Shahid Beheshti University

Sustainable Earth Trends

Journal homepage: http://sustainearth.sbu.ac.ir

Sustainable Earth Trends

Relationships of habitat quality to characteristics of soil, topography, and landscape features across Qeshlagh Dam watershed in western Iran

Kazhan Hasani[a], Bubak Souri[*a], Fazlolah Ahmadi Mirghaed[b]

[a] Department of Environmental Sciences, Faculty of Natural Resources, University of Kurdistan, P.O. Box 416 Sanandaj, Iran
[b] Department of Environmental Sciences, Faculty of Marine and Environmental Sciences, University of Mazandaran, Babolsar, Iran

A B S T R A C T

This research investigates the relationships between habitat quality, soil characteristics, topography and landscape metrics across soil zones and sub-basins of the Qeshlagh dam in western Iran. InVEST software was applied to determine habitat quality while soil characteristics were interpolated through the Inverse Distance Weighting (IDW) method using ArcGIS software. The results revealed that the higher habitat quality throughout the Qeshlagh basin is distributed on upland including northern and eastern parts and also western strips of the basin. Dense urban land use and agricultural development were amongst the factors for declining habitat quality in central and southern parts of the study area. Statistical analysis showed that there are significant relationships of habitat quality to characteristics of soil, topography and landscape features throughout soil zones and sub-basins while the scale of sampling may impact the results. Also, it was emphasized that the habitat quality is influenced by the landscape pattern. In this regard cohesiveness of the largest landscape spot was highly influential. It is suggested that land management pathways regarding the rate and magnification of the degradation of the habitat quality should be considered and urgent conservative measures need to be applied to improve habitat quality across the basin.

A R T I C L E I N F O

Keywords:
Characteristics of soil and
Habitat quality
InVEST
Landscape metrics
Land use
Topography

Article history:
Received: 23 Oct 2023
Accepted: 22 Dec 2023

*corresponding author
E-mail address:
bsouri@uok.ac.ir
(B. Souri)

Citation:
Hasani, K. et al., (2024). Relationships of habitat quality to characteristics of soil …, *Sustainable Earth Trends:* 4(1), (59-68).

DOI: 10.48308/set.2024.235106.1044

1. Introduction

Flowing water ecosystems, as one of the most diverse and dynamic ecosystems, provide goods and services such as land protection, soil purification, regional microclimates, habitat improvement and increasing biodiversity for humans (Joseph, 2010). Because of the acceleration of the urbanization which has significantly led to climate change and pollution; the ecosystems of the flowing waters have been seriously damaged and the ecological risks have been threatening the habitat quality and biodiversity. Habitat quality refers to the ability of an ecosystem to provide individuals and populations with sustainable survival and reproduction in a certain time and place which to some extent it can reflect the biodiversity of an area and is closely related to land use (Chenyu et al., 2021). On the other hand, landscape patterns change with the intensification of land use development. Changing landscape patterns affect the process of biodiversity, disrupts the cycle of ecosystem materials and energy flow which breaks the original ecological pattern and leads to habitat changes (Yuyang et al., 2021).
Therefore, the habitat quality responses to changes in the landscape pattern is very important to coordinate the relationships between the regional landscape patterns, environmental protection and ecological improvement.

Land surface patterns are characterized by spatial arrangement, density, dominance, connection, accumulation and diversity of spots created by land use distribution and land covers over time. Landscape metrics are quantitative tools that are widely used to evaluate the patterns and features of the landscape. These metrics can provide different aspects of the image in terms of diversity, geometry, distribution, aggregation, composition, shape and area as quantitative values. In addition to evaluating the fragmentations of the land surface; these values facilitate the analysis and monitoring of the land surface patterns (McGarigal et al., 2012). Assessing habitat quality is a complex process and using models is very beneficial to assess it (Chen et al., 2016). Some of the common models for habitat quality assessment are interaction among ecosystem services (ARIES) (Bagstad et al., 2011), comprehensive multiscale (MIMES) (Wanghe et al., 2022) and integrated valuation of ecosystem services and interaction between them (InVEST) (Chen et al., 2016). The InVEST model is a geographic information system (GIS)-based approach that provides a rapid assessment of the effects of various threats and land use changes on habitat quality (Xu et al., 2019). This model offers advantages such as low application costs, high accuracy, ease of operation, convenient access to data, and powerful spatial visualization (Li et al., 2021). Habitat quality and its relationship with land use changes have been widely considered in various studies. Xiaodong and Xuelu (2022) studied the impact of land use on habitat quality based on the InVEST model in the Zuli River basin, China. According to the results, the overall habitat quality of the Zuli river basin increased in 1980-2020 whereas the average habitat quality scores were 0.502, 0.5, 0.49, 0.504, and 0.52, respectively. Also, a synergistic relationship between land use and habitat quality was observed and the change of pasture area affected habitat quality. Aneseyee et al. (2020) investigated the impact of land use changes on habitat quality using the InVEST model in the Omo-Gibe watershed, southwestern Ethiopia. Physicochemical characteristics of soil support ecosystem services such as habitat quality, plant production and clean water supply (Ahmadi Mirghaed and Souri, 2021). Also, topographic metrics provide a lot of information about ecological environments, natural resources and environmental conditions. These criteria have a specific effect on soil formation processes and the resulting characteristics. Therefore, the characteristics of soil and topography can be used as indicators for monitoring and evaluating conditions of the ecosystems. Many studies have applied soil physicochemical properties such as pH, organic matter, texture, depth, cation exchange capacity, phosphorus, nitrogen, cations and bulk density to evaluate soil quality (Wu et al., 2019; Raiesi, 2017). It is noticeable that various factors such as inappropriate development, land mismanagement, erosion, improper land use, topographic intensity, destruction of vegetation and environmental pollution cause declines on soil quality. Accordingly; due to insufficient attention of the previous studies to assess habitat quality, soil characteristics, topography and landscape patterns and their relationship in the two scales of soil zones and sub-basins; the objectives of this study were (1) evaluation of habitat quality using the InVEST model, (2) determination of the relationships between habitat quality, soil characteristics and topography, (3) analysis of the effects of land use patterns on habitat quality throughout the sub-basins and soil zones using landscape metrics.

