ISSN: 2538-2152; ECOPERSIA 2025;13(2): 165-181.

Tarbiat Modares University

Sustainability Assessment of the Malekshahi Watershed Based on Ecological and Socio-Economic Criteria in Iran

ARTICLEINFO

Article Type
Original Research

Authors
Ehsan Fathi , *Ph.D.*[1]
Ali Talebi, *Ph.D.*[2*]
Mohammadreza Ekhtesasi, *Ph.D.*[3]
Jamal Mosaffaie, *Ph.D.*[4]
Zeinab Akbari, *Ph.D.*[1]

How to cite this article
Fathi E., Talebi T., Ekhtesasi MR., Mosaffaie J., Akbari Z. Sustainability Assessment of the Malekshahi Watershed Based on Ecological and Socio-Economic Criteria in Iran. ECOPERSIA 2025;13(2): 165-181.

DOI:
10.22034/ECOPERSIA.13.2.165

[1] Ph.D. Student in Watershed Management, Faculty of Natural Resources and Desert Studies, Yazd University, Yazd, Iran.
[2] Professor, Rangeland and Watershed Department, Faculty of Natural Resources and Desertology, Yazd University, Yazd, Iran
[3] Professor, Rangeland and Watershed Department, Faculty of Natural Resources and Desertology, Yazd University, Yazd, Iran.
[4] Associate Professor, Soil Conservation and Watershed Management Research Institute, Agricultural Research, Education and Extension Organization (AREEO), Tehran, Iran.

*** Correspondence**
Address: Professor, Rangeland and Watershed Department, Faculty of Natural Resources and Desertology, Yazd University, Yazd, Iran.
Tel: +98 9134137010
Email: talebisf@yazd.ac.ir

Article History
Received: March 7, 2025
Accepted: April 30, 2025
Published: May 19, 2025

ABSTRACT

Aims: Sustainable watershed management plays a key role in conserving and improving natural resources. This study aims to assess the sustainability of the Malekshahi Watershed based on the indicators defined in the Monitoring and Evaluation Guidelines for Natural Resource Management Plans in Iran.
Materials & Methods: In this regard, four ecosystems—forest, rangeland, aquatic, and human—were examined. The forest ecosystem was evaluated based on six criteria, including forest resource extent, biodiversity, health, vitality and integrity, productive functions of forest resources, protective and environmental functions, and socio-economic functions. The rangeland ecosystem was assessed using soil sustainability, vegetation cover, and socio-economic sustainability criteria. The aquatic ecosystem was analyzed using eight water quality indicators, including electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), dissolved phosphorus index, phytoplankton index, biological oxygen demand (BOD), FBI index, and fish index. The human ecosystem was analyzed based on nine criteria, including population dynamics, poverty and livelihood conditions, education and skills, nutrition and food security, health and sanitation, housing and public services, land-use change, technology, productivity, and institutional organization and development.
Findings: The results showed that the forest ecosystem (score: 55), human ecosystem (19.2), and aquatic ecosystem were in good condition, while the rangeland ecosystem (48) was in moderate condition. The final watershed sustainability score was 8.36, indicating a moderate level of sustainability in the region.
Conclusion: Forest and rangeland restoration, local community participation, and water resource monitoring should be implemented in this watershed to enhance sustainability and integrated natural resource management

Keywords: Ecosystem Assessment; Ecological Management; Natural Resources; Sustainability; Watershed.

CITATION LINKS

[1] Harris J.M. Basic principles of sustainable development. Dimensions ... [2] Asadi Nalivan O., Saravi M.M., Zahedi Amiri G.Z., Samani A.N. Compa ... [3] Hazbavi Z., Sadeghi S.H.R. Watershed health (Part three): Vigor, or ... [4] Kheirandish H., Sadeghipour A., Mohammadi Kangarani H. An Evaluatio ... [5] Sadeghi S.H.R., Sadoddin A., Asadi Neivan O.A., Hezbavi Z., Zarekar ... [6] Mirchooli F., Sadeghi S.H.R. (Comparative Analysis of Watershed Hea ... [7] Yilmaz B., Harmancioglu N.B. An indicator-based assessment for wate ... [8] McLaren R.A., Simonovic S.P. Evaluating sustainability criteria for ... [9] Sadeghi S.H.R., Hazbavi Z. Spatiotemporal variation of watershed he ... [10] Ahn S.R., Kim S.J. Assessment of watershed health, vulnerability an ... [11] Hazbavi Z., Sadeghi S.H.R., Gholamalifard M., Davudirad A.A. Waters ... [12] Alilou H., Rahmati O., Singh V.P., Choubin B., Pradhan B., Keesstra ... [13] Mosaffaie J., Salehpour Jam A. Assessment of the Kalaji watershed h ... [14] Gatgash Z.E., Sadeghi S.H.R. ... [15] Chandniha S.K., Kansal M.L., Anvesh ... [16] Xia J., Zhang Y., Zhao C., Bunn S.E. Bioindicator assessment framew ... [17] Momenian P., Nazarnejhad H., Miryaghoubzadeh M., Mostafazadeh R. As ... [18] Preciado-Jiménez M., Aparicio J., Güitrón-de-los-Reyes A., Hidalgo- ... [19] Barkey R.A., Nursaputra M. The ... [20] Heirany A.R., Behzadfar M., Hazbavi Z. Analyzing the sustainability ... [21] Jahdi R., Hazbavi Z. Evaluation of Watershed Scale Forest Ecosystem ... [22] Davoudi Moghaddam D., Haghizadeh A., Tahmasebipour N., Zeinivand H. ... [23] Engineering Advisory Firm of Catchment Plan., 2007. Detailed execut ... [24] Lu Y., Wang R., Zhang Y., Su H., Wang P., Jenkins A., Ferrier R.C., ... [25] Mottahedin P., Abdoos A. Evaluation of Hablehroud River Water Quali ... [26] Esmaeilzadeh M., Zare Bidaki R. Human Resources Potential Analysis ... [27] Rani G., Kaur J., Kumar A., Yogalakshmi K.N. Ecosystem health and d ... [28] Mosaffaie J., Salehpour Jam A.S., Tabatabaei M.R., Kousari M.R. Tre ... [29] Chen M.H., Chen F., ... [30] Rahimi Haghighi A., Ghanbari S.A., Asgharipour M.R. Assessing the s ... [31] Mirchooli F., Sadeghi S.H.R., Darvishan A.K., Strobl J. Multidimens ... [32] Li Z., Xu D., Guo X. Remote sensing of ecosystem health: opportunit ... [33] Mosaffaie J., Salehpour Jam A., Tabatabaei M.R., Gharibreza M.R. De ...

[DOI: 10.22034/ECOPERSIA.13.2.165]

Introduction

The increased consumption of renewable natural resources and poverty have placed severe pressure on ecosystems, making them more fragile, particularly in developing regions of the world in recent years [1]. This issue can pose serious challenges to water resources, soil, and other watershed components, leading to significant negative environmental and socio-economic consequences for local communities. Moreover, economic development may unintentionally result in negative social and environmental impacts, including climate change, excessive water resource exploitation, biodiversity loss, and rising inequalities [2]. For example, economic growth without proper management can lead to global warming and unsustainable climate changes. These issues may result in natural resource depletion, biodiversity loss, and increased social inequalities. Therefore, it is essential to consider social and environmental factors alongside economic development. Watershed monitoring and assessing their health and sustainability are inevitable necessities in planning and policymaking for adaptive management [3]. Sustainability fundamentally emphasizes preserving and properly managing natural, social, and economic capital for future generations. Sustainability is where available resources and capacities are maintained over time without depletion. This concept highlights the ability of ecosystems to sustain their functions and provide ecological services in the long term without leading to degradation or excessive resource exploitation [4, 5]. Sustainable development, which emphasizes maintaining a balance between environmental, social, and economic considerations for present and future generations, is achieved within the framework of integrated watershed management. To measure the degree of sustainability and assess progress toward sustainable development, a set of specific indicators is used to evaluate the state of ecosystems and natural resources accurately. In assessing watershed sustainability, it is essential to consider the long-term preservation of the watershed's health across social, economic, and environmental dimensions and the conservation of existing resources for current and future generations [6]. Sustainability indicators should reflect the interconnection between environmental, economic, and social aspects of sustainability and measure the impacts of management changes and human activities on the watershed over time [7]. Indicators are highly useful and effective in managing variables for monitoring and measuring sustainability status [8]. These indicators enable the assessment of a system's current state and monitoring its changes over time. Utilizing them makes it possible to evaluate system performance and determine its level of sustainability. These analytical tools are applied across various management domains, from organizational management to environmental management, which are crucial in improving decision-making processes. This study aims to assess the sustainability of the Malekshahi Watershed using the designated indicators outlined in the monitoring and evaluation guidelines for natural resource management plans. This method divides the watershed into five ecosystems: forest, rangeland, desert, aquatic environments, and human ecosystems, assigning appropriate criteria and indicators to each. Subsequently, variables are measured, and scores ranging from excellent to poor are assigned to each category. The results are then aggregated to obtain a final score [5]. Researchers have always focused on the assessment of watershed health and sustainability. These evaluations encompass a wide range of

