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Compatibility of climate adaptation strategies with livelihood vulnerability patterns: the case of Fars province, Iran

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ABSTRACT

Pastoralists' livelihood on natural rangelands is increasingly influenced by the destructive impacts of climate change. While the phenomenon of climate change continues globally, it is expected to put more pressure on unfavourable rangelands and pastoral households whose livelihood source is only based on pastoralism activities. Thus, it is vital to reduce the livelihood vulnerability of pastoralists to climate change impacts through appropriate adaptation strategies. Accordingly, the aim of the current study was to assess the compatibility of adaptation strategies with the vulnerabilities posed by climate change to pastoralists' livelihoods. The evaluation was based on a spatial survey that was conducted with a random sample of 393 Iranian pastoralists distributed in the counties of Eghlid, Sepidan, and Shiraz in the northern Fars province. The results showed that pastoralists were commonly vulnerable in terms of high-risk exposure and low adaptive capacity. About 27 livelihood vulnerability patterns were detected using data mining based on the relationships among the sub-components of exposure, sensitivity, and adaptation in three counties. The scores of the livelihood vulnerability were high in most of the livelihood vulnerability patterns. Only four patterns obtained relatively low vulnerability scores through accurate decisions on adopting the appropriate set of adaptation strategies. According to the low compatibility of pastoralists' livelihood with climate change, the results of this study can assist policymakers to introduce appropriate adaptation strategies for pastoralists. In this regard, appropriate adaptation strategies in each vulnerability pattern are able to reduce livelihood vulnerability to climate change.

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Adaptive capacity; climate change; data mining; degraded rangelands; pastoral livelihood

1. Introduction

Climate change is one of the main challenges facing the global community, which has increasingly aroused concern (Arıkan and Günay 2020; Carlson et al. 2020; Ng'ang'a et al. 2020). Climate change affects environmental ecosystems, such as natural rangeland ecosystems, alters rangeland quality, and causes the extinction of animal and plant species. In addition, climate change is affecting agriculture, reducing forage production, and eroding soils (Ng'ang'a et al. 2020; Wüst-Galley, Volk, and Bassin 2020). In addition, livelihood (i.e. natural capital, physical capital, financial capital, social capital, and human capital) based on traditional agriculture and pastoralism activities has been recently affected due to climate change and degraded environmental ecosystems (McMillen,

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Ticktin, and Springer 2017). Another issue is that the unfavourable environment as a result of human activities is recognised as one of the major causes of climate change. For example, pastoral activity is one of the main spheres of the agricultural sector that is vulnerable to climate change. In this context, overgrazing of natural rangelands to provide food and maintain food security causes widespread degraded rangelands. Following the destruction of rangelands, carbon dioxide emissions, and greenhouse gases increase, leading to climate change (Nandintsetseg, Shinoda, and Erdenetsetseg 2018).

Pastoralists who are traditional farmers raising livestock, e.g. sheep and goats, on natural rangelands have suffered severe damage due to exposure to climate impacts, i.e. drought, untimely floods, and the devastation of natural rangelands (Feng and Squires 2018; Neibergs et al. 2018). There are 7,472,000 traditional pastoralists in Iran (Statistical Center of Iran 2020). Low-income pastoralists are more vulnerable to climate change according to Intergovernmental Panel on Climate Change (IPCC) (Kogo, Kumar, and Koech 2020). Due to the impacts of climate change, the number of pastoralists has decreased in the last decade and they have changed their livelihood activities (Statistical Center of Iran 2020).

According to the fourth assessment report of IPCC (2007), vulnerability to climate change is the degree to which a system is susceptible to and unable to cope with the adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the nature, magnitude, and extent of climate change and changes that a system is exposed to; its sensitivity; and its adaptive capacity (Amos, Akpan, and Ogunjobi 2014; Hahn, Riederer, and Foster 2009; Jamshidi et al. 2019; Lee et al. 2014; Mabon and Shih 2021; Omerkhil et al. 2020). Risk exposure indicates how much a household or community is at risk from climate impacts (Amos, Akpan, and Ogunjobi 2014; Hahn, Riederer, and Foster 2009; Hamidi, Zeng, and Marwat 2020; Issahaku and Abdulai 2020). The sensitivity is the degree to which a household or community is affected by climate impacts (Amos, Akpan, and Ogunjobi 2014; Endalew and Sen 2020; Hahn, Riederer, and Foster 2009). According to the dependence of traditional pastoral livelihood on climatic conditions and rangeland ecosystems, the sensitivity of pastoralists to climate change has increased which has reduced the climatic effects of pastoralists' livelihood. Adaptive capacity refers to the ability of a household or community to cope with and recover from the effects of climate change (Amos, Akpan, and Ogunjobi 2014; Hahn, Riederer, and Foster 2009; Thathsarani and Gunaratne 2018). In contrast to the livelihood vulnerability concept, adaptation aims to raise community resilience to climate change. It is a framework to manage future climate risks and to prioritise measures (Setten and Lein 2019). According to the UN definition, adaptation refers to modifications in natural or human systems in response to climate change or its effects, which mitigate harm or seize useful opportunities (IPCC TAR 2001). Pastoralists' adaptation strategies for climate variability comprise primarily livestock and rangeland management interventions, such as "purchasing fodder", "reducing livestock", "part-time grazing", and "renting rangelands" (Zhang et al. 2019).