2. Material and Methods

2.1. Study area

The watershed of Qeshlagh dam with geographical coordinates of N35°59'24″ to N35°37'53″ latitude and E46°11'46″ to E46°59'15″ longitude is located in 12 km of northwest of Sanandaj city in western Iran (Fig. 1). Capacity of Qeshlagh dam reservoir is about 224 million cubic meters. The maximum length and area of the reservoir are 11.5 km and 937 hectares, respectively. March to May are the wettest months but July to August are the driest months of the year for the study area. The average annual precipitation is 470 mm although the average annual evaporation is 1771.5 mm. Considering soil evolution processes the soils across the study area are fairly young with the moisture and temperature regimes of xeric and mesic, respectively (Soil Survey Staff, 1999). The vegetation of the area is mostly pasture and shrub species as the dominant pasture type is Astragalus spp. in the south and west, Bromus tomentellus in the north, and Ferula Haussknechtii in the east of the basin.

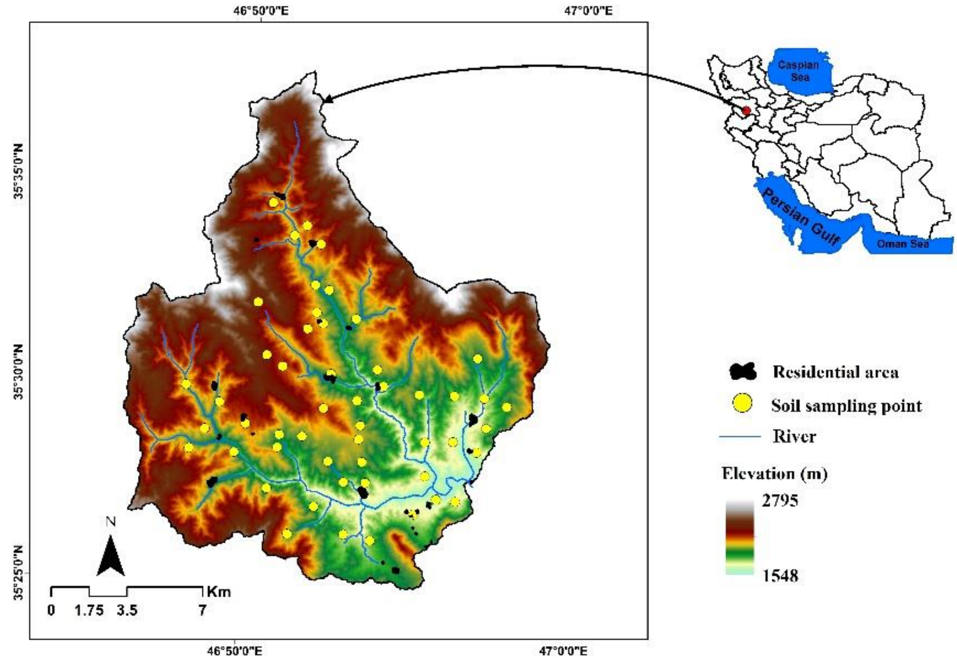

Fig. 1. Location of the study area in Iran

2.2. Data preparation

Table 1 has summerized the data used in this study. Fig. 2 illustrates the maps of elevation, slope, aspect, land use, sub-basins and soil zones of the studied area. A total of 51 soil samples were collected across the study area at depths of 0-20 cm. Soil samples were randomly collected from the study area between May to August 2020, based on the following criteria: area of the region, cost, and time (Mirghaed and Souri, 2021). To determine soil pH and Electrical Conductivity (EC), a saturated extract with a 2:1 ratio of soil to distilled water was used (Salinity Laboratory Staff, 1954). The amount of absorbable phosphorus and nitrogen in the soil samples were determined using Olsen (Olsen, 1954) and Kjeldahl (Van Reeuwijk, 1993) methods, respectively. Soil texture was estimated through hydrometric method (Day, 1965) and soil organic carbon was estimated by incubation and back titration of the produced carbon dioxide with diluted acid (Walkley and Black, 1934). Interpolation analysis was applied to prepare maps of soil characteristics based on the Inverse Distance Weighting method using ArcGIS software.

