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An Integration of Remote Sensing and the DPSIR Framework to Analyze the Land-Use Changes in the Future (Case study: Eskandari Watershed)

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ABSTRACT

Aims: This research analyzes the land-use change over the past, present, and future 20 years. In this regard, remote sensing and the DPSIR framework were integrated to analyze the land-use change in the Eskandari Watershed located in the Zayandehroud Watershed.

Materials & Methods: Through conducting a workshop and stakeholder interactions, a list of drivers (D), pressures (P), changes in the state of the land-use (S), subsequent impacts (I), and responses (R) were identified and analyzed within the DPSIR framework. Satellite images of Landsat 5 and 8 (2011 and 2021) and the Markov chain model for predicting land-use changes (2031) were used to assess land-use change dynamics. Land-use maps of the three dates, focus group discussions (FGDs), expert experiences, and stakeholders through an interview and questionnaire method were applied to identify the components of changes based on the DPSIR framework.

Findings: The results showed that in 2011, 2021, and 2031, irrigation and dry farming were the dominant land-use types in the Eskandari Watershed, covering 42.16%, 40.66%, and 52.19% of the total area, respectively. Also, Moderate rangeland (28.57%) in the Eskandari Watershed showed a declining trend. Furthermore, the major drivers for the increasing rate of land-use changes in The Eskandari Watershed were employment and food, water requirements, climate change, and drought. These drivers caused increased disputes and conflicts between local communities and stakeholders related to the utilization of water resources. They were identified as the most critical impacts of land-use change in the study area. In this regard, the non-compliance of water right and the decrease in the stability of surface and underground water were introduced as the significant state from the viewpoint of stakeholders and experts. Finally, the appropriate management responses are developing optimal allocation programs for water consumption, regulation of water rights, monitoring, and law enforcement to prevent land-use change.

Conclusion: Due to the increasing trend of land-use change in the future and the ineffectiveness of solutions in the past years, in order to prevent the cross-sectional solutions of the problems, it is recommended to use the DPSIR comprehensive approach for problem-solving and optimal management responses.

Keywords: DPSIR Framework; Land-use Change; Markov Model; Watershed Management.

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Introduction

Information about land-use is required for planning and sustainable management of natural resources, as land-use substantially impacts the functioning of socioeconomic and environmental systems, with significant tradeoffs for sustainability, biodiversity, and socioeconomic vulnerability of people and ecosystems [1]. Land-use changes have become synonymous with contemporary global discussions as these are intertwined and impact many aspects of livelihoods and socioeconomic developments [2,3]. Whereas land-use includes the natural physical features of the land and artificial structures that form the landscape, land-use covers how humans utilize land and its associated resources [4]. There are many drivers of land-use change at the international level, and they are divided into two main categories, i.e., proximate and underlying [5,7]. The proximate drivers directly impacting watersheds include natural phenomena associated with climate, droughts, topography, deforestation, agriculture, and wildfires [8]. The underlying drivers, with indirect consequences, include population density, poverty, the land tenure system, and weakly implemented regulations and policies [9].

Different ways have been used to identify land-use changes, including geographical information systems (GIS) and remote sensing using satellite data [10]. Remote sensing data are proper sources for assessing land-use [11]. With the invention of remote sensing techniques, land-use mapping has given a valuable and detailed way to improve the selection of areas designed for agricultural and urban areas [12]. Remote sensing technology is also essential for monitoring and quantifying the natural resources and dynamic phenomena on the Earth's surface [13]. In recent years, remote sensing data have effectively assessed long-term changes in land-use [14]. In this regard, there are several models available to classify land-use and cover using remote sensing (RS) techniques and geographic information systems (GIS), including but not limited to supervised and unsupervised classification techniques [15]. With the advent of more sophisticated models, it is now possible to evaluate former and current land cover and uses and project it onto the foreseeable future [16]. Among these models is the Markov Chain model, which calculates future changes based on past events [17]. In addition, the Markov-CA is a robust approach for predicting land-use change that has been recommended because it outperforms other methods [18]. In this regard, several studies with different objectives have been conducted by researchers [19,31].

On the other hand, rapid land-use changes are observed globally [32]. Thus, land-use change detection and analysis are crucial for understanding landscape dynamics over a known time frame [33]. Population growth and economic activities have quickly transformed land-use [34]. Humans and the interaction between natural and anthropogenic processes have significantly changed the surface of the Earth through time [35]. Studies by Wang et al. (2008) indicated socioeconomic development as the main driving force of land-use change in the Tibetan plateau (China). Others proved in their investigations that land-use change is a combination of the effects of anthropogenic activities, such as the expansion of farmland, and fundamental social processes, such as population growth, and impacts of policy, institutional settings, and cultural factors [37]. In this regard, using the driver, pressure, state, impact, and state (DPSIR) model to link socioeconomic growth effects on the environment [38] has also gained popularity. It effectively describes the cause-effect associations between human-led development sectors and the environment

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[39] and links its component elements [40]. The model's credibility is on its ability to serialize human effects on the environment, from drivers to the responses [41], and for establishing information on the status of the environment [42]. Thus, it is an essential tool for decision-makers, policy-makers, water and land managers, and the general public for effective and sustainable management [43] at regional and local levels [41]. In addition, unlike the remote sensing approach, the model allows researchers to interact with communities, identifying local drivers, pressures, states, impacts, and response mechanisms. Therefore, it provides a platform where local community knowledge can be incorporated into the scientific aspects of particular natural resources, bridging the gap between science and management and policy developments/ reviews [44]. Some research in this regard can be mentioned as follows: Tscherning et al. [2012]; Zhou et al. [2013]; Hashemi et al. [2014]; Gari et al. [2015]; Lewison et al. [2016]; Spano et al. [2017]; Ehara et al. [2018]; Haque et al. [2019]; Gedefaw et al. [2020]; Rasool et al. [2021]; Obubu et al [2022]; Quevedo et al [2023]; Von Dohren and Haase [2023].