[DOI: 10.22034/ECOPERSIA.13.2.165]

factors, including climatic conditions, soil erosion, flood risk, the quantity and quality of water resources, and socio-economic indicators. The goal of these studies is to optimize watershed resource management and ensure effective environmental protection to prevent ecosystem degradation and guarantee their long-term sustainability Sadeghi & Hazbavi (2017) [9], Ahn & Kim (2019) [10], Hazbavi et al. 2019 [11], Alilou et al. (2019) [12], Mosaffaie & Salehpour Jam (2024) [13], Gatgash & Sadeghi (2024) [14]. For example, Chandniha et al. (2014) [15] conducted a study on the assessment of the Watershed Sustainability Index (WSI) in the Chhattisgarh region of India, examining four main WSI indicators: hydrology, environment, living conditions, and policy. These indicators were also analyzed based on three indices, including pressure, state, and response. The results indicated that the WSI value for this watershed was calculated as 0.55, representing a moderate level of sustainability. Xia et al. (2014) [16] conducted a study evaluating biological indicators related to watershed health and their impact on air basin health in China. For this purpose, they examined water quality, soil, land cover, hydrology, and climate criteria. The results showed that 5% of the basin was classified as unhealthy, 51% as relatively healthy, and 44% as healthy. Momenian et al. (2018) [17] assessed the health status of the Qaturchai Watershed sub-basins using five key components, including Biotic status (species richness), Hydrological connectivity (number of structures per river length), Geomorphology (soil erosion susceptibility and climate sensitivity), Hydrology (perennial vegetation cover and impervious surfaces), and Water quality (point and non-point pollution sources). The results indicated that the overall health status of all sub-basins was classified as moderate. Preciado-Jiménez et al. (2013) [18] assessed the sustainability of the Lerma-Chapala Watershed using the Analytical Hierarchy Process (AHP) and a sustainability index. Their findings indicated that the region was in a poor sustainability condition. This study identified intensive agricultural and livestock activities and a lack of interaction among political, economic, and social factors as the main drivers of watershed degradation. Barkey and Nursaputra (2017) [19] conducted a study using Landsat 8 images from 2013 to assess the health of forests in the Maros Watershed. The forest health analysis results indicated that the forests in this watershed were in very healthy, healthy, unhealthy, and dead conditions. They recommended optimizing forest lands through forest restoration and reforestation. Heirany et al. (2021) [20], In a study, the level of sustainability based on the balance of human ecological well-being was analyzed in the Tutli Watershed in Iran. In the ecosystem sustainability section, they selected four criteria, eight indicators, and 20 variables. In contrast, in the human well-being section, they identified two criteria, seven indicators, and 19 variables, considering the basin's geographical, demographic, and hydro-geomorphological conditions. The results indicated that the sustainability level in both the ecosystem and human well-being sections of the Totli Basin was assessed as moderate. Jahdi and Hazbavi (2024) [21] assessed the health of the forest ecosystem in the Shenrud Siahkal Watershed using remote sensing and forest health monitoring methods. The results indicated that the current state of the ecosystem in the study area is generally of moderate health, primarily due to long-term deforestation, soil erosion, and improper human exploitation. Davoudi Moghaddam et al. (2021) [22], In a study, the water quality of the Ardak River was assessed using the Water Quality Index (WQI) and irrigation-related

[DOI: 10.22034/ECOPERSIA.13.2.165]

indices (sodium adsorption ratio (SAR), residual sodium carbonate (RSC), magnesium hazard (MH), Kelly's index (KI), and Permeability index (PI)) during dry and wet seasons. The results indicated that, based on the WQI, the water quality falls within the "poor" to "unsuitable for drinking" range. Regarding irrigation indices, the water quality is generally classified as "moderately suitable," while it is deemed unsuitable for irrigation at certain stations. Furthermore, the findings revealed that due to human activities such as animal husbandry, agricultural practices, and rural wastewater discharge, the water quality of the Ardak River is deteriorating. A review of studies shows that ecosystems are significantly affected by human and environmental activities, and these interventions can lead to the degradation of essential ecological services such as water supply, biodiversity conservation, and the regulation of environmental cycles. Therefore, precise assessment and sustainable management of ecosystems are essential for maintaining their health and preventing environmental crises. Despite the emphasis of previous sources on the importance of ecosystems and their vulnerability to human and environmental pressures, most past studies have lacked an integrated and structured approach for assessing sustainability status and prioritizing influential components. This study focusing on forest rangeland aquatic, and human ecosystems, employs a combined methodology to evaluate sustainability and aims to provide a multidimensional picture of the current situation. The findings of this study not only address the gaps present in previous analyses but also, by presenting a generalizable framework for sustainability assessment, represent a significant step toward integrated natural resource management and the realization of sustainable development in similar regions. sustainability assessment plays a fundamental role in natural resource management and environmental conservation. By identifying the strengths and weaknesses of ecosystems, this assessment enables effective planning for the optimal use of available watershed resources, reducing human pressures and enhancing ecosystem resilience. Moreover, understanding the sustainability status of a region helps decision-makers develop strategies tailored to environmental and social conditions, preventing environmental crises. Ultimately, sustainability assessment contributes to sustainable development and balancing resource utilization and conservation for future generations.

The Malekshahi Watershed has unique ecological characteristics, environmental issues such as soil erosion and threats to water resources, and economic and social dependencies on agriculture and natural resources. This study aims to assess the sustainability of the Malekshahi Watershed using the designated indicators outlined in the monitoring and evaluation guidelines for natural resource management plans. The findings can assist planners and managers in making optimal decisions to enhance watershed sustainability and serve as a foundation for developing future implementation strategies.

Materials & Methods

Study Area Description

The Malekshahi Watershed, covering an area of 12079.3 ha, is in Ilam Province. Geographically, it lies between 46°30'38" to 46°40'23" eastern longitude and 33°19'49" to 33°26'52" northern latitude. The watershed's maximum elevation reaches 2740 m, while the minimum elevation at its outlet is 1223 meters above sea level. It has a perimeter of 56.27 km, with a mean slope of

[DOI: 10.22034/ECOPERSIA.13.2.165]

27.9%. The watershed's drainage network follows a dendritic pattern, with the highest stream order at the outlet being sixth order. Climate analysis indicates that, based on the De Martonne method, the region has a Mediterranean climate. The mean annual precipitation during 2011–2021 was 590 mm, while the mean maximum and minimum temperatures were recorded at 23.25 °C and 11.06 °C, respectively. The study area is within the Folded Zagros Zone, with rock and alluvial units in various geological periods. Among these, the Ilam Formation is the most extensive geological unit in the watershed [23]. Figure 1 illustrates the location of the watershed within the country and Ilam Province.