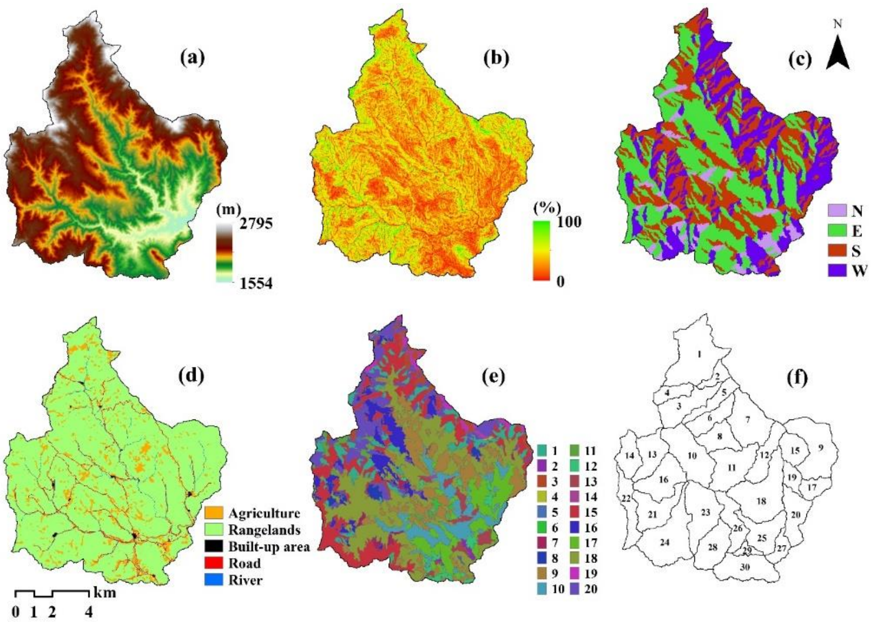

Fig. 2. Maps of (a) elevation; (b) slope; (c) aspect; (d) land use; (e) sub-basins and (f) soil zones of the study area

Table 1. Description of the data used in this study

Parameter	Unit	Type	Domain	Processing
Elevation	Meter	Raster	(1548-2795)	Extracted from ASTER images downloaded from the USGS website
Slope	Percent	Raster	(0-100)	Extracted from DEM using Slope function in ArcGIS environment
Aspect	-	Raster	5 classes	Extracted from DEM using Aspect function in ArcGIS environment
Land Use	-	Raster	5 classes	Extracted from Landsat images, downloaded from USGS website, using maximum likelihood algorithm in ENVI software
Sub-basin	-	Raster	30 sub-basins	Extracted from DEM using Arc Hydro tool In the ArcGIS environment
Soil Zone	-	Raster	20 zones	Produced on the basis of height, slope and direction maps based on the DEM, its classification using the Reclassify function and the elimination of small polygons using the Eliminate function in the ArcGIS environment.

2.3. Habitat quality

The habitat quality of the Qeshlagh Dam watershed was evaluated using the InVEST model. This model uses land use and land cover information as well as threat sources to estimate habitat quality. It also considers the sensitivity and effects of threats on the habitat. The factors that determine the impact of threats on the habitat are as follows:

a) The relative effect of a threat, which is assigned a weight value between 0 to 1 as indicators of no effect to maximum effect, respectively.

b) The distance between the source of the threat and the habitat. In fact, the greater the distance between the source of destruction and the habitat the less the impact of the threat on the habitat is expected. This effect can be defined either in linearly (equation 1) or exponentially (equation 2) trend depending on how the threat changes in space:

$$\mathrm{i_{rxy}} = 1 - \left(\mathrm{d_{xy}}/\mathrm{d_{r\,max}}\right) \quad (1)$$

$$\mathrm{i_{rxy}} = \exp\left(-(2.99/\mathrm{d_{r\,max}})\,\mathrm{d_{xy}}\right) \quad (2)$$

whereas i_{rxy} is the effect of threat r in cell y that is applied to a habitat in cell x; d_{xy} is the distance between cell x and y; $d_{r\,max}$ is the maximum distance of the threat effect.

c) Protective measures at different levels, which reduce the impact of environmental threats.

d) The relative sensitivity of a given habitat to a threat, where the overall level of destruction is estimated based on equation 3 (Ahmadi Mirghaed and Souri, 2021; Sharp et al., 2016):

$$D_{xj} = \sum_{r=1}^{R} \sum_{y=1}^{Y_r} (w_r / \sum_{r=1}^{R} w_r)\, r_y i_{rxy} B_x S_{jr} \quad (3)$$

whereas D_{xj} is the level of total destruction in cell x with user j; w_r is the weight of threat r; r_y is the level of threat in cell y; i_{rxy} is the effect of threat r in cell y on a habitat in cell x; B_x is the overall access level in pixel x; S_{jr} is the sensitivity of user j to the threat r. If S_{jr} is equal to zero, then D_{xj} will not be a function of threat r. The quality of the habitat is determined based on the degradation level and the semi-saturation constant. Therefore, as the level of destruction increases, the habitat quality decreases. Equation 4 estimates the habitat quality:

$$Q_{xj} = H_j\left(1 - (D_{xj}^z / D_{xj}^z + k^z)\right) \quad (4)$$

where Q_{xj} is the quality of the habitat in cell x with use j; H_j is the habitat suitability value of use j; D_{xj} is the overall degradation level in cell x with use j; k is the semi-saturation constant determined by the user. The constant z is equal to 2.5.

2.4. The relationships between habitat quality, soil characteristics and topography

The relationships between habitat quality, soil characteristics, and topography (elevation and slope) were quantified across sub-basins and soil zones. This entailed the calculation of habitat quality, soil characteristics, and topography values in sub-basins and soil zones, followed by the evaluation of their relationships using Pearson's correlation in SPSS software. Additionally, linear regression graphs were generated using the Excel software.