The research summary shows that although the Markov and DPSIR methods have been used with different objectives, the land-use change prediction with the Markov and DPSIR methods has yet to be investigated. Therefore, this research aims to analyze the land-use change over the past, present, and future 20 years in the Eskandari Watershed in

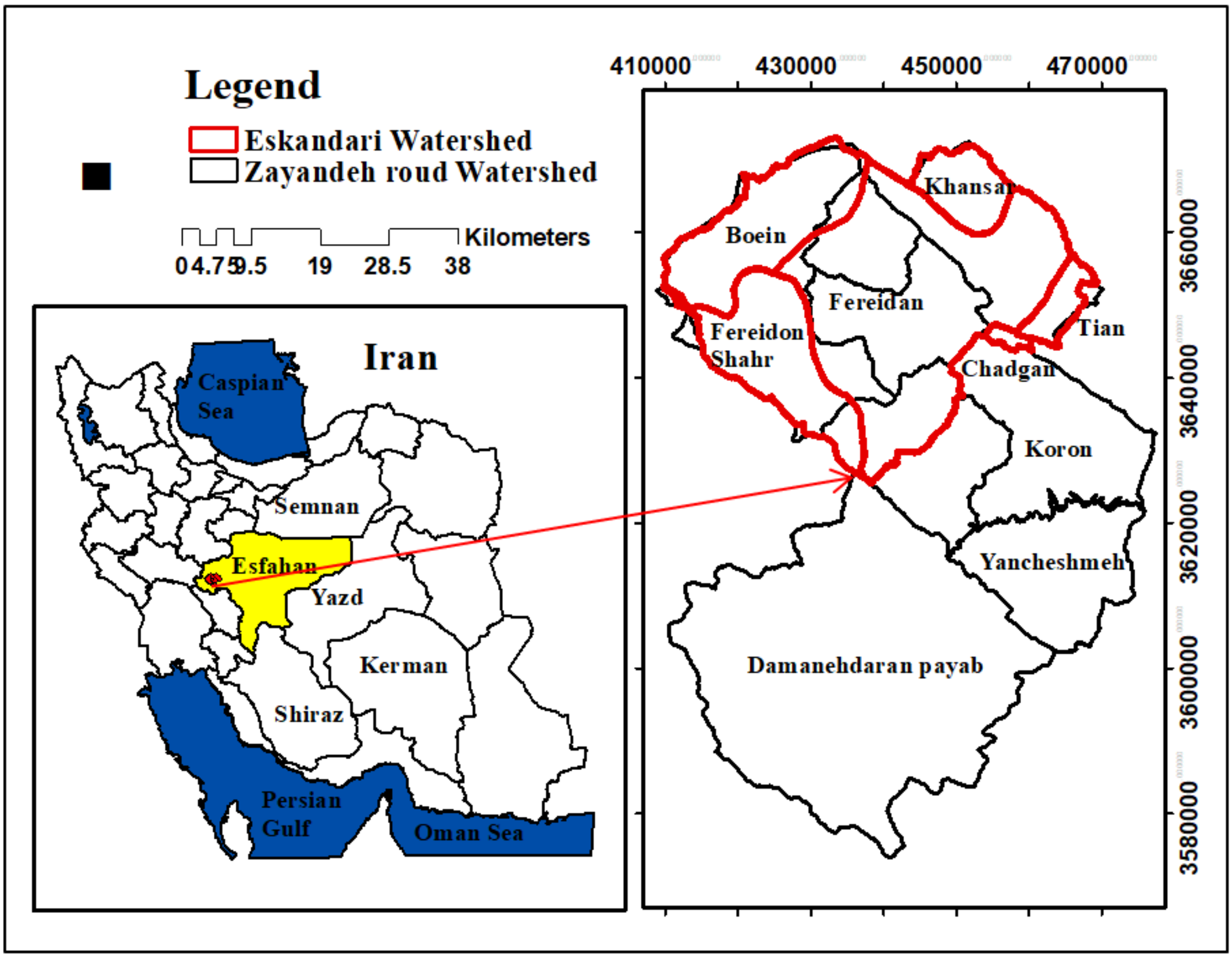

Figure 1) Location of the Eskandari Watershed in Iran.

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the Zayandehroud Watershed. The research used focus-group discussions (FGDs), key informant interviews (KIIs) with indigenous knowledge and stakeholder interactions, and field observations to identify these drivers, pressures, state, impacts, and managerial responses.

Materials & methods

Study area

The present study was conducted for the Eskandari Watershed in Esfahan Province, Iran (Figure. 1). The Eskandari Watershed is one of the upstream sub-watersheds of the Zayandehroud Dam (50°20′ to 50°30′ E and 32°42′ to 33°11′ N). This watershed is one of the most essential primary sources of the region's agricultural water supply, drinkable water, and industry. Also, The Eskandari Watershed is one of the important upstream watersheds of the Zayandehroud Dam that covers approximately 1649 km^2. The mean annual temperature and rainfall of the study area are 13.5 °C and 339 mm, respectively. The population of the Eskandari Watershed is over 164,000 and includes the cities of Boein-Miandasht, Tiran-Koron, Chadgan, Khansar, Fereidan, and Fereidon Shahr. Major land-uses include agriculture and rangeland; the main crops are wheat and barley.