Research Methodology

This study assessed watershed sustainability based on the Monitoring and Evaluation Guidelines for Natural Resources and Watershed Management Plans in Iran. This method involves defining criteria, indicators, and relevant variables, which are scored based on numerical classifications. The total score determines the final sustainability level of the watershed. This method offers a quantitative and qualitative approach to sustainability assessment and enables regional comparison. Figure 2 shows the visual summary of the research stages.

Forest Ecosystems

Iran's climatic and geological diversity has led to the formation of various forest ecosystems, including the Caspian (Hyrcanian) forest ecosystem or humid broadleaf forests, the Arasbaran forest ecosystem or semi-humid broadleaf forests, the Zagros forest ecosystem or semi-arid broadleaf forests, such as the forests of the Malekshahi Watershed, the Iranian-Turanian juniper forest ecosystem or arid

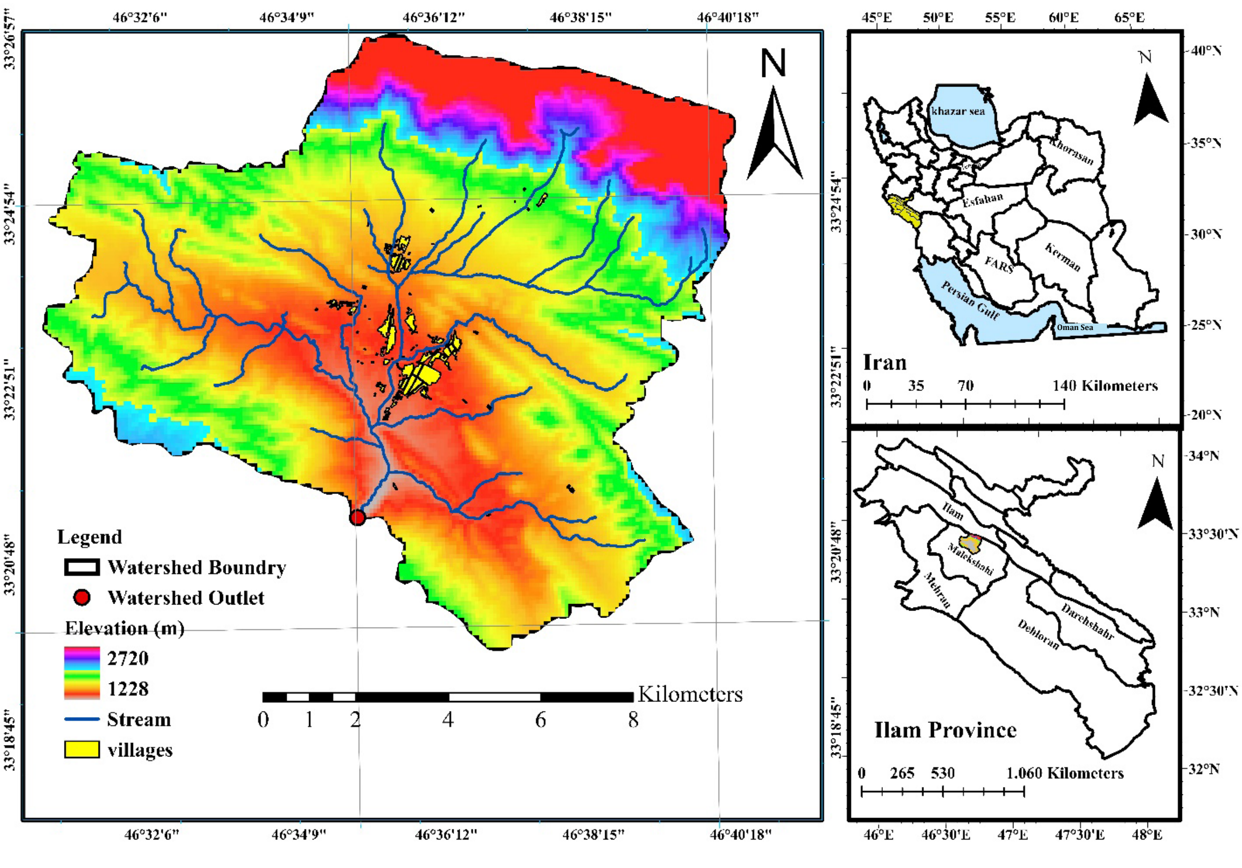

Figure 1) Location of the Study Area in Ilam Province and Iran.

[DOI: 10.22034/ECOPERSIA.13.2.165]

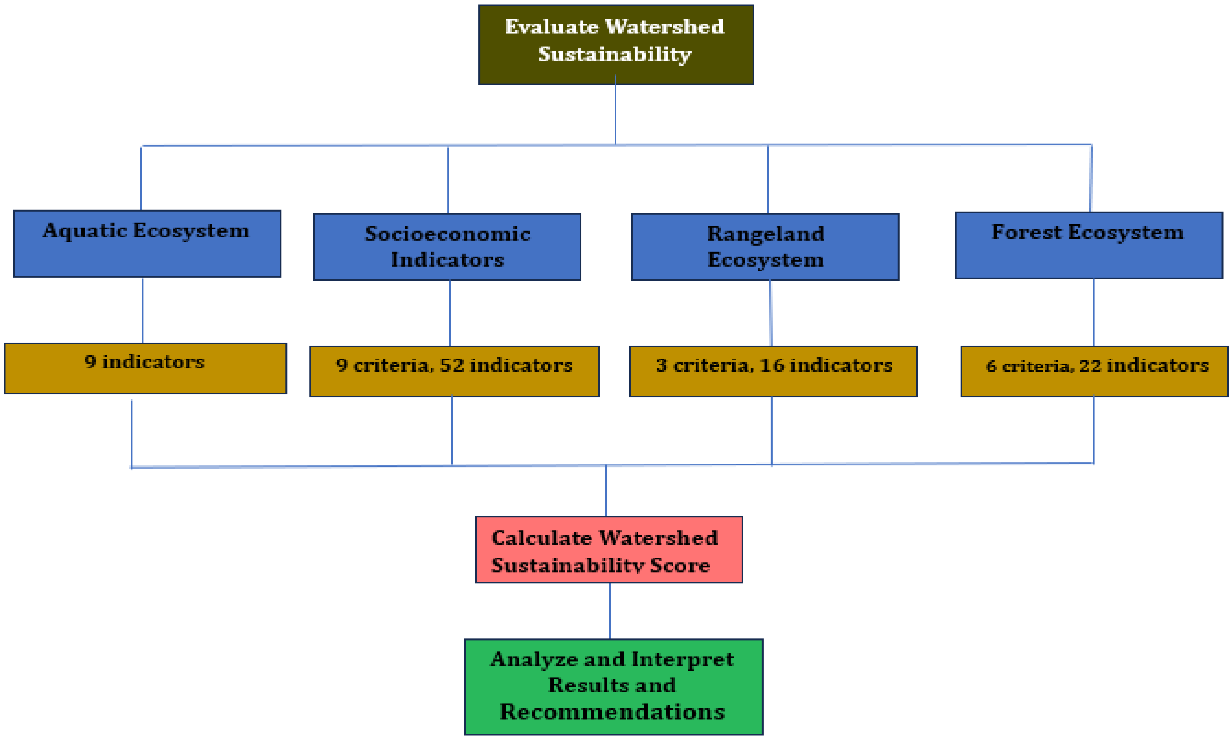

Figure 2) Flowchart of the study for the watershed sustainability assessment.

[DOI: 10.22034/ECOPERSIA.13.2.165]

coniferous forests, the Iranian-Turanian pistachio and almond forest ecosystem or arid broadleaf forests, and the Persian Gulf and Omanian tropical forest ecosystem or dry semi-tropical broadleaf forests. The quantification of indicators, criteria, and variables in each forest ecosystem varies depending on the regional climate. The sustainability of Zagros forest ecosystems is assessed using six criteria, 22 indicators, and 83 variables. The sustainability of the Zagros forest ecosystem is classified into five categories based on scoring: very poor (22-31), poor (32-41), moderate (42-53), good (54-70), and very good (71-83).