2.5. The relationships between habitat quality and land use pattern

Terrain measurements are suitable tool for calculating the spatial characteristics of land use patterns. Landscape metrics can accurately describe the relationships between landscape structure, performance, and quantitative changes. Through using land use metrics, the effects of land use on habitats and ecosystems can be evaluated. In this study; the effects of land use patterns on habitat quality were evaluated using spot density (PD), number of spots (NP), largest spot index (LPI), spot continuity index (PCI) and landscape shape index (LSI). Terrain measurements can show different features of landscape in terms of shape, size, continuity, composition and fragmentation. An increase in the values of spot density and number of spots indicates habitat fragmentation and discontinuity. The largest spot index shows the percentage of the area corresponding to the greatest spot of land use in a certain area while the landscape shape index shows the ratio of the environment to the area of the landscape. This is a standard scale for estimating the total landscape environment, which expresses the complexity of the landscape. The spot continuity index is a standard measure to quantify the physical connectivity of a specific range at the class level (Ahmadi Mirghaed and Souri, 2022; Borges et al., 2017). Following classification of the habitat quality of the study area; terrain parameters were calculated using the land use map at the level of sub-basins and soil zones using Fragstats software. It is also crucial to acknowledge that the measurement of landscape metrics is susceptible to map resolution. In this study, Landsat 8 images with a resolution of 30 meters were utilized to calculate the metrics (Sadeghi et al., 2021).

3. Results and discussion

The land use map was classified based on the maximum likelihood method and validated using the error matrix method. Kappa coefficient and overall accuracy were obtained as 0.89 and 92%, respectively, which confirms the accuracy of the classification. Rangeland, agriculture, roads, rivers, and residential areas have occupied 23,559, 2,416, 647, 292, and 68 hectares of the land of the entire region, respectively, which are equivalent to 87%, 9%, 2.4%, 1.1% and 0.3% of the basin area (Table 2). The analysis of soil physicochemical properties showed that the average values of pH was 7.69 as electrical conductivity was equal to 0.43 dSm^{-1}. The average concentration of absorbable phosphorus, total nitrogen and organic carbon of soil were 7.96 $mgkg^{-1}$, 0.16% and 0.92%, respectively (Table 3). Fig. 3 illustrates the maps of soil physicochemical characteristics as higher amounts of clay, silt and sand were observed at the center, center to eastern and northern parts of the study area, respectively. The highest values of pH and EC were found at the south, east and center of the Qeshlagh dam watershed. Total nitrogen, absorbable phosphorus and organic carbon of the soil all had the highest concentrations in the south and southeast of the study area. The minimum values of habitat quality determined were mostly distributed throughout the center and south of the Qeshlagh watershed but the rest of the study area has considerably higher habitat quality.

Table 2. The area allocated to each of the land uses across the study area

Land use	**Area** (Hectares)	(%)
Rangeland	23559	87.0
Agriculture	2416	9.0
Road	647	2.4
River	292	1.1
Residential area	68	0.3

The results of Pearson's correlation between habitat quality, soil characteristics and topography metrics at the levels of sub-basins and soil zones are presented in table 4. The relationship between the size of the largest spot, percentage of soil sand, slope and height in the soil zones was estimated to be positive and significant with the correlation coefficient of 0.89, 0.73, 0.61 and 0.78, respectively (P-value<0.01). Also, there was a positive and significant relationship between the continuity metric at the level of soil zones with a correlation coefficient of 0.48 (P-value<0.05). The relationships between the metrics of the largest stain, continuity, slope and height across the sub-basins determined were positive and significant with correlation coefficients of 0.52, 0.53, 0.63 and 0.59, respectively (P-value<0.01). Also, negative and significant relationship were observed between the spot density and total nitrogen for the sub-basins with correlation coefficient of -0.39 and -0.40, respectively (P-value<0.05). Fig. 4 shows the regression charts of the criteria with correlation coefficient higher than 0.7 across the soil zones.