Methodology

The flowchart of the methodology is presented in Figure 2. This flowchart includes a detailed description of the methodology steps. According to this, the satellite images of Landsat 5 TM from 2011 and Landsat 8 OLI from 2021 were used to produce the land-use maps. Landsat images with a spatial resolution of 30 m were downloaded from the United States Geological Survey (USGS) (https://earthexplorer.usgs.gov/). The following details and other information about the data utilized for this research are summarized in Table 1.

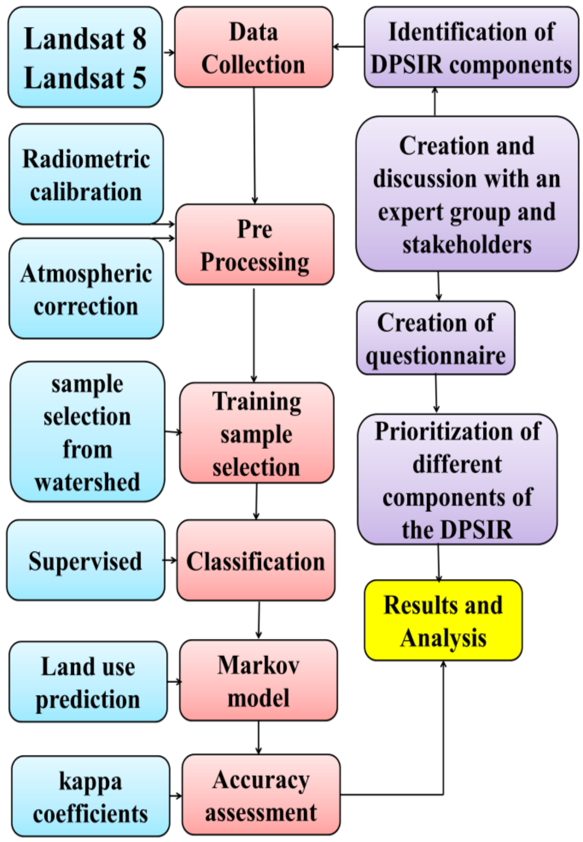

Figure 2) Flowchart of the methodology.

- Image pre-processing

Different pre-processing techniques were applied using ArcGIS 10.6 and ENVI classic 5.3 software to prepare the Landsat TM and OLI images for mapping the land-use changes [58]. The image pre-processing techniques include layer stacking, mosaicking, and subsetting or clipping to the borders of the study area. After that, the images were radiometrically corrected using the atmospheric correction function [58]. Finally, the images were geometrically co-registered, ortho-rectified, and atmospherically corrected. Multi-temporal images assessed by different sensors were resampled to 30 m resolution, applying nearest neighbor resampling because of the ability to preserve the original values in the unaltered scene [59].

In the following, after performing the image pre-processing, the training dataset for each LULC class was obtained using the Google

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Table 1) List of the satellite data used in the Eskandari Watershed.

SL. No	Date	Sensor type	Path/Row	Resolution (m)	Image Type
1	2011/7/12	Landsat 5 TM	130/38	30	Level-1 Geo TIFF
2	2021/7/16	Landsat 8 OLI	130/38	30	Level-1 Geo TIFF

Earth images and field points [60]. There is no universally accepted single benchmark of sample size for reference data points. According to Lillesand et al. [2008], at least 50 samples for each of the seven land-use classes were selected to ensure a representative sampling. Finally, to ensure representative sampling, at least 60 points were taken from the study areas [62], and a map with a raster structure was prepared (Figure 4).

- Land-use classification

This research applied supervised classification on Landsat images [63]. Supervise classification was chosen because of its accuracy for a large area [14]. A supervised approach for image classification was adopted, with the maximum likelihood rule used as a parametric rule [64]. This classification mode is considered a simple, powerful approach if precise samples were employed in the software training [65]. The images were classified by selecting accurate polygons as training areas based on a field survey of the study area [20]. Therefore, the land-use classifications for the two years (2011 and 2021) were carried out by supervised pixel-based classification with a maximum-likelihood classifier (MLC). This technique was selected as it takes the normal distribution of a cloud of points and parameters to compute the statistical probability of a given pixel value being a member of a particular land-use class [61]. In addition to the reflectance values, this tool considers the covariance of the information in the sensor's spectral bands of land-use classes [66]. Finally, this approach is more likely to consider minority classes that larger classes in unsupervised training can swamp. Supervised classification is based on reference data where land-use is known. Based on these data, a maximum likelihood classification was applied to produce the land-use maps of 2011 and 2021 for the whole study area.

- Land-use change prediction

Numerous methods, such as mathematical-equation-based, spatiotemporal modeling [67], system dynamic simulation [68], statistical, cellular and hybrid models [69], cellular and agent-based models or a hybrid of the two [70], and the cellular automata–Markov chain (CA-Markov) model [71], have been utilized in different research. The remote sensing and GIS datasets defined CA-Markov initial conditions, model parameterization, transition probabilities calculations, and neighborhood rules determination [72]. The CA-Markov model is one of the most ideal and widely accepted methods for land-use modeling because it considers 't-1' to 't' to project probabilities of land-use for the future date 't+1' [73]. The probabilities are generated based on past and future changes [73]. The CA-Markov model can simulate changes in different land-use and can simulate the transition from one category of land-use change to another [73]. However, a combined CA-Markov model to simulate future land-use by integrating natural and socioeconomic data is still challenging due to the different datasets [74].

