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

Munkhdulam Otgonbayar[1,*], Batnyam Tseveengerel[1], Purevsuren Munkhtur[1], Davaagatan Tuyagerel[1]

[1] *Institute of Geography and Geoecology, Mongolian Academy of Sciences, Ulaanbaatar, Mongolia*
[*]*Corresponding author. Email: munkhdulamo@mas.ac.mn*

ABSTRACT
The western region of Mongolia is the homeland of endangered species including saiga, and snow leopard. In other words, this region is the habitat to support healthy populations of threatened wildlife. Therefore, this investigation is significant to detect the quality and degradation of habitat for this region. The aim of this study is to assess habitat quality using a tool to support decision making process. In this study, we used widely used two models: Integrated Valuation of Ecosystem Services and Trade-offs (InVEST)-based habitat quality model and Analytical hierarchy process (AHP). Geographic information system (GIS)-based AHP model was used to estimate the weight of each threat. 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 area, paved and unpaved roads, cropland, location of herders, and nightlight). The raster data were obtained from Landsat Operational Land Imager (OLI) imagery, Google Earth map, and geodatabase of Mongolia. Those raster files of the distribution and intensity of each threat, with values between 0 and 1. After estimation of the weighted value of each threat, we assessed threat impact on specific LULC types. The weighted value is created applying the Eigen vector that is determined each threat 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 locations of herder camp. Most low-quality habitats were detected in the overlapped human activity areas. A large size of study area were highly affected by unpaved road impacts. Our study results of habitat quality and habitat degradation maps are 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 as 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 the individual and population persistence [1]. The loss, fragmentation, and degradation of habitat are the greatest extinction threats to biodiversity [2], and those are processes contributing to landscape change [3]. The loss, fragmentation, and degradation of habitat are determined as loss of habitat for a given species from an area, dividing apart 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 raise mortality, loss, and fragmentation of the habitat [5]. Moreover, land use and land cover (LULC) change are high effects on habitat quality.

Valuation of habitat quality is required complex integration of many properties of the ecosystem [6]. Where data collection process as a traditional method for habitat quality has been extremely time-demanding, and its accuracy is complicated to assess due to inter-subjective differences [7]. This problem generates the need for methods to create repeatable results over a large scale easier and with quantified precision [8]. To solve the challenge of assessing habitat quality at different levels of information processing, Zlinszky et al [6] suggested implementing the following 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 that given area for identifying habitat quality. The third stage is to develop a model based on ecological knowledge that represents and how environmental variables impact habitat quality and applying remote sensing (RS) to measure those variables and geographic information system (GIS) to combine them to a final quality map.

The western region of Mongolia, with the Altai Mountains in the west, Gobi desert in the east and south, depression of the Great Lakes, forest, steppe, and desert mixed in the north and center, is the homeland of endangered many species, for instance, saiga, and snow leopard [9]. Moreover, the region with a large number of fresh and salt lakes and those are globally important habitat of birds. In other words, the region is a habitat to support healthy populations of threatened wildlife species. Therefore, habitat quality assessment of this region is significant to detect 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 has been developed at Stanford University by Sharp et al [10] in 2018. The InVEST-based habitat quality model [10] evaluates biodiversity status in a landscape and creates habitat quality maps applying data on LULC change and biodiversity threats [11]. The InVEST-based habitat quality model provides easy access to data, significant analytical capabilities with several factors, simple operation, and data processing [12]. The InVEST-based habitat quality model has been employed for the 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 western economic region of Mongolia, with a total area of 415.3 thousand km^2 of 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 the year 2020, a western region has a population of 415 thousand persons, and this population comprised 106.8 thousand households, 66.8% of which were classified as herder households [13]. In addition, Regional Development Concept states that pasturing livestock, irrigated agriculture, and the manufacturing sector should be developed as priorities in the western economic region under this region's natural, raw material, and intellectual potential [14]. In the western region, the annual mean temperature is 0.1°C, and the average temperature in January ranges from -18.2°C to -31.8°C, in July from +15.6°C to +21.0°C during last 20 years. The total annual mean precipitation is approximately 150.4 mm, and it 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 Analytical hierarchy process (AHP) model. InVEST is a tool for geographic, economic, and ecological accounting on ecosystem services, according to specific types of LULC. The software has been including 17 models that evaluate ecosystems, both biophysical processes, and processes related to economic value. 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 protect threatened species. The InVEST habitat model will be produce two results: habitat quality and habitat degradation (equations are found in Morrone [16]). AHP model is commonly used to estimate the weight of each threat. Therefore, the GIS-based AHP model is used to estimate the weighted value of each threat. 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 is the order of the matrix, 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.

$$CR = \frac{CI}{RI} \tag{2}$$

Where CI-consistency index, RI- random index, CR-consistency ratio. Calculating the consistency index is used to the following equation.