Rangeland Ecosystems

The sustainability of the rangeland ecosystem is evaluated using three criteria, 16 indicators, and 91 quantities (Table 2). Based on scoring, it is classified into five categories: very weak (less than 25), weak (25–44), moderate (45–64), good (65–80), and excellent (above 80).

Desert Ecosystems

The sustainability of the desert ecosystem is evaluated using five criteria and 15 indicators (Table 3). Based on scoring, it is classified into four categories: weak (less than 15), moderate (15–30), good (30–45), and excellent (above 45).

Aquatic Ecosystem

Eight indicators have been considered for the aquatic ecosystem: Electrical Conductivity (EC), Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Soluble Phosphorus Index, Phytoplankton Index, Biochemical Oxygen Demand (BOD), Benthic Invertebrate Index for Lentic and Lotic Waters (FBI), and Fish Index. The evaluation method for each indicator is presented in Table 4.

Socio-Economic (Human) Ecosystem

As detailed in Table 5, this ecosystem has considered nine criteria and 52 indicators. All scores are summed to classify the ecosystem in economic and social aspects, and the final value is estimated using the

Table 1) Criteria and Indicators Used for Evaluating Forest Ecosystem Sustainability.

Criteria	Indicators, Variables, and Range of Scores for Each Indicator and Variable
Extent of Forest Resources (F1)	Indices of extent (score 1-4), density (1-4), and management (1-3).
Biodiversity (F2)	Indicators include species mixture (1-4), continuity (1-4), natural regeneration (1-4), and species count (1-3).
Health, Vitality, and Integrity (F3)	Indicators include healthy natural regeneration (1-4), livestock grazing (1-4), land-use change (1-4), pests and diseases (1-3), wildfires (1-3), and per capita fuelwood and rural consumption (1-4).
Productive Functions of Forest Resources (F4)	Indicators include timber production (1-4), non-timber product production (1-3), and ecosystem production services of forest (1-4)
Protective and Environmental Functions (F5)	Indicators include water and soil conservation (1-4) and the extent of protected forest (1-4).
Social and Economic Functions (F6)	Includes the value of non-timber products (1-4), the value of forest ecosystem production services (1-4), participation of forest dwellers in forest management (1-4), and the share of forest households' income (1-4).

Table 2) Criteria and Indicators Used for Evaluating Rangeland Ecosystem Sustainability.

Criteria	Indicators, Variables, and Range of Scores for Each Indicator and Variable
Soil Stability (R1)	Soil conservation index (1-5), erosion susceptibility index (1-4), soil surface roughness (1-4), soil stability (1-5), and soil texture (1-4).
Vegetation Sustainability (R2)	The biodiversity index includes variables such as species diversity (1-4), degree of purity of the type (1-3), regeneration and age class index, including variables such as regeneration status and species regeneration (1-5), presence of various age classes (1-4), plant vigor and vitality index, including variables such as the height of rangeland plants (1-4), color and vitality of plants (1-4), and seed production of rangeland plants (1-4). The plant composition index includes variables such as palatability class (1-4) and growth form (1-4). The canopy cover percentage index (1-4), percentage of grass and litter index (1-3), status of invasive toxic plants index (1-4), and annual production index (1-4).
Economic and Social Sustainability (R3)	Livestock and Rangeland Suitability includes variables such as the ratio of existing livestock to the permitted rangeland capacity (1-3), adherence to livestock suitability with rangeland (1-3), the suitability index between human population and rangeland (1-4), and the exploitation suitability index, including variables such as the conversion of rangeland to other land uses (1-4) and the protection level (1-3).

Table 3) Criteria and Indicators Used for Evaluating Desert Ecosystem Sustainability.

Criteria	Indicators, Variables, and Range of Scores for Each Indicator and Variable
Vegetation Cover (D1)	Permanent canopy cover (1-4), rangeland quality (1-4), and species diversity (1-4).
Water Erosion (D2)	Exposed rocks and gravel (1-4), type of erosion (1-4), and percentage of gully-affected areas (1-4).
Wind Erosion (D3)	Percentage of ridge area (1-4), percentage of exposed plant roots (1-4), and exposed rocks and gravel (1-4).
Salinization (D4)	Mean depth of the water table in centimeters (1-4), soil texture sensitivity to salinization (1-4), and percentage of land area affected by salinity (1-4).
Water Resources (D5)	Drought periods (1-4), lithological characteristics (1-4), and annual decrease in water table depth in centimeters (1-4).

[DOI: 10.22034/ECOPERSIA.13.2.165]

Table 4) Classification of Aquatic Ecosystems based on the Mentioned Indices.

Status	EC (μ mho.cm^{-1})	TDS (mg.l^{-1})	DO (mg.l^{-1})	Soluble Phosphorus (mg.l^{-1})	Chl-a (mg.l^{-1})
Very Good	300<	200<	<8	8<	2.5<
Good	500-300	500- 200	8 – 7	8	2.5
Moderate	1500 -500	1000-500	6	20 – 10	8 2.5-
Bad	2000-1500	3000 - 1000	4	50 – 20	25 - 8
Very Bad	<2000	<3000	2≤	≤ 50	<25
Status	**Phytoplankton Biomass (mg.l^{-1})**	**BOD (mg.l^{-1})**	**FBI**	**Fish Index**	**-**
Very good	0.5<	1.5<	3<	****	-
Good	0.5	1.5-2	3-5	Trout	-
Moderate	0.5-2.5	2-3	5-7.5	Carp	-
Bad	2.5-10	3-5	7.5-9	Without fish	-
Very Bad	<10	<5	<9	****	-

Table 5) Criteria and Indicators Used for Evaluating the Sustainability of the Human Sector.

Criteria	Indicators, Variables, and Range of Scores for Each Indicator and Variable
Population Change and Transformation (H1)	Relative and Biological Population Density (1-3), Rural Population Number (1-3), Urban Population Share (1-3), Household Size (1-3), Age and Gender Composition of Population (1-3), Crude Activity Rate (1-3), Migration Rate (1-3)
Poverty and Livelihood Status (H2)	The employment rate (1-3), the number of employed rural workers (1-3), the net dependency burden (1-3), the yield per hectare of major agricultural products (1-3), the gross income of each agricultural activity (1-3), the added value of each rural area within the watershed (1-3), the mean net household income (1-3), the mean loan received by households (1-3), access to product markets (1-3), the number of handicraft workshops (1-3), and the number of agricultural processing units and related industries (1-3).
Education and Skills (H3)	The net enrollment ratio in primary schools (1-3), the adult literacy rate (1-3), and the number of skilled and professional workers in the village (1-3).
Nutrition and Food Security (H4)	Per capita agricultural land (1-3), per capita livestock number (1-3), per capita agricultural production (1-3), and the share of food expenses in total expenditures (1-3).
Health and Sanitation (H5)	The number of households with access to drinking water (1-3), the number of households with access to sanitary toilets (1-3), the number of households with access to a bathroom (1-3), and the number of active health houses in the village and the entire watershed (1-3).
Housing and Public Services (H6)	The number of households with a complete residential unit (1-3), the mean number of people per room (1-3), the age of residential units (new or deteriorated) (1-3), the durability of residential units (resistant or non-resistant materials) (1-3), the length of main, secondary, and rural roads usable throughout the year (1-3), and the availability of public transportation (1-3).
Land Use Change (H7)	The extent of degraded forest or rangeland areas (1-3), the cultivated area under forest trees (1-3), the percentage of rainfed or plowed lands with a slope greater than 12% (1-3), the number of deep and semi-deep wells (1-3), excessive extraction from groundwater aquifers (1-3), and bush clearing and firewood collection (1-3).
Technology and Productivity (H8)	The number of tractors combines and other machinery (1-3), the ratio of modern irrigation network length to the total irrigation system (1-3), the ratio of land under sprinkler and drip irrigation to total irrigated land (1-3), the number of dairy farms (1-3), the number of poultry farms (1-3), the area of greenhouse halls (1-3), other agricultural production units (1-3), and labor productivity (1-3).
Organizational and Institutional Development Criteria (H9)	The number of grassroots organizations (1-3), the number of rural development institutions in the watershed (1-3), and the number of modern resource management organizations for water and soil (1-3).

arithmetic mean. Based on this scoring, the classification is divided into five categories: very weak (less than 0.6-0), weak (0.6-1.2), intermediate (1.2-1.8), good (1.8-2.4), and very good (2.4-3).