In this regard, the prediction of the land-use information for this research was

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undertaken with the cellular automata–Markov (CA–Markov) model. The Markov model was used to calculate the amounts of change that may occur to some selected locations in the future [75]. The Markov model is a stochastic process model that describes the probability of change from one state to another. The transition probability would be that a land-use type (pixels) at the time t_0 changes to another land-use type at the time t_1. Therefore, changes in land-use among the dates were used to develop a probability transition matrix and then predict land-uses for a future time. This matrix is the result of the crossing between the images by setting a proportional error. The combination of Markov and Cellular Automata (CA-Markov) allows simulation of the evolution of the geographical area represented by pixels. Also, to evaluate the accuracy, model validation is needed. Thus, the validation process aims to compare the accuracy of the 2019 projected map to the 2019 classified Land-use map [76]. A sample of 50% was used for training, with the remaining 50% kept for validation [77]. The predictions were compared to the classified using the Kappa index statistic [20].

- Accuracy assessment

After classification, ground verification was done to check the precision of the classified land-use map [78]. In this regard, accuracy assessment helps to understand how precisely the maps use the data accurately and effectively [28]. The accuracy of the classification was assessed using randomly selected reference sample points. The accuracy measures, such as overall accuracies, kappa coefficients, and user's and producer's accuracies, were calculated, and an error matrix of the land-use classification was generated [29, 79]. The classification error matrix was generated for validation points and classified data. The literature recommends the Kappa coefficient (KC) to measure and compare the accuracy of the image classification. Overall accuracy (OA), producer accuracy (PA), and consumer accuracy (CA) derived from the confusion matrix are analyzed for each classification [80,61].

- DPSIR framework

To manage land-use sustainably, it is necessary to understand the causes (drivers, pressures) of change and their interactions. To do that, we used the DPSIR framework. The DPSIR framework has developed the Organization for Economic Co-operation and Development [81] and has been used widely by international agencies [82]. This framework helps to understand the interacting factors and interfaces that change the environment. Drivers are forces that cause socioeconomic and sociocultural forces that change in order to fulfill basic needs. These forces can be global, regional, or local.

Using indicators to describe, quantify, and monitor the individual process components improves the performance of the DPSIR approach [82]. Figure 3 illustrates the DPSIR framework at its most basic [83]. In this regard, a driver refers to various factors that may lead to a system's change or behavior. They may be caused by nature or by human beings. Drivers can be divided into direct and indirect drivers [82]. Pressures are stressors caused by driving forces on the environment, such as land-use change. State is the condition of the land-use in terms of its constituents. The state of land-use may be altered depending on the pressures exerted. Impacts are changes in land-use that affect human well-being. Responses are the reactions of humans to perceived changes in land-use. Responses can be at different levels, including policy and local actions for remediation. Responses can address the pressures or attempt to maintain or improve the state of the land-use [84]. As an example, increased demand for food (Driving force) can lead to the intensification of agriculture via increased fertilizer use, resulting in the increase of nitrate runoff into nearby streams

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(Pressure), leading to the eutrophication of downstream water bodies (State) and subsequent changes in the aquatic life and biodiversity (Impact). One means to address this situation (Response) would be to increase taxes on fertilizer; another would be to require changes in land management practices to reduce nitrate leaching [83].

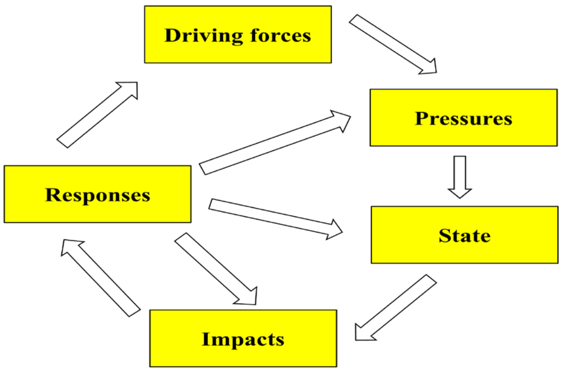

Figure 3) The Driving forces, pressures, state, impacts, and responses framework [83].

- Data analysis of DPSIR framework of land-use change

Data was collected using three principal approaches: focus group discussions (FGDs), key informant interviews (KIIs), and field observations. KIIs often supplement other research methods, such as FGDs and surveys [85]. Within the hierarchy of research methods, KIIs may be inadvertently positioned as producing more valuable knowledge because of the status and expertise of the key informant. Key informants are perceived as providing necessary knowledge—more knowledge than might be contributed by interviews with "ordinary" people [85]. Key informants may be "elites" who maintain a high social position in a particular context [86]. They may be community leaders or experts on an issue who act as "owners" of essential contextual knowledge [87]. Engaging with critical informants is particularly important for gaining "insider" knowledge, including on sensitive topics where an FGD might not offer the same freedom to share knowledge [88]. In this regard, the focus group discussion (FGD), also called group interviewing, is a qualitative research methodology. It is based on structured, semi-structured, or unstructured interviews. It allows qualitative researchers to interview several respondents systematically and simultaneously [89]. The FGDs is a key that was first developed in the 1920s [90], formalized in the 1940s [91], and has been refined and widely used by various scientists for qualitative data collection [92]. In this method, focus groups consisted of a minimum of 12 and a maximum of 15 members, although there were 30 members in the Eskandari Watershed. Many authors have recommended and used fifteen members for each FGD to allow members to express themselves [93]. Open-ended questions were administered on the types of land-use changes and the drivers, pressures, states, impacts, and responses to land-use changes. For example:

- What are the main drivers of land-use change in the region?
- What pressures have been created due to land-use change in the region?
- How do government or provincial directors act on reports of land-use change?
- What is the management procedure for dealing with land-use change? What about the people's committee?
- What was expected of you as an official or as a people's committee chairman/ people's representative/ leader during the land-use change?
- What steps did you take to manage the land-use change? What about the people's committee chairman/people's representative/ leader in the area?
- What were your worries about the land-use change?
- What were your worries about the land-use change management option you have

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chosen and recommended to stakeholders?