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

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

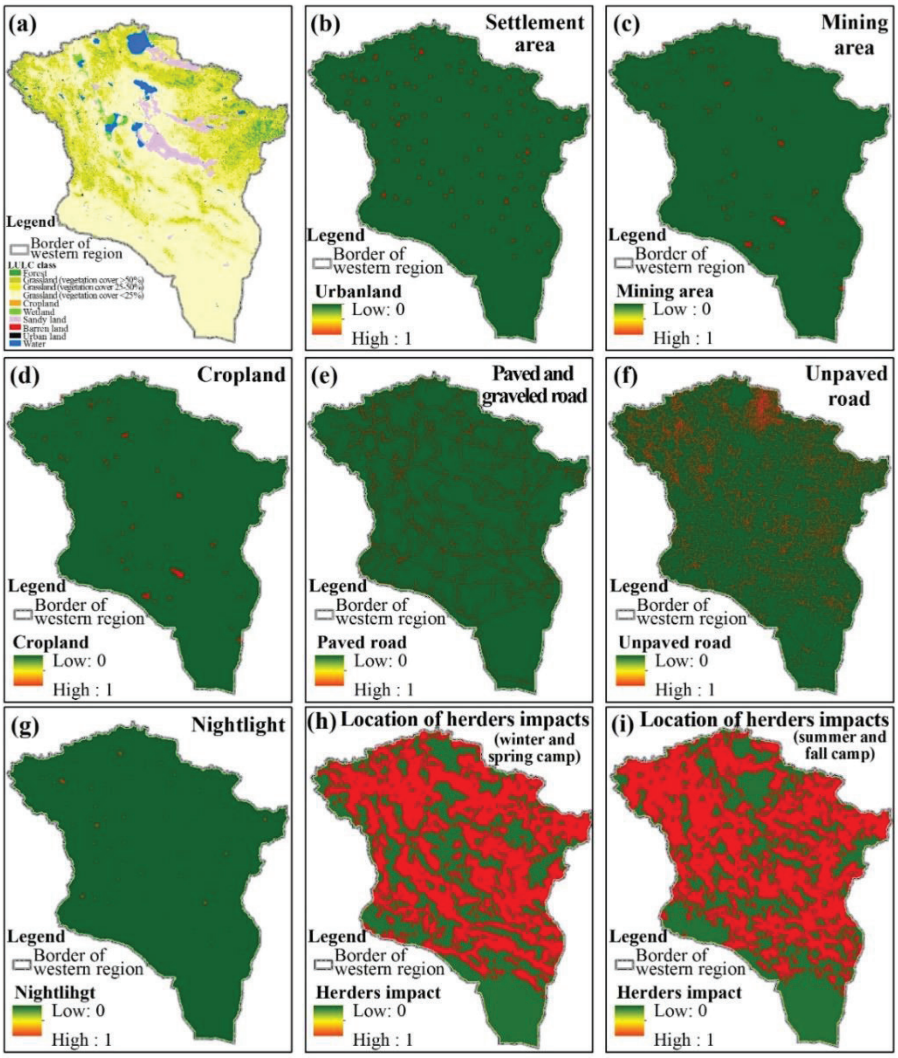

Figure 1. (a) Spatial distribution map of LULC in 2019. The map generated from Landsat OLI imagery using Random Forest classifier with 303 training samples; (b) Spatial distribution map settlement area extracted from geodatabase ALAMGG; (c) Spatial distribution map of mining area (with license) extracted from geodatabase of Mongolia (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 map and geodatabase ALAMGG; (f) Spatial distribution map of unpaved road obtained from Google Earth map and geodatabase ALAMGG; (g) Spatial distribution map of nightlight impact extracted from geodatabase of ALAMGG; (h) Location of herders impact (winter and spring camp), obtained from geodatabase of ALAMGG; (i) Location of herders impact (summer and fall camp), obtained from geodatabase of ALAMGG.