Aquatic Ecosystem

Sampling was conducted in March 2022 and April 2022 at the watershed outlet to assess water quality, following the Standard Methods guidelines. The analysis included measuring total dissolved solids (TDS), electrical conductivity (EC), dissolved oxygen (DO), and biochemical oxygen demand (BOD). For this purpose, polypropylene containers were pre-washed with nitric acid and distilled water. The sampling containers were rinsed thrice with river water before collecting 4 liters at the station. The samples were stored in a refrigerator at 4°C to prevent microbial decomposition and transported to the laboratory for analysis.

To assess the water quality, all laboratory tests were repeated at least three times to minimize experimental error. After sampling, the samples were transported to the laboratory alongside ice at a temperature of 4 °C and stored in a refrigerator until the start of the analysis process. The analysis of the samples was carried out immediately upon arrival. All stages of sterilizing the sampling containers and their transportation and storage in the laboratory followed the guidelines provided in the 2017 edition of the Standard Methods book.

The coefficient for each ecosystem was determined using the expert consensus method and brainstorming. These coefficients have been determined through surveys and consultations with more than twenty experts from various fields of specialization (Table 6). The matrix provided in Table 7 is used to obtain quantitative values for watershed sustainability. The ecosystem status is listed in the rows of this matrix, while the columns represent the ecosystems forming the watershed. The matrix cells contain score values, which are obtained through the linear multiplication of factor scores as described in Eq. (1). Finally, the overall assessment of watershed sustainability is conducted based on the obtained scores, as presented in Table 8.

$$WS = \left(\frac{a}{A} \times 100 \right) \times S \times C \qquad \text{Eq. (1)}$$

Where *WS* is the Watershed Sustainability (Without dimension), *a* is Ecosystem area (ha), *A* is the entire watershed (ha), *S* is the status score (Without dimension), and *C* is the functional nature coefficient (Without dimension).

Findings

To analyze and evaluate the selected indicators and variables, data and information were collected from various reliable sources, including the General Department of Natural Resources and Watershed Management, the Regional Water Company, the Department of Environment, the Ilam Governorate, implementation studies of the Malekshahi Watershed [23], field visits to the watershed, and meetings and interviews with local residents and experts from relevant sectors. This diversity of sources provided a foundation for obtaining comprehensive, accurate, and multidimensional information for assessing the study's indicators. The final score for the forest ecosystem was calculated as 55, placing it in the good category. Similarly, the rangeland ecosystem scored 48, which is also classified as moderate. Since the Malekshahi Watershed lacks a desert environment, the desert ecosystem was not assessed for this area. The socio-economic ecosystem scored 2.19, placing it in the good category. Figures 3, 4, and 5 illustrate the scores of the criteria for the forest, rangeland, and socio-economic (human) ecosystems, respectively.

[DOI: 10.22034/ECOPERSIA.13.2.165]

Table 6) Ecological and Functional Nature of Ecosystems Based on Expert Consensus.

Ecosystem	Aquatic Environment	Forest	Rangeland	Human	Desert
Coefficient	4	3	2	1	0.9

Table 7) Watershed Sustainability Assessment Matrix.

Ecosystems	Percentage Ratio in the Watershed	Intrinsic Score	Status				
			Very Good (5)	Good (4)	Moderate (3)	Bad (2)	Very Bad (1)
Aquatic Environment		4					
Forest		3					
Rangeland		2					
Human		1					
Desert		0.9					
Total							
Total Score of the Watershed							

Table 8) Watershed Sustainability Classification.

Score	0.9-3.9	4-7.9	8-11.9	12-15.9	16-20
Status	Very Bad	Bad	Moderate	Good	Very Good

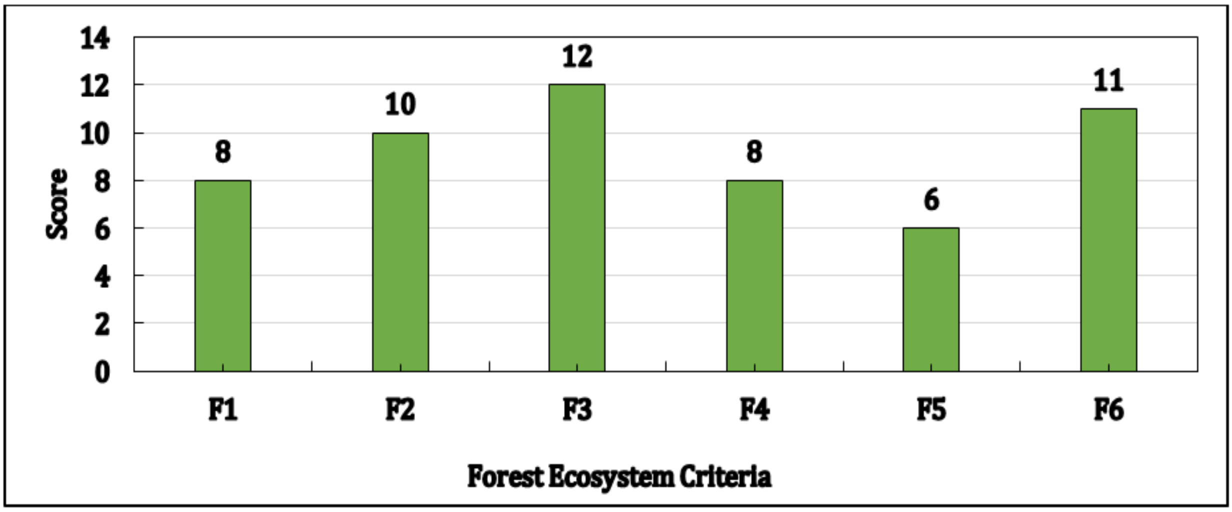

Figure 3) The Score of Forest Ecosystem Criteria in the Malekshahi Watershed, Iran.

[DOI: 10.22034/ECOPERSIA.13.2.165]

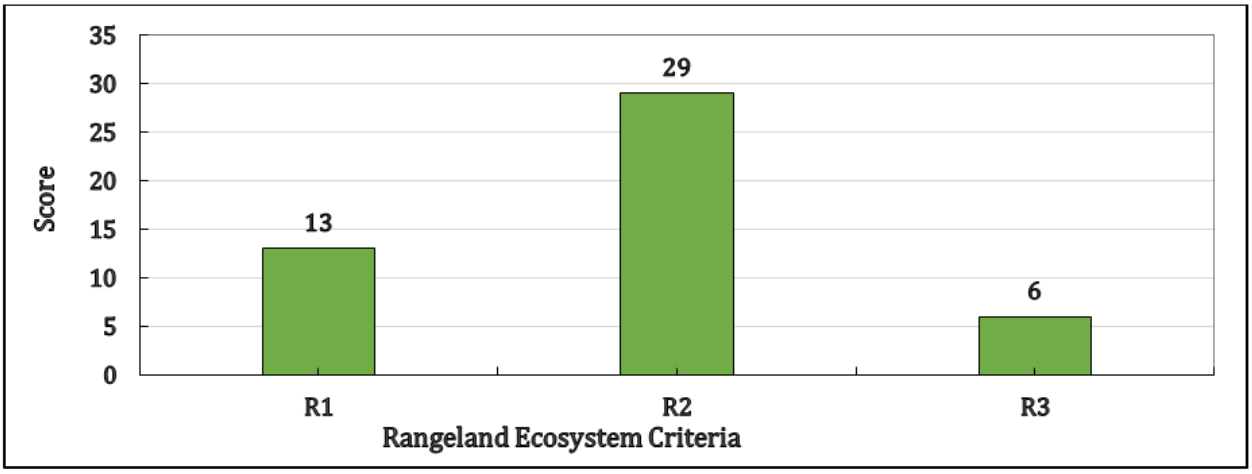

Figure 4) The Score of Rangeland Ecosystem Criteria in the Malekshahi Watershed, Iran.