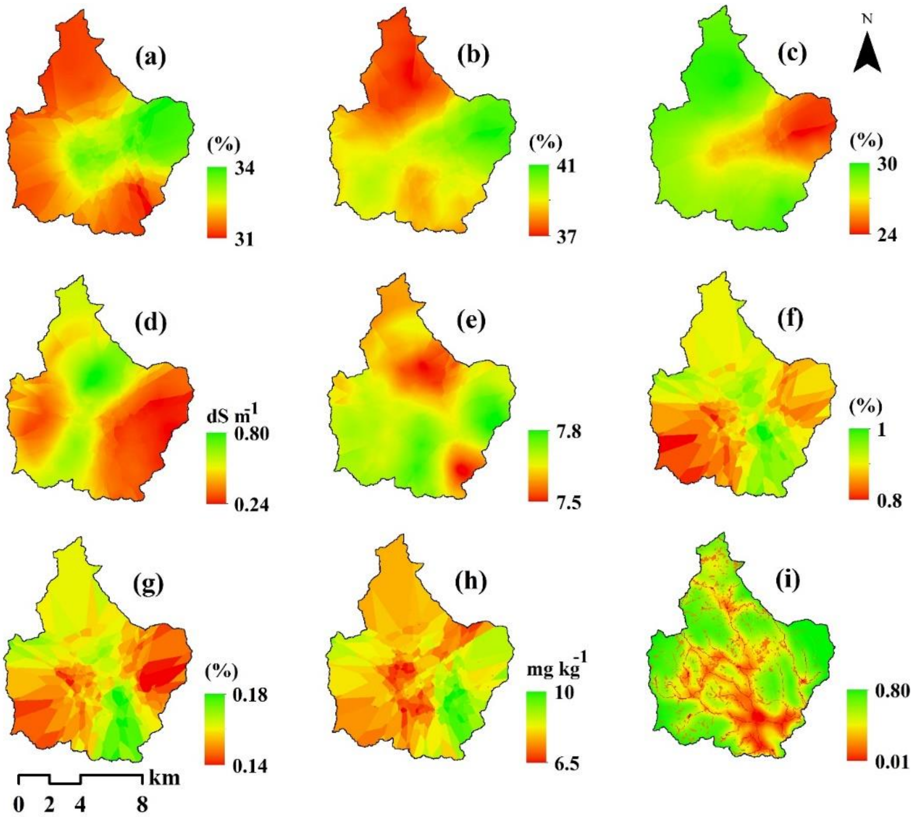

Fig. 3. Maps of (a) percentage of clay; (b) percentage of silt; (c) percentage of sand; (d) Electrical Conductivity; (e) pH; (f) Organic Carbon percentage; (g) Total Nitrogen; (h) Absorbable Phosphorus and (i) Habitat Quality across the study area

Table 3. Statistical description of soil physicochemical characteristics in the watershed of Qeshlagh Dam

Soil Characteristic	Minimum	Maximum	Average	Standard Deviation
pH	7.23	7.94	7.69	0.13
Electrical Conductivity (dSm^{-1})	0.16	1.28	0.43	0.29
Clay (%)	29	36	32.45	1.52
Silt (%)	36	42	39.43	1.64
Sand (%)	23	33	28.03	2.27
Organic Carbon (%)	0.72	1.21	0.92	0.13
Absorbable Phosphorus ($mgkg^{-1}$)	6.10	20.84	7.96	0.93
Total Nitrogen (%)	0.11	0.22	0.16	0.03

Table 4. Pearson's correlation coefficients for the relationships of habitat quality to characteristics of soil, topography, and land use features

Characteristics of soil, topography and land use features		Pearson's correlation coefficient	
Symbol	**Title**	**Soil Zone**	**Sub-basin**
NP	Number of spots	-0.72**	-0.14
PD	Spot density	·0.31	-0.39*
LPI	The biggest spot	0.89**	0.59**
LSI	Spot shape	-0.74**	-0.34
COHESION	Continuity of spot	0.48*	0.53**
SHDI	Shannon variety	-0.88**	-0.51**
Clay	Clay	-0.74**	-0.15
Sand	Sand	0.73**	0.22
Silt	Silt	-0.57**	-0.48**

EC	Electrical conductivity	0.28	0.01
N	Total nitrogen	-0.20	-0.40*
OC	Organic carbon	-0.46*	-0.15
P	Phosphorus	-0.53*	-0.05
pH	Acidity	0.35	0.08
Slope	Slope	0.61**	0.63**
Elevation	Height	0.78**	0.59**