- What extension mechanisms were used to communicate to stakeholders about land-use change?

The creation of the FGDs and KIIs lasted three months, and the identification of cause-and-effect relations among the DPSIR components should be mentioned. Finally, the participants ranked the components of DPSIR according to the Likert scale, from 1–5 (1= most important, and 5= least important) [94]. In other words, the importance of each variable was examined from the perspective of experts and watershed residents [95].

In this research, 30 members from stakeholders (random sampling method) were selected as the sample size for the resident questionnaire. The opinion of 28 experts was also considered a large group decision-making to prioritize items [96]. The expert group consisted of experts from the Departments of Natural Resources and Watershed Management, Environment, and Regional Water, scientific members of the Universities of Yazd and Esfahan, and some village council members. Finally, Friedman's test analyzed two-way variance by ranking and comparing different groups' average rankings using SPSS software [95].

Findings

- Land-use change

The accuracy reports for the classified images in 2011, 2021, and 2031 are presented in Table 2. We compared the simulated and classified land-use maps using Kappa variations. The results show a high level of agreement. This result shows the model's reliability and strength in simulating future land-use changes in the Eskandari Watershed.

Table 2) Accuracy assessment results of land-use classification in the Eskandari Watershed.

Year	2011	2021	2031
Overall accuracy (%)	94.7	89.3	90.9
Kappa coefficient	0.89	0.85	0.85

In the following, the results of land-use maps of the Eskandari Watershed for 2011, 2021, and 2031 are documented graphically in Fig. 4. Quantitative details about the land-use in

Table 3) Changes in land-use class (Area) of the Eskandari Watershed in 2011, 2021, and 2031.

Types of land-use	2011		2021		2031		2011-2021	2011-2031
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(%)	(%)
Irrigation	7389.67	4.50	21273.73	12.97	13596.72	8.29	+8.47	+3.79
Dry farming	10710.87	6.53	-	0.00	-	0.00	6.53	0.00
Irrigation and dry farming	33056.77	20.16	66683.92	40.66	85581.52	52.19	+20.50	+32.03
Good rangeland	1241.84	0.75	-	0.00	-	0.00	0.75	0.00
Moderate rangeland	55767.28	34.01	6209.66	3.78	8926.96	5.44	-30.23	-28.57
Poor rangeland	42269.49	25.77	57420.66	35.01	53068.94	32.36	+9.24	+6.59
Fallow	9660.36	5.89	11089.92	6.76	-	0.00	+0.87	0.00
Rock	3873.53	2.36	1292.38	0.78	2795.64	1.70	-1.58	-0.66

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the respective years are presented in Table 3. In this regard, the current research identified that, for 2011-201, a high rate of land-use change was for irrigation and dry farming (20.50%), then poor rangeland (9.24%), and then irrigation farming (8.47%), followed by fallow (0.87%). Moderate rangeland (30.23%) and rock (1.58%) in the Eskandari Watershed showed a declining trend. From 2011 to 2031, the research identified a high rate of land-use change for irrigation and dry farming (32.03%), then poor rangeland (6.59%), followed by irrigation farming (3.79%). Moderate rangeland (28.57%) and rock (0.66%) showed a declining trend (Table 3). Based on the obtained results in 2011, 2021, and 2031, irrigation and dry farming was the dominant type of land-use in the Eskandari Watershed, covering 420.16%, 40.66%, and 52.19% of the total area, respectively. Each period saw an increase in irrigation and dry farming area, with the area increasing by 20.50% between 2011 and 2021 and 32.03% between 2011 and 2031. Also, moderate rangeland in the Eskandari Watershed showed a declining trend. In other words, in contrast to irrigation and dry farming, moderate rangeland in this region has decreased in each period.

- DPSIR framework

The list of DPSIR components is presented in Table 4. In other words, Table 4 lists all the answers received from farmers' lived experiences, knowledge, and experience of local communities, key stakeholders, and natural resources experts in the questionnaire survey but also includes factors mentioned in the focus group discussions. Also, relations among the DPSIR components related to