A group of researchers has calculated vulnerabilities to drought due to climate change for traditional livelihoods based on agriculture and pastoralism in different countries (Adu et al. 2018; Dendir and Simane 2019; Jamshidi et al. 2019; Karimi, Karami, and Keshavarz 2018; Keshavarz, Maleksaeidi, and Karami 2017). Adu et al. (2018) evaluated the vulnerability of farming households to climate change using the livelihood vulnerability index with a specific emphasis on water resources in Ghana. Their results showed that farming households in the study area were differently vulnerable to climate change and weather variability in terms of vulnerability components. Thus, Adu et al. (2018) explained the consequences of implementing state plans to adapt farmers to climate change in the region. Dendir and Simane (2019) examined the livelihood vulnerability of farm households to climate variability and change in the Gurage zone, Ethiopia using livelihood vulnerability index approaches. Their results indicated that although there was a difference in vulnerability components score across various areas, the overall index showed that the lowland region was more vulnerable to climate variability and change. They asked officials to take specific steps to decrease farmers' vulnerability to climate change. In addition, Jamshidi et al. (2019) investigated the perceptions of farmers towards climate change, climate impacts, and the factors contributing to livelihood vulnerability in six counties of Hamadan province, Iran. They incorporated various indicators for measuring three components of livelihood vulnerability: risk exposure, sensitivity, and adaptive capacity. Their survey reported that climate change was perceived by most farmers at a high level, and they recognised this phenomenon as a result of human activities. Moreover, the livelihood vulnerability of the majority of farmers to climate change was relatively high. In another similar study by Karimi, Karami, and Keshavarz (2018), they found three patterns of low, medium, and high vulnerability for the livelihood of herder households in Mamasani County, Iran. Furthermore, they identified the main adaptation strategies adopted by the herders of this region. Some adaptation strategies including forage purchase, grazing rotation, herd composition, and post-harvest grazing have been adopted by a large number of herders. Keshavarz, Maleksaeidi, and Karami (2017) investigated the livelihood vulnerability of farm families to drought in Fars province, Iran. Their results showed that drought was the most important threat to livelihood security. Furthermore, farming households were categorised into three patterns of low vulnerability, moderate vulnerability, and high vulnerability. They applied various adaptation strategies in each pattern.

There are some shortcomings in previous studies assessing livelihood vulnerability (Karimi, Karami, and Keshavarz 2018; Keshavarz, Maleksaeidi, and Karami 2017). First, the relationships among the sub-components of livelihood vulnerability have been ignored in determining vulnerability patterns while considering those sub-components can provide more accuracy. Second, the adaptation strategies to reduce vulnerability have not been investigated. The current study aims to fill gaps by detecting vulnerability patterns in the form of association relations among the sub-components of livelihood vulnerability using data mining. The global novelty of this study is that with the interrelationships between the sub-components in each vulnerability pattern, it has assessed the contribution of adaptation strategies to reducing pastoralists' vulnerability. Thus, this study shows whether households' decisions in choosing adaptation strategies have reduced their vulnerability to climate change. Hence, the approach presented in the current paper can be helpful globally in facing the challenge of climate change.