**P-value<0.01
*P-value<0.05

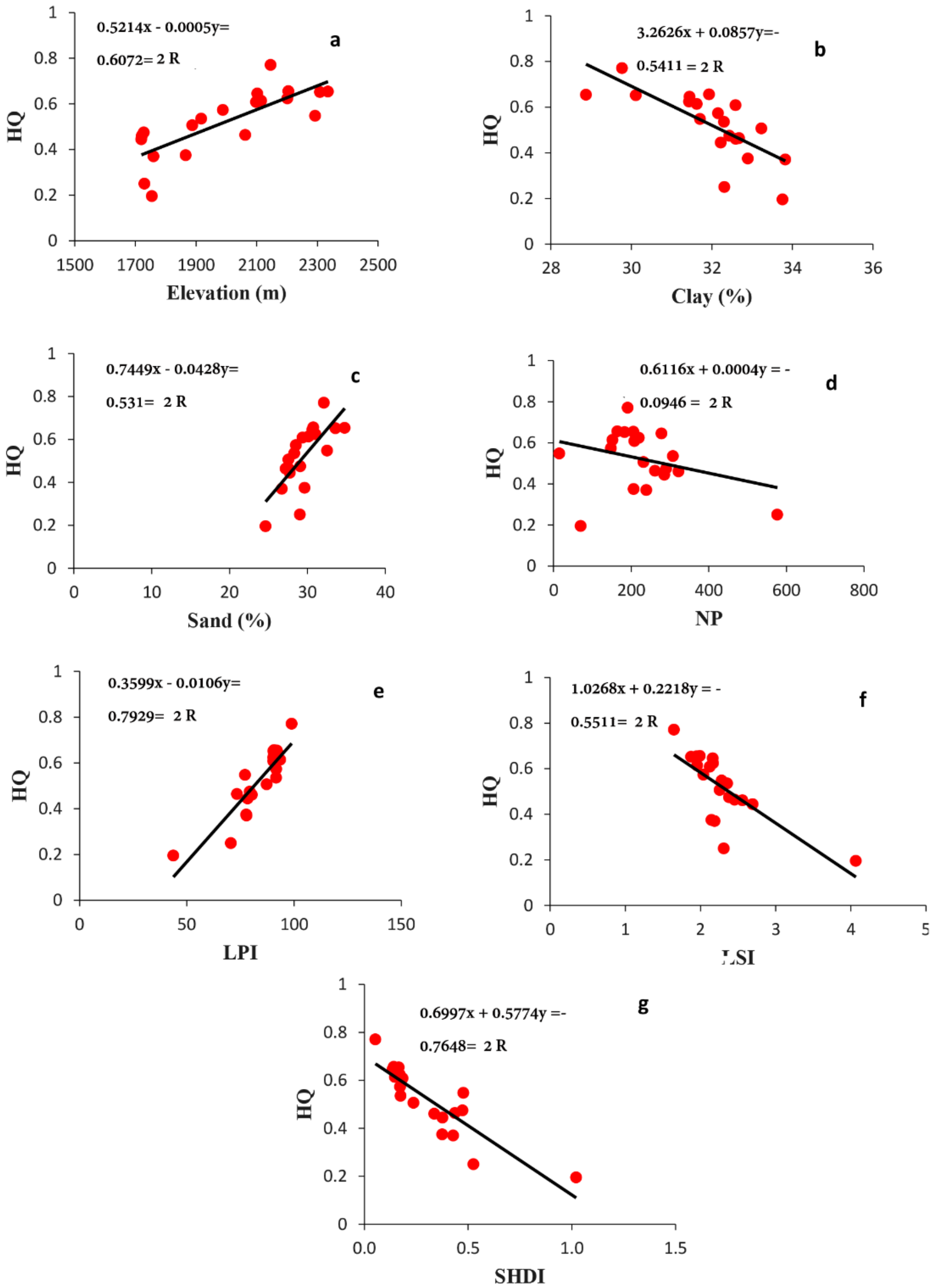

Fig. 4. Relationships of habitat quality to a) elevation; b) clay percentage; c) gravel percentage; d) NP; g) LPI; r) LSI and g) SHDI across the soil zones of the study area

The InVEST model can be used to estimate and put together the relative impact of threats to identify the threats that are most damaging to biodiversity in a specific landscape (Aneseyee et al., 2020). In the current study; agricultural lands, roads and residential areas were considered as threat factors since they can facilitate human disturbances, cutting trees and overexploitation through improving access to market. The results revealed that the habitats located at the central and the southern parts across the Qeshlagh watershed have lower quality but the northern and eastern parts alongside with the western margins have higher quality (Fig. 3i). It is found that the urban areas and agricultural development are amongst the factors that reduce the habitat quality at the central and southern parts of the study area. Also, the evaluation of the study area based on topography parameters showed that the fragmentation of habitats in the southern and central parts of the basin is more than other parts which is another reason to decline the quality of habitats throughout the southern and central parts of the basin. According to the research results of Xiao-Mei et al. (2023); the construction of industrial companies and the progress of urbanization caused considerable parts of Ciyao river basin to be brought under construction activities which resulted into a decline on the habitat quality. Ahmadi Mirghaed and Souri (2021) assessed the habitat quality of Ziarat watershed in Golestan province using the InVEST model while emphasized that the habitat quality will change with the changes of landscape. Sun et al. (2019) confirmed that intensive agricultural activities directly affect habitat quality and biodiversity. Moreover, the identification of habitat quality threats and sensitivity analysis for the Qeshlagh Dam watershed in this study is consistent to the results of Baral et al. (2014). Among the threats particularly the expansion of agricultural land use significantly contributed to the degradation of habitat quality. Petit et al. (2001) showed that the expansion of agriculture land use led to major eradication of indigenous vegetation also fragmentation and loss of habitat and biodiversity. The habitat quality highly depends on natural features of the landscape including topography, soil, vegetation as well as any land use change caused by human (Yan et al., 2018). The relationships of the habitat quality to characteristics of soil and topography disclosed that at the level of soil zones; the habitat quality had negative and significant correlations to the percentage of clay (R=-0.74, P-value<0.01) and silt (R=-0.57, P-value<0.05). Meanwhile, the relationship of the habitat quality to the percentage of was positive and significant (R=0.73, P-value<0.01). It was also found that the habitat quality had negative and significant correlations to organic carbon (R=-0.46, P-value<0.05) and absorbable phosphorus (R=-0.53, P-value<0.05) across the soil zones but to total nitrogen (R=-0.40, P-value<0.05) throughout the sub-basins. It should be noted that no significant correlation was obtained for the relationships between the habitat quality and soil electrical conductivity neither across soil zones nor sub-basins. At the level of the sub-basins; the habitat quality only had negative and significant correlation to total nitrogen (R=-0.40, P-value<0.05) although soil silt percentage performed negative significant relationship to the habitat quality at the level of soil zones and sub-basins both. Moreover, it was found that amongst the soil characteristics at the level of soil zones; the percentage of clay and sand had the highest negative and positive significant correlations to the habitat quality, respectively. Ahmadi Mirghaed and Souri (2022) investigated the relationships between the habitat quality and some soil characteristics throughout the Shoor River Basin. They obtained significant and negative relationships of the habitat quality to the percentage of clay, silt and soil erodibility while the relationships of the habitat quality to the percentage of sand, organic matter and soil porosity estimated were significant and positive. They pointed out that the habitat quality has a significant correlation to soil organic carbon and soil phosphorus which is similar to the current study at the level of soil zones. Willy et al. (2019) expressed the impact of land use change on the soil environment. Doi et al. (2010) also reported that habitat degradation can affect soil conditions and properties. The results of this study confirmed that there are positive and significant correlations of habitat quality to topographic features including slope (R=0.61 and R=0.63, P-value <0.01) and elevation (R=0.78 and R=0.59, P-value <0.01) across the soil zones and the sub-basins, respectively. Ahmadi Mirghaed and Souri (2021) confirmed that there is positive and significant correlation between the habitat quality and topographic features of slope and elevation. Aneseyee et al. (2020) reported that population density, land use intensity, altitude and slope significantly correlated with habitat quality in the Omo-Gibe watershed. Sun et al. (2019) also noted that the habitat quality pattern is mainly influenced by topographic features such as slope, elevation, and normalized difference vegetation index