4. RESULT

Examination of each threat's potential impact on the habitat was applied a pairwise comparison matrix, with 0 to 1 preference. In table 1 showed the ranking of 7 threats based on literature reviews and expert knowledge. And then the calculated weighing value of each threat using GIS-based AHP. We evaluated a CR=0.025, suggesting that there was a reasonable level of consistency in a 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 applying the eigen vector that is 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 their coverage quantified. 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 area	2	0.24
Urban land	1	0.35
Location of herders impact	6	0.04
Nightlight impact	7	0.03
Cropland	5	0.07

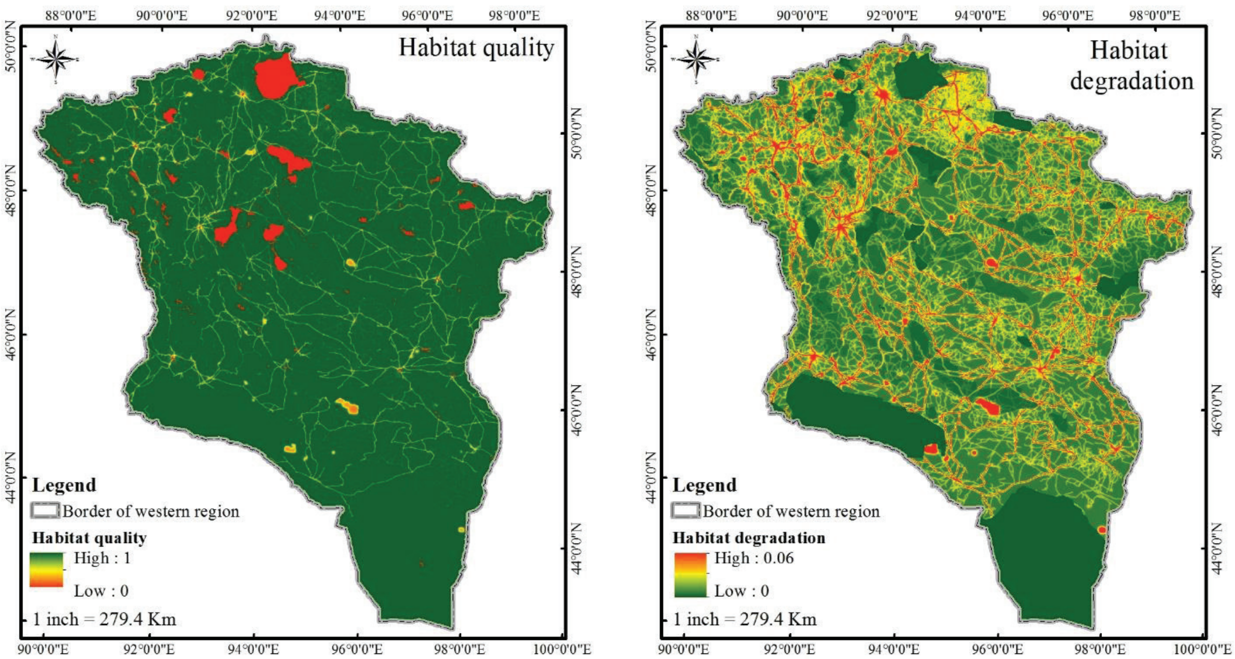

Figure 2. Spatial distribution map of habitat quality (left) and habitat degradation (right) using InVEST-based habitat quality model

5. CONCLUSION

In this study, we used two models: InVEST habitat quality and GIS-based AHP. GIS-based AHP model was used to estimate the weight of each threat. 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. Spatial distribution maps of habitat quality and habitat degradation are express the level of habitat quality within the landscape, and the level of habitat degradation on the current landscape, respectively. Those maps are indicate the landscape level of the habitat, is allowing to analyze trade-offs between biodiversity, ecosystem services, and level 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 shows 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 camp. Most low-quality habitats were detected in the overlapped human activity areas. A large size of study area were highly affected by unpaved road impacts. Our study results of habitat quality and habitat degradation maps are valuable information that will contribute to developing nature conservation planning and improving ecosystem services.

ACKNOWLEDGMENTS

The authors would like to express our great appreciation to teams of the Natural Capital Project (Nat Cap) of Stanford University, and the Wildlife Conservation Society (WCS) of Mongolia for giving us the to participate in the training-hackathon of the ecosystem services. In particular, we are grateful to Ginger Kowal, GIS programmer analyst of the Nat Cap project, and Avirmed Otgonsuren, program officer of WCS of Mongolia. We would also like to thank our colleagues of the division of Physical Geography, Institute of Geography and Geoecology, Mongolian Academy of Sciences.

REFERENCES

[1] Hall, L. S., Krausman, P. R., & Morrison, M. L. (1997). The habitat concept and a plea for standard terminology. Wildlife society bulletin, 173-182.

[2] Mortelliti, A., Amori, G., & Boitani, L. (2010). The role of habitat quality in fragmented landscapes: a conceptual overview and prospectus for future research. Oecologia, 163(2), 535-547.

[3] Fischer, J., Lindenmayer, D. B., & Fazey, I. (2004). Appreciating ecological complexity: habitat contours as a conceptual landscape model. Conservation Biology, 18(5), 1245-1253.