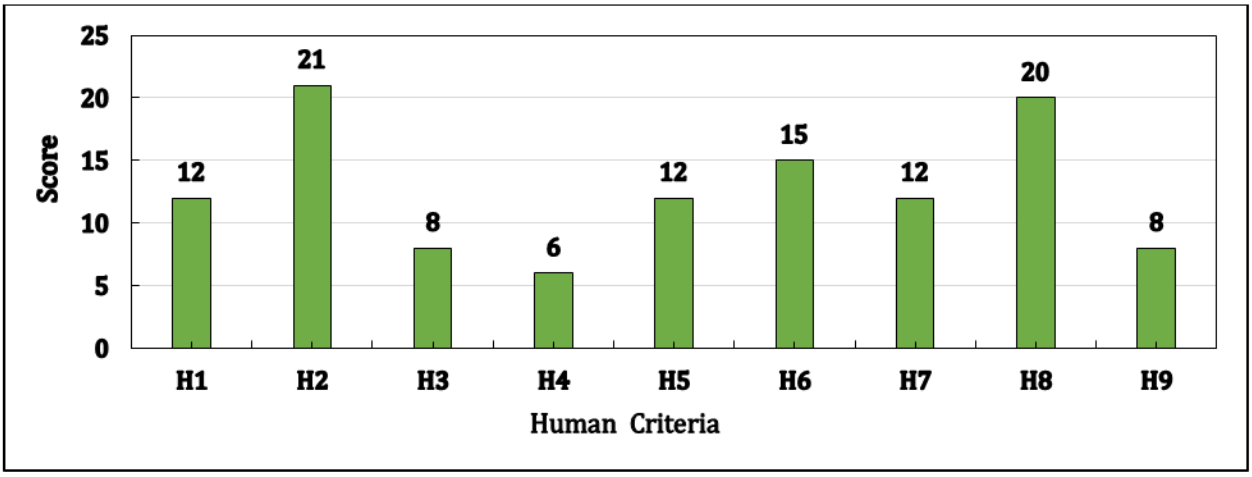

Figure 5) The Score of Socio-Economic Criteria in the Malekshahi Watershed, Iran.

Table 9) Mean and Status of Measured Factors at the River Outlet of the Maleksah Watershed, Iran.

Factor	TDS ($mg.l^{-1}$)	EC ($mho.cm^{-1}$)	DO ($g.l^{-1}$)	BOD ($mg.l^{-1}$)	Soluble Phosphorus ($g.l^{-1}$)	Fish Index
Mean	470	706	8.98	2.71	17	*
Status	good	Moderate	Very Good	Moderate	Moderate	Good

Table 10) Score and Status of Different Ecosystems in the Maleksah Watershed, Iran.

Ecosystem	Score	Percentage (%)	Status	Score Status
Forest	55	44.4	Good	4
Rangeland	48	11	Moderate	3
Desert	Without Desert	0	-	-
Aquatic Environment	3.83	5	Good	4
Human	2.19	39.6	Good	4
Total Watershed Area			Moderate	8.36

[DOI: 10.22034/ECOPERSIA.13.2.165]

The results of the factors are presented in Table 9. The fish index also classified the river water quality as good. Table 10 provides the scores and status of various ecosystems within the Malekshahi Watershed.

Discussion

Given the importance of preserving watershed ecosystems to prevent adverse economic and social consequences, assessing the relative condition of watersheds at national and local scales has become essential [24]. Accordingly, this study evaluates the sustainability of the Malekshahi Watershed using the country's natural resources and watershed management approach. In this regard, the sustainability status of the watershed has been examined by measuring criteria related to forest, rangeland, aquatic environment, and socio-economic dimensions.

According to the results, the forest ecosystem was classified as good. One of the main factors contributing to this condition is the improper and excessive use of forests due to easy access and lower exploitation costs. This issue can lead to a decline in forest cover, depletion of natural resources, loss of biodiversity, and destruction of wildlife habitats. Moreover, deforestation has widespread impacts on the water cycle, soil stability, and local climate changes, potentially exacerbating environmental risks. To address this challenge, implementing effective conservation policies and programs is essential. These measures include sustainable forest management, restoration projects, stricter monitoring of resource exploitation, and enhancing public education and awareness regarding the importance of forest conservation. Integrating these strategies with economic incentives and supporting alternative livelihoods for forest-dependent communities can significantly mitigate deforestation and improve forest conditions.

The sustainability of the rangeland ecosystem, with a score of 48, was classified as moderate. The main factors contributing to the decline in rangeland sustainability in the Malekshahi Watershed include excessive livestock numbers beyond the carrying capacity, overgrazing, early-season grazing, soil compaction, and increased soil density. These factors can lead to reduced plant productivity, soil erosion, decreased soil water retention, and a decline in rangeland biodiversity. Excessive grazing pressure and uncontrolled livestock grazing degrade vegetation cover, diminish rangeland regeneration capacity, increase surface runoff, and reduce soil permeability. Consequently, these conditions heighten the risk of flooding and accelerate soil erosion. Moreover, excessive soil compaction due to continuous livestock movement prevents the regrowth of rangeland vegetation, weakens soil structure, and reduces its capacity to absorb and retain water. This situation threatens the sustainability of the rangeland ecosystem and puts the livelihoods of communities dependent on these resources at risk. Therefore, implementing effective management programs—such as controlling livestock numbers, regulating grazing seasons and intensity, restoring and rehabilitating degraded rangelands, and preventing soil compaction—is essential for maintaining and enhancing rangeland sustainability in this region. Additionally, educating local communities on sustainable rangeland management and promoting environmentally compatible utilization patterns can help alleviate pressure on these valuable resources and maintain ecological balance.

The assessment of measured factors at the river outlet of the Malekshahi Watershed indicated that the aquatic ecosystem is in good condition. The aquatic environment

[DOI: 10.22034/ECOPERSIA.13.2.165]

is one of the most crucial components of an ecosystem, playing a key role in ecological stability, providing water resources for human communities, and preserving aquatic habitats. Various factors, including precipitation, land use, soil erosion, pollutant inflow, and human exploitation, influence the quality and quantity of river water and other water resources. Maintaining the sustainability of the aquatic ecosystem requires proper water resource management, pollution prevention, regulation of excessive water extraction, and the implementation of watershed restoration and conservation programs. Additionally, continuous water quality monitoring and implementing sustainable water resource management policies can help prevent issues such as reduced river flow, water pollution, and biodiversity loss in aquatic ecosystems. Mottahedin and Abdoos (2021) [25] assessed the quality of the Hablehroud River in Semnan Province using the IRWQISC index. For this purpose, factors including COD, BOD_5, dissolved oxygen, electrical conductivity, fecal coliform, ammonium, nitrate, phosphate, turbidity, total hardness, and pH were measured across four seasons—from winter 2019 to autumn 2020—at three sampling stations. The results showed that the value of the index ranged from 38.3 to 55.6. Additionally, according to the findings, water quality at the upstream station near Bonkouh Village during the summer was better than in other stations and seasons.

The assessment of human and socio-economic criteria and indicators in the watershed revealed that this sector is in good condition regarding sustainability. In watershed sustainability evaluations, human-related factors are considered an integral component. Many researchers and experts define sustainable development as interacting with social, economic, and environmental domains. This perspective emphasizes that human factors should not be overlooked in watershed sustainability assessments but rather analyzed alongside ecological and economic indicators in an integrated manner. These factors have exerted significant pressure on water, soil, and vegetation resources, leading to their gradual depletion. Overexploitation of rangelands and forests, climate change, and reduced precipitation have further intensified this trend. To address these challenges, implementing comprehensive management policies and programs—such as promoting sustainable agriculture, controlling land-use changes, supporting alternative livelihoods for local communities, and raising public awareness about the importance of natural resource conservation—is essential. Additionally, engaging local communities and integrating traditional knowledge alongside large-scale management policies can help reduce pressure on resources and balance human activities and the environment. Esmailzadeh and Zare-Bidaki (2019) [26], in their analysis of human resources in Chaharmahal and Bakhtiari Province using the Human Development Index, showed that life expectancy in 2016 had increased compared to previous years. This improvement was attributed to enhancing health and medical services, increasing the number of healthcare centers, better quality of service delivery, appropriate infrastructure, and healthier nutrition.