(NDVI). The results of this study indicated that at the level of soil zones, the habitat quality has negative and significant correlations with the number of spots (R=-0.72, P-value<0.01), shapes (R=-0.74, P-value<0.01) and variety of spots (R=-0.88, P-value<0.01). Also, it was shown that habitat quality had positive and significant relationships to the greatest spot (R=0.89, P-value<0.01) and the continuity of spots (R=0.48, P-value<0.05) while no significant correlation was found to spot density at the level of soil zones. At the level of sub-basins; the quality of the habitat performed positive and significant correlations to the greatest spot (R=0.59, P-value<0.01) and the continuity of spots (R=0.53, P-value<0.01) while the relationships to the spot density (R=-0.39, P-value<0.05) and variety of spot (R=-0.51, P-value<0.01) were negative and significant. The relationships of the habitat quality to number of spot and spot shape were insignificant at the sub-basin level. These findings indorse that the land use pattern and its changes have significantly affected the habitat quality of the Qeshlagh watershed which is quite similar to the findings by Ahmadi Mirghaed and Souri (2022) for Shoor river basin. Uuemaa et al. (2011) showed that the metric of the shape of spot is one of the most important consequences of human impacts on the habitat quality. Panahandeh and Faizi (2019) reported the decrease in the territorial integrity of the watershed of Anzali lagoon alongside with the decrease in the continuity of its most important green cover i.e., the key spots of the forest. Particularly, forest spots experienced surface area decreases due to the simultaneous occurrence of patterns of removal, halving and consolidation because of disturbances by agricultural activities. Meanwhile, Arokhi (2014) confirmed the number of spots increase with their average area decrease as an important indicator of decomposition and destruction of the habitat. Linear regression analysis emphasized that spots variety (R=-0.88, P-value<0.01) and the greatest spots (R=0.89, P-value<0.01) had negative and positive relationships to the habitat quality at the level of soil zones, respectively, which affirmed that the more habitat quality the more biodiversity is expected. Moreover, the linear regression analysis results approved that the spot variety and the greatest spot are reliable metrics to predict the habitat quality.

4. Conclusion

Understanding the changes on habitat quality and its related factors is essential for the effective management of ecosystems. The results showed that the most suitable habitat quality in the watershed of Qeshlagh Dam is mainly distributed in high lands including the northern and eastern parts, as well as the western margins of the basin. This is while the density of urban areas and agricultural development are amongst the factors of the habitat quality declination in the basin central and southern parts. Statistical analysis showed that there are significant correlations of the habitat quality to characteristics of soil and topography at the levels of sub-basins and soil zones both although the cases of significations and values of the correlation coefficients were more at the level of soil zones compared to the level of sub-basins. Therefore, it can be concluded that the habitat quality is considerably depended on land use pattern while the scale of the study may influence the results of evaluation. According to the findings of this study mentioned on above; investigation of characteristics of soil, topography and landscape features can provide decision makers, local managers and stakeholders with a more accurate assessment of the habitat quality and land degradation.

Acknowledgment

The authors would like to thank Mr. Hooshyar Gavilian the authority of Soil, Water and Air Laboratory of the Department of Environmental Sciences in University of Kurdistan, Sanandaj, Iran, for his kind guidance and helps during experimental analysis of the soil samples applied in this study.

References

Ahmadi Mirghaed, F. & Souri, B., 2022. Spatial analysis of soil quality through landscape patterns in the Shoor River Basin, Southwestern Iran. *Catena*, 211, 106028.

Ahmadi Mirghaed, F. & Souri, B., 2021. Relationships between habitat quality and ecological properties across Ziarat Basin in northern Iran. *Environment, Development and Sustainability*, 1-16.

Aneseyee, A.B., 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, 1103.

Bagstad, K.J., Villa, F., Johnson, G.W. & Voigt, B., 2011. Artificial intelligence for ecosystem services. A guide to models and data, version 1.0. ARIES report series n.1, Geneva, Switzerland, 129-142.

Baral, H., Keenan, R.J., Sharma, S.K., Stork, N.E. & Kasel, S., 2014. Spatial assessment and mapping of biodiversity and conservation priorities in a heavily modified and fragmented production landscape in north-central Victoria, Australia. *Ecological Indicators*, 36, 552-562.

Borges, F., Glemnitz, M., Schultz, A. & Stachow, U., 2017. Assessing the habitat suitability of agricultural landscapes for characteristic breeding bird guilds using landscape metrics. *Environmental Monitoring and Assessment*, 189(4), 166.

Chen, Y., Qiao, F. & Jiang, L., 2016. Effects of land use pattern change on regional scale habitat quality based on InVEST model: a case study in Beijing. *Acta Scientiarum Naturalium Universitatis Pekinensis*, 52, 1-10.

Chenyu, L., Jianhua, Z. & Xueyuan, G., 2021. Spatial and temporal variation of habitat quality in forestry ecological engineering area of Yangtze River Economic Belt [J]. *Chinese Journal of Ecology*, 40(12), 3788-3799.