[4] Fischer, J., & Lindenmayer, D. B. (2007). Landscape modification and habitat fragmentation: a synthesis. Global ecology and biogeography, 16(3), 265-280.

[5] Whittington, J., Low, P., & Hunt, B. (2019). Temporal road closures improve habitat quality for wildlife. Scientific reports, 9(1), 1-10.

[6] Zlinszky, A., Heilmeier, H., Balzter, H., Czúcz, B., & Pfeifer, N. (2015). Remote sensing and GIS for habitat quality monitoring: New approaches and future research.

[7] Lengyel, S., Déri, E., Varga, Z., Horváth, R., Tóthmérész, B., Henry, P. Y., ... & Henle, K. (2008). Habitat monitoring in Europe: a description of current practices. Biodiversity and Conservation, 17(14), 3327-3339.

[8] Zlinszky, A., Deák, B., Kania, A., Schroiff, A., & Pfeifer, N. (2015). Mapping Natura 2000 habitat conservation status in a pannonic salt steppe with airborne laser scanning. Remote Sensing, 7(3), 2991-3019.

[9] Overview of western Mongolia. (Accessed on 16 September 2021). Available online: https://en.wikivoyage.org/wiki/Western_Mongolia

[10] Sharp, R.; Tallis, H.T.; Ricketts, T.; Guerry, A.D.;Wood, S.A.; Chaplin-Kramer, R.; Nelson, E.; Ennaanay, D.; Wolny, S.; Olwero, N.; et al. InVEST 3.6.0 User's Guide; Collaborative Publication by The Natural Capital Project, Stanford University, the University of Minnesota, The Nature Conservancy, and the World Wildlife Fund; Stanford University: Stanford, CA, USA, 2018. Available online: https://naturalcapitalproject.stanford.edu/software/invest (accessed on 24 August 2021).

[11] Terrado, M., Sabater, S., Chaplin-Kramer, B., Mandle, L., Ziv, G., & Acuña, V. (2016). Model development for the assessment of terrestrial and aquatic habitat quality in conservation planning. Science of the total environment, 540, 63-70.

[12] Polasky, S., Nelson, E., Pennington, D., & Johnson, K. A. (2011). The impact of land-use change on ecosystem services, biodiversity and returns to landowners: a case study in the state of Minnesota. Environmental and Resource Economics, 48(2), 219-242.

[13] National Statistics Office of Mongolia, "Mongolian Statistical Yearbook 2020." 2021.

[14] The State Great Khural, "Regional Development Concept of Mongolia." 2001.

[15] Arcidiacono, A., Ronchi, S., & Salata, S. (2015, June). Ecosystem Services assessment using InVEST as a tool to support decision making process: critical issues and opportunities. In International Conference on Computational Science and Its Applications (pp. 35-49). Springer, Cham.

[16] Morrone, R. (2019). Using Sentinel-2 derived deforestation maps of Bialowieza forest to assess habitat quality with invest.

[17] Saaty, T. L. (2004). Decision making—the analytic hierarchy and network processes (AHP/ANP). Journal of systems science and systems engineering, 13(1), 1-35.

[18] Otgonbayar M., Atzberger C., Damdinsuren A., Sumiya E., Dalantai S. (2020). Trend and BFAST analysis of the multi-sources remotely sensed time

series for detecting land degradation of Mongolia.Environmental Degradation in Asia: Land Degradation, Environmental Contamination, and Human Activities project, Ed: Ayad M. Fadhil Al-Quraishi, by Springer book. Under review

[19] Berta Aneseyee, A., Noszczyk, T., Soromessa, T., & Elias, E. (2020). The InVEST habitat quality model associated with land use/cover changes: A qualitative case study of the Winike Watershed in the Omo-Gibe Basin, Southwest Ethiopia. Remote Sensing, 12(7), 1103.

[20] Sharp, R., Douglass, J., Wolny, S., Arkema, K., Bernhardt, J., Bierbower, W., Chaumont, N., Denu, D., Fisher, D., Glowinski, K., Griffin, R., Guannel, G., Guerry, A., Johnson, J., Hamel, P., Kennedy, C., Kim, C.K., Lacayo, M., Lonsdorf, E., Mandle, L., Rogers, L., Silver, J., Toft, J., Verutes, G., Vogl, A. L., Wood, S, and Wyatt, K. 2020, InVEST 3.9.0.post239+ug.gd1ce7ee User's Guide. The Natural Capital Project, Stanford University, University of Minnesota, the Nature Conservancy, and World Wildlife Fund. (Accessed on 24 August 2021). Available online: https://naturalcapitalproject.stanford.edu/software/invest