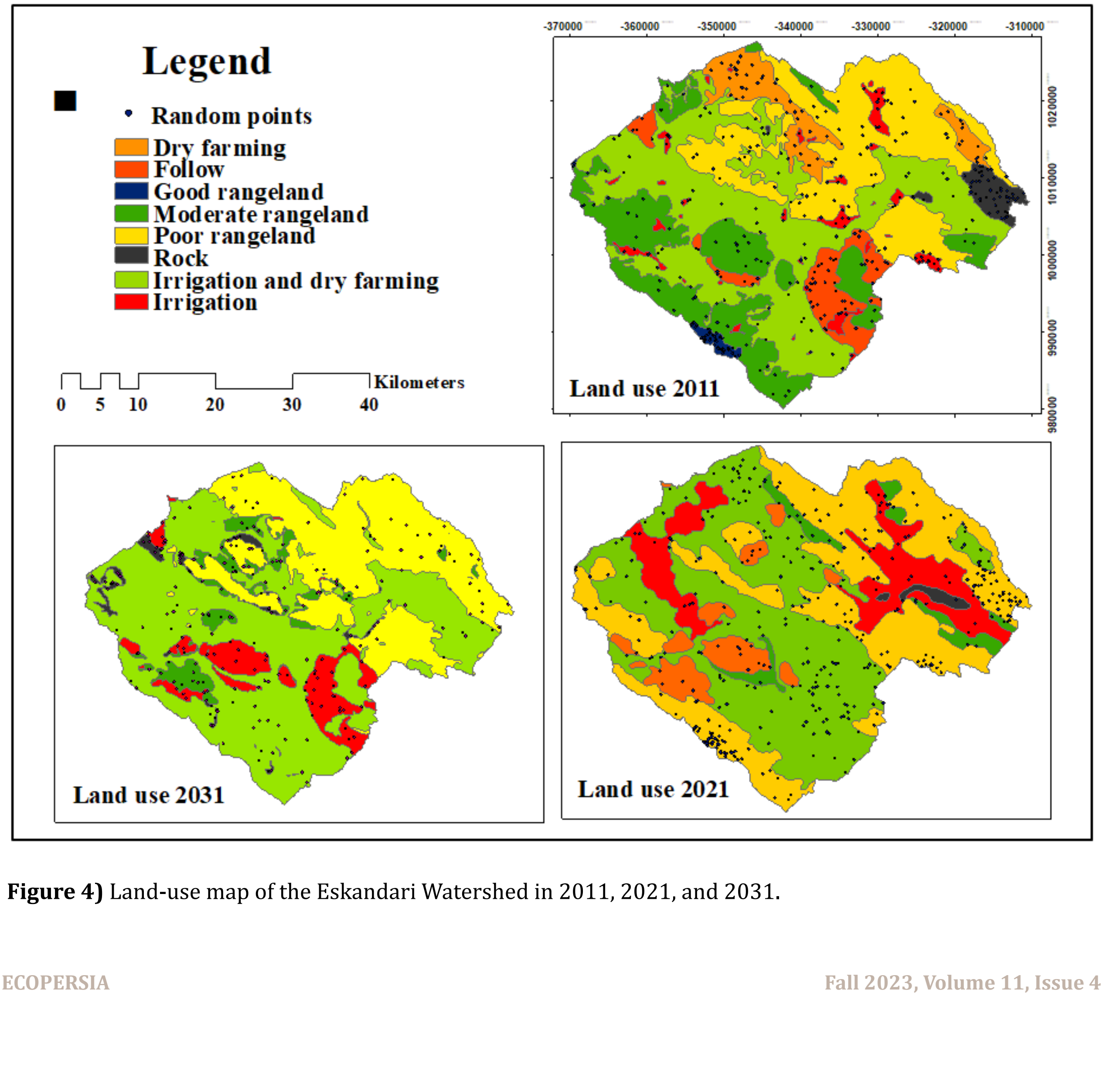

Figure 4) Land-use map of the Eskandari Watershed in 2011, 2021, and 2031.

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Table 4) List of DPSIR components (Drivers, pressures, state, effects, and solutions) for the Eskandari Watershed.

Drivers			
DPSIR components	Employment and food (D1)	Water requirements (D2)	Climate changes and drought (D3)
Pressures	- Development of improper agriculture (P1) - Livestock grazing in inappropriate season (P2) - Lack of market and cooperatives for the supply of agricultural and livestock products (P3)	- Excessive exploitation of the capacity of surface and underground water sources (P4) - Weakness of water resources utilization law (P5)	- Water and wind erosion (P6) - Increasing pressure on water resources as a result of drought (P7)
State	- Destruction of land-use (S1) - Reduction of soil fertility (S2) - Economic weakness of local communities (S3) - Reduction of grazing capacity and production of quality fodder (S4)	- Decreasing the level of stability of surface and underground water (S5) - Non-compliance of water right (S6) - Water quality reduction and sediment load increase (S7) - Increase in per capita consumption and imbalance between water supply and demand (S8)	- Disruption of hydrological balance (S9) - Changes in the quantity and quality of the habitats of the region (S10) - Intensification of flooding and water erosion (S11) - Change of cultivation pattern (S12) - Pollution of surface and underground water (S13)
Impact	- Disproportionate development of agricultural land (I1) - Reduction of household income (I2)	- Disputes and conflicts between local communities and stakeholders related to the utilization of water resources (I3) - Change in hydrological regimes (I4) - Destruction of pastures and quality land-use (I5) - Increase of surface and underground water pollution (I6) - Reduction of beauty landscape (I7)	- Increase of invasive plant species and lack of animal fodder (I8) - Reduction of agricultural and livestock products (I9) - Migration of local communities (I10) - Reduction of biodiversity (I11)
Response	- Monitoring and law enforcement to prevent land-use change (R1) - Supporting livestock farmers in providing fodder (R2) - Determination of alternative livelihood (R3) - Implementation of biomechanical measures to control flood and water storage (R4)	- Development of optimal allocation programs for water consumption and regulation of water rights (R5) - Restoration of springs and aqueducts (R6) - Presentation of new solutions and indigenous knowledge in the direction of water resources management (R7)	- Risk management and prevention of flood and drought events (R8) - Cultivation of crops adapted to the region (R9) - Modification of irrigation and modification of cultivation patterns (R10) - Modification of irrigation pattern (R11)

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land-use changes, various drivers, and their occurrence in The Eskandari Watershed are described in the following (Figure. 5).