Given the challenge of climate change in the form of the vulnerability of pastoral livelihood, it is necessary to implement an appropriate set of adaptation strategies. These strategies are to adapt to climate change and reduce the livelihood vulnerability of Iranian pastoralists. To successfully make adaptation decisions, all pastoralists need to be trained by stakeholders and rangeland managers about their vulnerability components and appropriate adaptation strategies. This action helps them to improve their understanding of their risks and vulnerabilities to climate change. Therefore, the main aim of the current study is to assess the compatibility of adaptation strategies to the vulnerabilities posed by climate change to pastoralists' livelihoods in the northern rangelands of Fars province in Iran. To this end, this study attempts to answer the following research questions:

How is climate change affecting the livelihoods of pastoralists in Fars province?
What are these vulnerabilities?
To what extent are the livelihoods of pastoralists compatible with increasing climate change and to what extent is vulnerability reduced through the adoption of adaptation strategies?

2. Methods

2.1. Survey area

The current study was conducted in the rangelands of three counties of Eghlid, Sepidan, and Shiraz located in Fars province, Iran (Figure 1), as these counties are the main residence of pastoralists. These areas have also faced the problems of climate change and reduced quality of rangelands in recent years. There are 12,348 pastoralists who graze sheep and goats on these rangelands according to the latest census (Statistical Center of Iran 2016). These rangelands which are communal lands

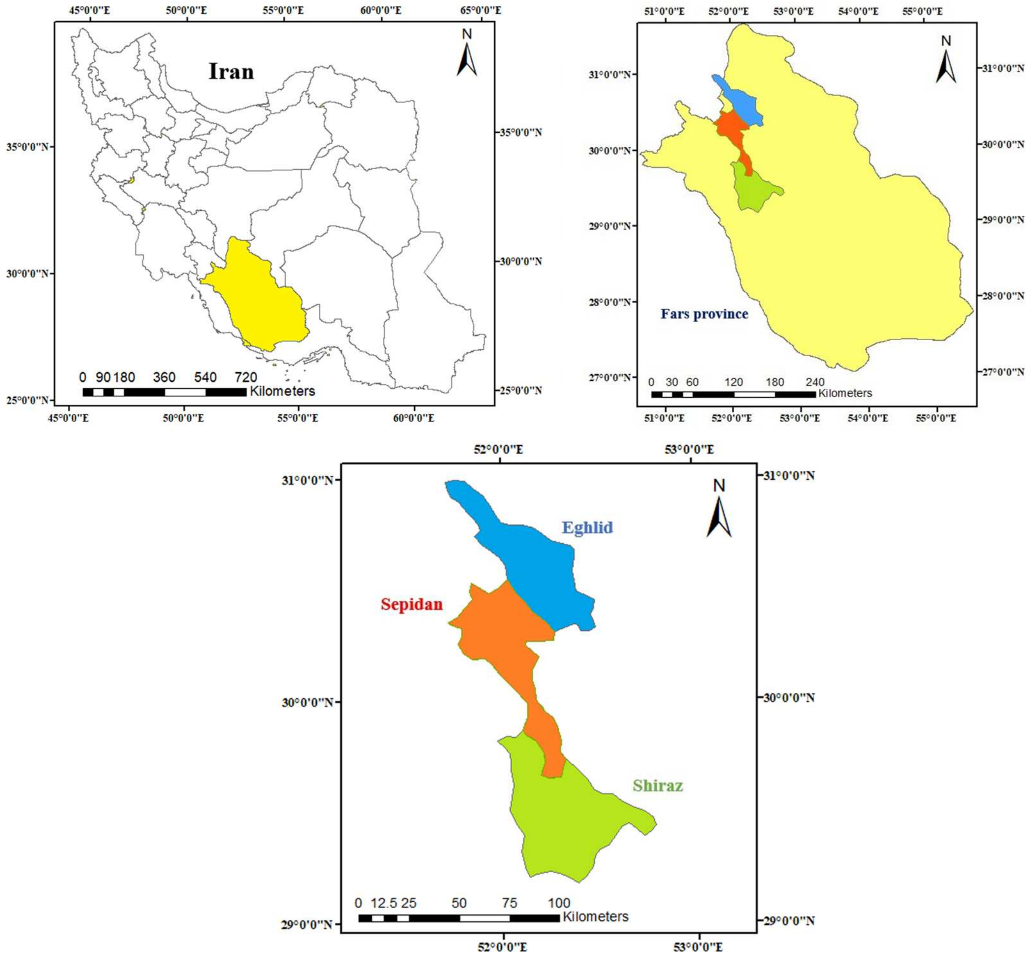

Figure 1. The location of Eghlid, Sepidan, and Shiraz in Fars province, Iran.

have an area of 73,744 Km^2. The studied rangelands are located in the northern zones of Fars province which is the pole of rangeland in Iran. Notwithstanding the drought resulting from climate change, Fars province is the first producer of mutton in the country with a production of more than 60 thousand tons per year (Agricultural Jihad Organization 2018).