The strengths of this method include the consideration of diverse indicators, the use of quantitative and documented data, the identification of weaknesses through analysis, and the enhancement of result credibility by utilizing official sources, field studies, and expert opinions. Despite its comprehensiveness, one of the weaknesses of this method is the equal weighting of

[DOI: 10.22034/ECOPERSIA.13.2.165]

all indicators. Using multi-criteria analysis methods and techniques such as the Analytical Hierarchy Process (AHP) can help assign more accurate weights to the indicators based on their relative importance, thereby enhancing the credibility of the results.

The Malekshahi Watershed possesses significant potential in beekeeping, medicinal plants, and handicrafts. Natural attractions, stunning landscapes, and a rich rural and nomadic culture also provide a strong foundation for tourism development. Despite these advantages, a large portion of the region's economic activities is focused on directly exploiting natural resources, placing considerable pressure on them. Therefore, investing in appropriate infrastructure to develop these capacities— which exert less strain on watershed resources—can improve environmental conditions and enhance local communities' income and well-being. Creating alternative livelihood opportunities, such as developing ecotourism, producing and processing medicinal plants, and promoting sustainable occupations, can reduce the region's economic dependence on agriculture and livestock farming, thereby alleviating pressure on water, soil, and vegetation resources.

Rani et al. (2019) [27] examined ecosystem health and dynamics based on the Global Climate Change Index. They stated that abnormal changes in climate patterns could affect ecosystem health by causing species loss, extinction, migration, and behavioral shifts. The findings of Mosafaie et al. (2021) [28], in assessing the health trends of the Gorganrud Watershed using the DPSIR framework, indicated that groundwater depletion, flood potential, and soil erosion were the most critical challenges in the watershed. This implies that the health of the Gorganrud Watershed has deteriorated over time due to socio-economic activities and associated pressures. Chen et al. (2022) [29] evaluated the ecosystem health of the Zhangjian Bay coastal region in China from 2010 to 2018 using the DPSIR framework and the TOPSIS model. Their results showed that the ecosystem health in this region was generally at a suboptimal level. Ultimately, they proposed integrated management strategies to prevent further ecosystem degradation. Asadi Nalivan et al. (2015) [2], Using the IUCN methods and the guidelines of Iran's Natural Resources and Watershed Management Organization, assessed the sustainability of the Taleghan Watershed. Their results indicated that, based on the IUCN method and the Iranian guidelines, the watershed is in a moderate and weak sustainability condition, respectively. However, sustainability in the mentioned watershed can be improved through ecosystem conservation and enhancement of local living standards. Rahimi-Haghighi et al. (2022)[30]] in a study aimed at evaluating the ecosystem of the Khosroshirin Watershed in Abadeh, employed two methods: the International Union for Conservation of Nature (IUCN) approach—focusing on human and ecological criteria—and the guidelines of the Natural Resources and Watershed Management Organization of Iran—assessing the sustainability of socio-economic and rangeland sectors. The results showed that, according to the IUCN method, the watershed's sustainability was moderate, while based on the Iranian guideline, it was classified as weak. They suggested that improving indicators such as existing livestock, plant production, and composition in the ecological sustainability sector, along with indicators such as ownership, equity and equality, and nutrition and food security in the human ecological sector, would not only enhance people's living standards but also improve the health and sustainability of the mentioned ecosystem.

Mirchooli et al. [31], in a study aimed at

[DOI: 10.22034/ECOPERSIA.13.2.165]

multidimensional assessment of the sustainability status of the Shazand Watershed in Iran, an innovative and newly developed index based on social, economic, environmental, and policy dimensions was designed and applied. This index was employed in the Shazand Watershed in 1986, 1998, 2008, and 2016 to analyze the status of individual dimensions and the overall watershed sustainability. The findings indicated that the distribution of sustainability dimensions across the watershed was not uniform. While the social dimension demonstrated high effectiveness in the sub-watersheds, the policy dimension consistently remained undesirable in all years. Moreover, the sustainability index, recorded as 0.32, 0.32, 0.35, and 0.35 for 1986, 1998, 2008, and 2016 respectively, confirms only a slight improvement. This study indicates that the proposed index can be an effective tool for better understanding watershed sustainability and developing effective management strategies. It also has the potential to be applied in other watersheds.

The assessment and monitoring of watersheds provide early warnings of environmental degradation, and help identify the underlying causes of existing issues. These actions are of great importance, as they enable the detection of harmful impacts on natural resources and the environment, paving the way for implementing appropriate measures. Therefore, examining ecosystem health and sustainability is a fundamental step in ecological protection and the evaluation of environmental services [32]. The lack of strategies compatible with watershed characteristics may confuse watershed management practices, leading to a decrease in watershed health [33]. This assessment holds particular significance for policymakers, planners, and decision-makers, as it allows them to evaluate the outcomes of management actions and determine their effectiveness or inefficiency. Additionally, this process facilitates the identification of critical areas and the prioritization of interventions within the ecosystem.

Based on the results obtained from assessing various ecosystems in the study area, providing practical solutions to enhance sustainability and improve natural resource management appears essential. In this regard, it is recommended that stakeholders and watershed managers implement programs to restore vegetation cover in rangelands and forests and prevent livestock overgrazing. Furthermore, utilizing the capacities of local communities through education, empowerment, and active participation in decision-making can play a significant role in improving the condition of natural resources. Continuous monitoring of water resource quality, focusing on key indicators, should also be prioritized to enable timely identification and management of potential changes. In addition, strengthening local institutions and developing alternative livelihoods to reduce pressure on natural resources are among the other essential measures for sustainability. These recommendations are a foundation for action within the macro-level policymaking and operational planning framework to achieve sustainable regional development.

Conclusion

Assessing watershed health and sustainability is valuable for identifying and determining appropriate human, ecological, and water resource management strategies. Therefore methods should be developed to evaluate watershed health and assess their level of sustainability. In this study the sustainability of the Malekshahi Watershed was evaluated based on various criteria, including forest, rangeland, desert, water, and human factors. Based on the results, the forest ecosystem was assessed as being in good condition, the rangeland ecosystem in moderate condition,

[DOI: 10.22034/ECOPERSIA.13.2.165]

and both the human ecosystem and aquatic environment in good condition. However, the final watershed sustainability score was determined to be 8.36, indicating a moderate sustainability status for the watershed. Enhancing education, strengthening human resources, and increasing policymakers' attention to natural resources can improve watershed sustainability. Participating the public in water resource management and environmental conservation can reduce watershed vulnerability and enhance the efficiency of natural resource utilization. Additionally, public participation in watershed improvement activities, such as tree planting, soil and water conservation, and water use management, can contribute to strengthening the sustainability of the watershed. Moreover the findings of such research can assist decision-makers and managers in better managing natural resources for sustainable development. This approach holds significant potential for improving environmental conditions and addressing economic and social challenges by analyzing watershed sustainability. This study acknowledges certain limitations, such as the lack of precise and long-term data in some areas and the absence of local stakeholders' perspectives and indigenous knowledge in the assessment process, which may affect the comprehensiveness and accuracy of the results. Although the proposed recommendations are generalizable, their effectiveness depends on their adaptation to the specific conditions of the region. It is recommended that future studies utilize local indicators, more accurate field data, and active participation of local communities to achieve a more precise and reliable sustainability assessment.

Acknowledgments

The authors hereby express their sincere appreciation and gratitude to all individuals who contributed to the completion of this research.