Employment and food (D1): The pressures of the development of improper agriculture (P1), livestock grazing in inappropriate season (P2), and lack of market and cooperatives for the supply of agricultural and livestock products (P3) are some of the most important causes of the destruction of land-use (S1), reduction of soil fertility (S2), economic weakness of local communities (S3), and reduction of grazing capacity and production of quality fodder (S4) in the watershed, which have caused impacts of the disproportionate development of agricultural land (I1) and reduction of household income (I2). Monitoring and law enforcement to prevent land-use change (R1), supporting livestock farmers in providing fodder (R2), determination of alternative livelihood (R3), and implementation of biomechanical measures to control flood and water storage (R4) are the appropriate management responses in the Eskandari Watershed.

Water requirements (D2): Excessive exploitation of the capacity of surface and underground water sources (P4) and weakness of water resources utilization law (P5) are the most important causes of decreasing the level of stability of surface and underground water (S5), non-compliance of water right (S6), water quality reduction and sediment load increase (S7), and increase in per capita consumption and imbalance between water supply and demand (S8) in the watershed, which have caused impacts on the disputes and conflicts of local communities and stakeholders related to the utilization of water resources (I3), change in hydrological regimes (I4), destruction of pastures and quality land-use (I5), increase of surface and underground water pollution (I6), and reduction of beauty landscape (I7). In this regard, the development of optimal allocation programs of water consumption and regulation of water rights (R5), restoration of springs and aqueducts (R6), and presentation of new solutions and indigenous knowledge in the direction of water resources management (R7) are the management responses.

Climate changes and drought (D3): Water and wind erosion (P6) and increasing pressure on water resources as a result of drought (P7) are the most important causes of the disruption of hydrological balance (S9), changes in the quantity and quality of the habitats of the region (S10), intensification of flooding and water erosion (S11), change of cultivation pattern (S12), and pollution of surface and underground water (S13) in the watershed, which have caused different impacts including: increase of invasive plant species and lack of animal fodder (I8), reduction of agricultural and livestock products (I9), migration of local communities, and reduction of biodiversity (I11). In this regard, risk management and prevention of flood and drought events (R8), cultivation of crops adapted to the region (R9), modification of irrigation and modification of cultivation patterns (R10), and modification of irrigation pattern (R11) is to solve the problems.

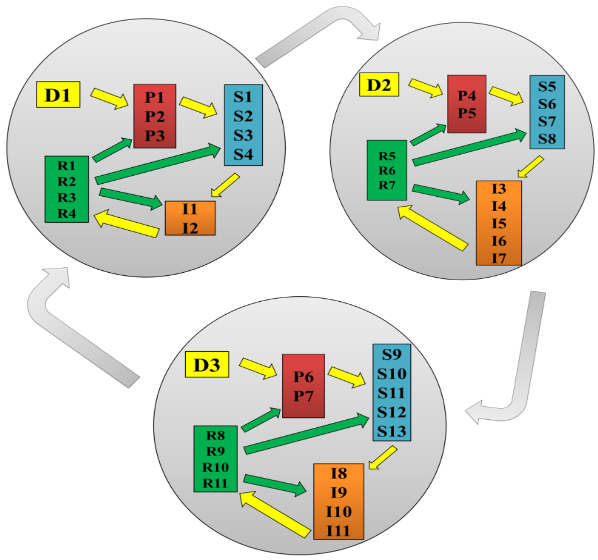

Figure 5) Relations among the DPSIR components related to land-use changes in The Eskandari Watershed.

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Table 5) Friedman's test results and prioritization of the different components of the DPSIR from the viewpoint of stakeholders and experts.

Viewpoint	Component	Number	Degree of Freedom	Min rank	Max rank	Sig	Prioritization
Stakeholders	Pressure	30	6	P3	P1	0.002	**P**5,4,2,1,7,6,3
	State		12	S3	S6		**S**6,4,9,8,5,12,1,6,10,1,11,3,13,2
	Impact		10	I6	I3		**I**3,5,9,11,1,2,4,8,11,7,6
	Response		6	R8	R5		**R**5,1,2,11,10,7,6,9,4,3,8
Experts	Pressure	28	6	P3	P4	0.000	**P**4,1,5,2,6,7,3
	State		12	S8	S5		**S**9,12,5,1,4,6,10,11,8,3,13,10,2
	Impact		10	I7	I3		**I**3,4,5,1,8,11,7,9,6,2,10
	Response		6	R3	R1		**R**1,11,10,5,2,7,9,6,4, 4,3,8

In the next step, after the preparation of the DPSIR conceptual map to observe the interactions and complex interactions between components, the pressures, state, impacts, and responses in terms of importance and frequency in different situations based on the same expert's viewpoint and stakeholders were ranked and prioritized (Table 5). Also, Friedman's test results of the questionnaires completed by stakeholders and experts are presented in Table 5. The statistical analysis results in Table 5 show that the viewpoint of experts and stakeholders was statistically significant ($P<0.05$).