Eghlid has an eastern longitude of 52° 41′ 12″ E and a northern latitude of 30° 53′ 56″ N that is located at an altitude of 2,250 m above sea level. This County has an extent of 7,054 Km^2 and a population of 90,869 (Statistical Center of Iran 2016). The climate of Eghlid is cold and semi-arid (Keshavarz and Karami 2016) and the quality of rangelands has recently decreased due to climatic reasons (Omidvar and Mohtasham Nia 2015). Sepidan, which is located at an eastern longitude of 52° 27′ 62″ E and a northern latitude of 30° 04′ 51″ N, has an altitude of 2,650 m above sea level. The County with an expanse of 2,846 Km^2 has a population of 51,166 (Statistical Center of Iran 2016). Sepidan climate is cold and humid (Keshavarz and Karami 2016) and has the largest number of pastoralists (2,147 pastoralists) in Fars province due to the relatively suitable rangelands (Khodahami and Zandi Esfahan 2015). Shiraz with an eastern longitude of 52° 31′ 52.07″ E and a northern latitude of 29° 36′ 37.12″ N has an altitude of 1,582 m above sea level. Shiraz County which is the capital of Fars province has an area of 6,049 Km^2 and a population of 1,869,001 (Statistical Center of Iran 2016). The climate of Shiraz County is temperate and semi-arid (Keshavarz and Karami 2016), and excessive pastoralism has led to degraded rangelands in the region (Habibyian and Barani 2019).

The sum of annual precipitation and the average temperature of the three counties were illustrated in Figure 2. Over a period of 30 years, the sum of annual precipitation in the counties decreased (Eghlid: −2.453; Sepidan: −0.314; Shiraz: −3.735) and the average temperature in those areas increased (Eghlid: 0.030; Sepidan: 0.007; Shiraz: 0.004) (Meteorological Organization 2020).