Author’s Contributions

E Fathi and Z Akbari: Writing – Preparing the main draft - Performing calculations and software - Editing the article, A Talebi, MR Ekhtesasi, abd J Mosaffaie: Analyzing and reviewing data - Supervising the research process.

Conflict of Interest

All authors declare that they have no conflicts of interest in the publication of this paper.

Ethical Permission

No ethical approval was required for this study.

References

1. Harris J.M. Basic principles of sustainable development. Dimens. Sustain. Dev. 2000;1:21-40.
2. Asadi Nalivan O., Saravi M.M., Zahedi Amiri G.Z., Samani A.N. Comparison of two methods of IUCN and watershed, range and forest management in assessing watershed sustainability (case study: Talleghan-Zeidasht). J. Watershed Manag. Res. 2015;6(11):73-89.
3. Hazbavi Z., Sadeghi S.H.R. Watershed health (Part three): Vigor, organization, and resilience conceptual model. Ext. Dev. Watershed Manag. 2017; 5(16):1-7.
4. Kheirandish H., Sadeghipour A., Mohammadi Kangarani H. An Evaluation of the Bakhtegan Watershed Sustainability Using the HELP Model. J. Watershed Manag. Res. 2021;34(2):48-60.
5. Sadeghi S.H.R., Sadoddin A., Asadi Neivan O.A., Hezbavi Z., Zarekarizi A., Moayeri M.H. Watershed health and sustainability (fundamentals, approaches and assessment methods). Tarbiat Modares University Publications. 233p.
6. Mirchooli F., Sadeghi S.H.R. (Comparative Analysis of Watershed Health and Sustainability)Technical Note. J. Water Sustain. Dev. 2019; 5(2):163-168.
7. Yilmaz B., Harmancioglu N.B. An indicator-based assessment for water resources management in Gediz River Basin, Turkey. J. Water Resour. Manag. 2010; 24(1):4359-4379.
8. McLaren R.A., Simonovic S.P. Evaluating sustainability criteria for water resource decision making: a case study from the Assiniboine delta aquifer region. Can. Water Resour. J. 1999; 24(2):147-163.
9. Sadeghi S.H.R., Hazbavi Z. Spatiotemporal variation of watershed health propensity through reliability-resilience-vulnerability based drought index (case study: Shazand Watershed in Iran). Sci. Total Environ. 2017; 587(1):168-176.

[DOI: 10.22034/ECOPERSIA.13.2.165]

10. Ahn S.R., Kim S.J. Assessment of watershed health, vulnerability and resilience for determining protection and restoration Priorities. Environ. Model. Softw. 2019; 122:103926.
11. Hazbavi Z., Sadeghi S.H.R., Gholamalifard M., Davudirad A.A. Watershed health assessment using the pressure–state–response (PSR) framework. Land Degrad. Dev. 2020; 31(1):3-19.
12. Alilou H., Rahmati O., Singh V.P., Choubin B., Pradhan B., Keesstra S., Ghiasi S.S., Sadeghi S.H. Evaluation of watershed health using Fuzzy-ANP approach considering geo-environmental and topo-hydrological criteria. J. Environ. Manag. 2019;232(1):22-36.
13. Mosaffaie J., Salehpour Jam A. Assessment of the Kalaji watershed health based on hydrological and geomorphological criteria: relative and absolute approaches. AQUA-Water Infrastruct. Ecosyst. Soc. 2024; 73(9):1854-1867.
14. Gatgash Z.E., Sadeghi S.H.R. Comparative effect of conventional and adaptive management approaches on watershed health. Soil. Tillage. Res. 2024;235:105869.
15. Chandniha S.K., Kansal M.L., Anvesh G. Watershed sustainability index assessment of a watershed in Chhattisgarh, India. Curr. World. Environ. 2014; 9(2):403.
16. Xia J., Zhang Y., Zhao C., Bunn S.E. Bioindicator assessment framework of river ecosystem health and the detection of factors influencing the health of the Huai River Basin, China. J. Hydrol. Eng. 2014; 19(8):04014008.
17. Momenian P., Nazarnejhad H., Miryaghoubzadeh M., Mostafazadeh R. Assessment and prioritizing of sub-watersheds based on watershed health scores (case study: Ghotorchay, Khoy, West Azerbaijan). J. Watershed Manag. Res. 2018; 9(17):1-3.
18. Preciado-Jiménez M., Aparicio J., Güitrón-de-los-Reyes A., Hidalgo-Toledo J.A. Watershed sustainability index for the Lerma-Chapala Basin. Tecnol. Cienc. Agua. 2013;4(4):93-113.
19. Barkey R.A., Nursaputra M. The Detection of Forest Health Level as an Effort to Protecting Main Ecosystem in the Term of Watershed Management in Maros Watershed, South Sulawesi. InIOP Conference Series: Earth Environ. Sci. 2019; 270 (1): 012006. IOP Publishing.
20. Heirany A.R., Behzadfar M., Hazbavi Z. Analyzing the sustainability level based on the ecological-anthropogenic balance in the Toutli Watersheds. Geogr. Environ. Sustain. 2021;11(3):9-30.
21. Jahdi R., Hazbavi Z. Evaluation of Watershed Scale Forest Ecosystem Health by Remote Sensing and Forest Health Monitoring (FHM) Method. J. Environ. Sci. Stud. 2024;8(4):7612-7627.
22. Davoudi Moghaddam D., Haghizadeh A., Tahmasebipour N., Zeinivand H. Spatial and temporal water quality analysis of a semi-arid river for drinking and irrigation purposes using water quality indices and GIS. ECOPERSIA 2021; 9(2):79-93.
23. Engineering Advisory Firm of Catchment Plan., 2007. Detailed executive studies of the Malekshahi Watershed.General Natural Resource Office of Ilam Province.
24. Lu Y., Wang R., Zhang Y., Su H., Wang P., Jenkins A., Ferrier R.C., Bailey M., Squire G. Ecosystem health towards sustainability. Ecosyst. Health Sustain. 2015; 1(1):1-5.
25. Mottahedin P., Abdoos A. Evaluation of Hablehroud River Water Quality Using Iran Water Quality Index for Surface Water Resources-Conventional Parameters (IRWQISC) and Response Surface Methodology. Iran. Water. Resour. Res. 2021; 22;17(3):1-9.
26. Esmaeilzadeh M., Zare Bidaki R. Human Resources Potential Analysis in Chaharmahal Bakhtiari Province Using Human Development Index. J. Econ. Dev. Sociol. 2020; 20;8(2):1-21.
27. Rani G., Kaur J., Kumar A., Yogalakshmi K.N. Ecosystem health and dynamics: An indicator of global climate change. Contemp. Environ. Issues Challenges Clim. Change. 2020:1-32.
28. Mosaffaie J., Salehpour Jam A.S., Tabatabaei M.R., Kousari M.R. Trend assessment of the watershed health based on DPSIR framework. Land use policy. 2021; 100:104911.
29. Chen M.H., Chen F., Tang C.J., Lu Y., Feng Y.X. Integration of DPSIR framework and TOPSIS model reveals insight into the coastal zone ecosystem health. Ocean Coast. Manag. 2022; 226:106285.
30. Rahimi Haghighi A., Ghanbari S.A., Asgharipour M.R. Assessing the sustainability of ecosystems in the Khosrow-Shirin-Abadeh watershed. J. Arid Biome. 2022;12(1):121-40.
31. Mirchooli F., Sadeghi S.H.R., Darvishan A.K., Strobl J. Multidimensional assessment of watershed condition using a newly developed barometer of sustainability. Sci. Total Environ. 2021;791:148389.
32. Li Z., Xu D., Guo X. Remote sensing of ecosystem health: opportunities, challenges, and future perspectives. Sensors. 2014; 14(11):21117-21139.
33. Mosaffaie J., Salehpour Jam A., Tabatabaei M.R., Gharibreza M.R. Developing watershed management strategies using SWOT and QSPM techniques. Intl. J. Environ. Sci. Technol. 2025; 27(1):1-3.

[DOI: 10.22034/ECOPERSIA.13.2.165]