
Urban land	1	0.35
Location of herders' impact	6	0.04
Night light impact	7	0.03
Cropland	5	0.07

Figure 2. Spatial distribution map of habitat quality (left) and habitat degradation (right) using InVEST-based habitat quality model

5. CONCLUSION

In this study, we used two models: InVEST habitat quality and GIS-based AHP. The GIS-based AHP model was used to estimate the weight of each threat. The InVEST habitat quality model was used to integrate information on LULC and threats to biodiversity to assess habitat quality for the given area. We successfully generated two spatial

distribution maps of habitat quality and habitat degradation. These maps display the habitat quality within the landscape, and the level of habitat degradation in the current landscape. These maps indicate the landscape of the habitat, which allows analysis of trade-offs between biodiversity, ecosystem services, and the level of protection of the area [16; 20]. Habitat quality assessment shows that 90.7% of the total territory was high-quality, 6.8%

medium-quality, and 2.5% low-quality. Habitat degradation assessment showed that 65.1% of the total territory was un-degraded, 27.7% medium-degraded, and 7.2% strongly degraded. Generally, high-quality habitats were detected in the special protected areas and low-density locations of herder camps. Most low-quality habitats were detected in areas that overlapped human activity. Large portions of the study area were highly affected by unpaved road impacts. Our habitat quality and habitat degradation maps are a valuable source of information that will contribute to development of nature conservation planning and improvement of ecosystem services.

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