Discussion

In this research, the decrease in the moderate rangeland of the watershed and the increasing trend of agricultural lands indicates the replacement and transformation of the natural cover of the region to agricultural lands. In the study of Caldas et al. [2010], the settlement formation process within a land-use was associated with destroying the natural cover. This increasing trend of agricultural lands shows the destruction of land-use. In addition, the poor rangeland has increased over time in the region. Also, as the prediction of land-use in the future shows, if this trend continues in the watershed, we will have the destruction of the natural cover of the region. The reasons for these changes were investigated from the stakeholder's viewpoint based on the DPSIR framework. Land-use changes are the result of a bundle of driving factors. Studies have documented that drivers for land-use change are technological, economic, demographic, political, institutional, and sociocultural [98]. Also, the results of Salehpour Jam et al. [2021] showed that employment (i.e., agriculture and ranching), climate change, population growth, land laws, and, finally, management and organization were the most important driving forces affecting the health of the Chehel-Chay Watershed. According to the current findings, studies in the Eskandari Watershed have indicated employment and food as critical drivers for land-use change. Long et al. [2007] also confirmed in a study on land-use change in Kunshan that expanding employment and food (population growth) are major driving forces contributing to land-use change.

In addition, overuse of land, climate change, scarcity of grazing land, and reduced farm size were also seen by the participants of the FGDs as essential factors of land-use change [100]. In this regard, due to the increase in the number of farmers in the region, receiving government services and support in the agricultural sector, and reducing and controlling land destruction can improve the livelihood of the beneficiary communities.

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In addition, it should be mentioned that the type of agriculture practiced also puts pressure on land. Therefore, changing the cultivation pattern can reduce pressure on the Eskandari Watershed. On the other hand, studies reported that the reduction in good and moderate rangeland has caused a lack of available suitable grazing lands, which has caused over-grazing and discouraged households from raising large-sized animals [101]. Almost all focus group discussants reported that the land-use change has severe consequences for soil erosion, causes a decline in normal feed, and worsens the production of crops and livestock [96]. In addition, the participants said that rapid population growth, a decline in agricultural production, and unstable economic growth have posed a severe migration challenge. Also, many studies around the globe [101] have investigated the negative impacts of land-use change on biodiversity loss. All these studies deduced that human-made land-use change has aggravated the loss of habitats and biodiversity fragmentation by increasing the vulnerability of biological populations to speculative risk loss [53]. Finally, responses are understood as actions to be taken by the government to mitigate adverse impacts of land-use change [97].

It should be mentioned that the major drivers for the increasing rate of land-use changes in the Eskandari Watershed were identified as employment and food (D1), water requirements (D2), and climate changes and drought (D3). Those drivers caused increased disputes and conflicts between local communities and stakeholders related to the utilization of water resources (I3). They were identified as the most critical impacts of land-use change in the study area. For example, agricultural and industrial sectors have created tensions between the stakeholders in water distribution in the Zayandehroud Watershed area. In this regard, the allocation of water to industries and the limitation of water resources reduced the stakeholders' participation and ignored their rights, so the drinking and sanitation and urban and industrial uses that did not have rights in Zayandehroud water have become shareholders of this water. In the meantime, due to the limitation of water resources in this watershed, farmers' rights have been reduced, and in some cases, the rights of many farmers have been ignored and even interrupted. This matter has caused loss and damage to the farmers and has become a serious challenge and a vast crisis.

In addition, from the viewpoint of stakeholders and experts, the development of optimal allocation programs for water consumption and improper agriculture (P1) and the excessive exploitation of the capacity of surface and underground water sources (P4) were identified as the most important pressure factors, which causes of different states including the most important cause of the non-compliance of water right (S6) and the decreasing the level of stability of surface and underground water (S5).

Finally, responses are understood as actions to be taken by the government to mitigate adverse impacts of land-use change [96]. In this research, 11 responses were identified and introduced to reduce the driving forces and related pressures, improve the state, and reduce the impacts of land-use change. In this regard, the development of optimal allocation programs of water consumption and regulation of water rights (R5) and monitoring and law enforcement to prevent land-use change (R1) are the appropriate management responses in the Eskandari Watershed.

Conclusions

In managing and planning the watershed, preparing land-use maps and recognizing the potential and capacity of lands is considered

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an essential source of information for adopting basic policies and compiling integrated management plans.

In this regard, using the Markov model, the current research analyzed the land-use change over the past, present, and future 20 years in the Eskandari Watershed located in the Zayandehroud Watershed. In addition, in order to identify the cause-and-effect relationships between components that determine effective characteristics of land-use changes, the DPSIR framework was used. The summary of the results can be presented as follows:

- Due to the increasing trend of land-use change in the future and the ineffectiveness of solutions in the past years, in order to prevent the cross-sectional solutions of the problems, it is recommended to use the DPSIR comprehensive approach to solve problems and find optimal management responses.
- Organization of joint meetings between all the stakeholders in order to reduce and solve problems;
- Attention to the opinions and suggestions of all the stakeholders;
- Strengthening supervisory and executive mechanisms and modification of laws in interaction with the existing pressures in the watershed. A fundamental review should be done regarding the laws and policies currently being implemented
- Creating compatible institutions with the watershed conditions should be a solution to equitable water allocation according to the stakeholders' needs.
- The increase in agricultural land is at a high rate. Maintaining this trend would require an enhancement of present land management practices. Information about appropriate cultivation techniques and soil and water conservation measures has to be given to the farmers to mitigate land degradation and improve the community's welfare in the area.
- Livestock are fed entirely on natural rangelands. Suppose this condition continues similarly in the future. In that case, land degradation can put the sustainability and health of agriculture and the availability of natural resources in the area at great risk, leading to a decline in the production of agriculture as well as a shortage of fodder for livestock.

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