Day, P.R., 1965. Particle fractions and particle-size analysis. In Methods of soil analysis: Part 1, ed. C.A. Black. Madison, United States: *American Society of Agronomy*.

Doi, R., Wachrinrat, C., Teejuntuk, S., Sakurai, K. & Sahunalu, P., 2010. Semiquantitative color profiling of soils over a land degradation gradient in Sakaerat, Thailand. *Environmental Monitoring and Assessment*, 170(1-4), 301-309.

Joseph, H., 2010. The case for an ecosystem service approach to decision-making: An overview. *Biosci. Horizons*, 3, 188-196.

Li, M., Liang, D., Xia, J., Song, J., Cheng, D. & Wu, J., 2021. Evaluation of water conservation function of Danjiang River Basin in Qinling Mountains, China based on InVEST model. *Journal of Environmental Management*. 286, 112212.

McGarigal, K., Cushman, S.A. & Ene, E., 2012. FRAGSTATS v4: Spatial pattern analysis program for categorical and continuous maps. Computer software program produced by the authors at the University of Massachusetts, Amherst.

Olsen, S.R., 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate (No. 939). US Department of Agriculture.

Petit, S., Firbank, L., Wyatt's, B. & Howard, D.C., 2001. MIRABEL: models for integrated review and assessment of biodiversity in European landscapes. *AMBIO: A J. of the Human Environment*, 30(2), 81-88.

Raiesi, F., 2017. A minimum data set and soil quality index to quantify the effect of land use conversion on soil quality and degradation in native rangelands of upland arid and semiarid regions. *Ecological Indicators*, 75, 307-320

Sadeghi, S.H., Dashtpagerdi, M.M., Rekabdarkoolai, H.M. & Schoorl, J. M., 2021. Sensitivity analysis of relationships between hydrograph components and landscapes metrics extracted from digital elevation models with different spatial resolutions. *Ecological Indicators*, 121, 107025.

Salinity Laboratory Staff., 1954. Diagnosis and improvement of saline and alkali soils, 60. United States: Department of Agriculture Handbook.

Sharp, R., Tallis, H.T., Ricketts, T., Guerry, A.D., Wood, S.A., Chaplin-Kramer, R. & Douglass, J., 2016. InVEST+ VERSION+ User's guide. The natural capital projects.

Soil Survey Staff., 1999. Soil Taxonomy, 2nd edn. Natural Resources Conservation Service, United States Department of Agriculture Handbook No 436.

Sun, X., Jiang, Z., Liu, F. & Zhang, D., 2019. Monitoring spatio-temporal dynamics of habitat quality in Nansihu Lake basin, eastern China, from 1980 to 2015. *Ecological Indicators*, 102, 716-723.

Tian, K., Zhang, B., Zhang, H., Huang, B., Darilek, J., Zhao, Y. & Yang, J., 2020. Evaluation of soil quality in major grain-producing region of the North China Plain: Integrating minimum data set and established critical limits. *Ecological Indicators*, 117, 106613.

Uuemaa, E., Roosaare, J., Oja, T. & Mander, U., 2011. Analysing the spatial structure of the Estonian landscapes: which landscape metrics are the most suitable for comparing different landscapes? *Estonian Journal of Ecology*, 60, 70-80.

Van Reeuwijk, L.P., 1993. Procedures for soil analysis. International Soil Reference and Information Centre.

Walkley, A. & Black, I.A., 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Science*, 37(1), 29-38.

Wanghe, K., Guo, X., Ahmad, S., Tian, F., Nabi, G. & Strelnikov, I.I., 2022. FRESF model: An ArcGIS toolbox for rapid assessment of the supply, demand, and flow of flood regulation ecosystem services. *Ecological Indicators*, 143, 109264.

Willy, D.K., Muyanga, M., Mbuvi, J. & Jayne, T., 2019. The effect of land use change on soil fertility parameters in densely populated areas of Kenya. *Geoderma*, 343, 254-262.

Wu, C., Liu, G., Huang, C. & Liu, Q., 2019. Soil quality assessment in Yellow River Delta: Establishing a minimum data set and fuzzy logic model. *Geoderma*, 334(15), 82-89.

Xiaodong, Z. & Xuelu, L., 2022. Effects of land use on habitat quality based on INVEST model: A Case Study of the Zuli River Basin, china. *Research Square*, 1-23.

Xiao-Mei, H., Jin, Y., Chao, L., Xiao-Jun, F. & Yuan, Z., 2023. Impact of watershed habitat quality based on land use: a case study of taking Ciyao River Basin. *Quality Assurance and Safety of Crops and Foods*, 15(1), 18-31.

Xu, L., Chen, S.S., Xu, Y., Li, G. & Su, W., 2019. Impacts of land - use change on habitat quality during 1985-2015 in the taihu lake basin. *Sustainability*, 11 (3513).

Yan, S., Wang, X., Cai, Y., Li, C. & Yan, R., 2018. An integrated investigation of spatiotemporal habitat quality dynamics and driving forces in the upper basin of miyun reservoir, north China. *Sustainability*, 10(4625), 1-17.

Yuyang, C., Yang, G., Zhen, X., Tianzhu, Z. & Xize, Y., 2021. Evolution and correlation of habitat quality and landscape pattern in Beijing-Tianjin-Hebei region [J]. *China Environmental Science*, 41(02), 848-859.