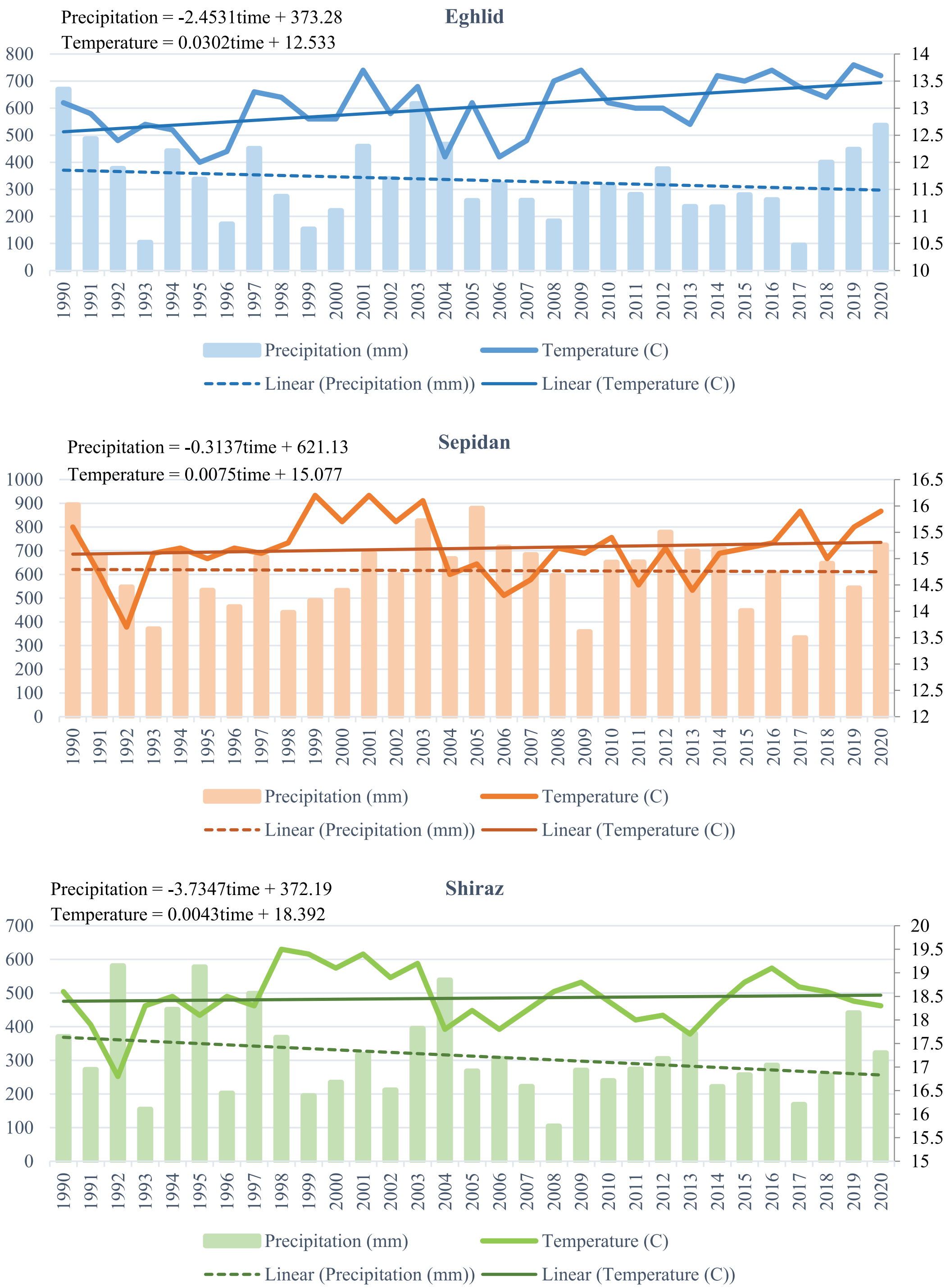

Figure 2. Sum of annual precipitation and average temperature of the three counties.

2.2. Sampling and questionnaire design

According to multistage cluster sampling, sample villages and pastoralists were randomly chosen. The formula of the sampling method is shown in Equation (1) (Scheaffer et al. 2012):

$$n = \frac{Nq(1-q)}{(N-1)D + q(1-q)} \tag{1}$$

In each stage of sampling, n, and N represent the statistical sample and pastoralist population, respectively, and q is the percentage of the pastoral households continuing pastoral occupation. A bound of error (B) was taken into account (0.10) and, therefore, $D = B^2/4$. Hence, the sampling procedure was performed in two steps as follows: first, sample villages in three counties of Eghlid (5 ones), Sepidan (15 ones), and Shiraz (four ones) were randomly selected. In the next step, 168, 149, and 76 sample pastoralists were randomly selected from the villages of Eghlid, Sepidan, and Shiraz, respectively.

The main instrument of data collection was a questionnaire that was designed in a semi-structured way and was reviewed by the faculty members of Shiraz University. The semi-structured questionnaire was effective in gathering data on the main components of livelihood vulnerability and adopting adaptation measures against climate change (Amos, Akpan, and Ogunjobi 2014; Dang et al. 2014; Karimi, Karami, and Keshavarz 2018). Face-to-face interviews were implemented with sample pastoralists in Fars province from May to September 2018. The interview with each pastoralist lasted about an hour. Two trained experts were used to interview the pastoralists. Finally, the collected data were used to evaluate livelihood vulnerability and discover adaptation strategies.

The questionnaire was designed for gathering the required data in four main components, including risk exposure, sensitivity, adaptive capacity, and adaptation strategies (Table 1). In the risk exposure component, it was examined to analyse to what extent pastoralists' revenue has been affected by climate change and degraded rangelands (Amos, Akpan, and Ogunjobi 2014; Karimi, Karami, and Keshavarz 2018). The sensitivity component actually surveyed the sensitivity of

Table 1. The main components and sub-components considered in the questionnaire.

Main component	Sub-component	Question
Risk exposure	Climate exposure	To what extent has pastoralists' revenue been affected by climate change, including drought, frost, and untimely floods?
	Rangeland exposure	To what extent has pastoralists' revenue been affected by degraded rangelands?
Sensitivity	Health sensitivity	To what extent has households' health been affected by climatic conditions?
	Nutrition sensitivity	To what extent has households' nutrition been affected by traditional pastoralists?
	Ecology sensitivity	To what extent has rangelands' ecology been affected by climate impacts?
Adaptive capacity	Time adaptation	To what extent have households had time to engage in other income earning activities?
	Budget adaptation	To what extent have households had the budget to engage in other income earning activities?
	Skill adaptation	To what extent have households had the skills to engage in other income earning activities?
Adaptation strategies	Diversification	To what extent have households diversified the income earning activities?
	Herd size	To what extent have pastoralists reduced their herd size?
	Fodder	To what extent have pastoralists fed their herds with fodder?
	Insurance	To what extent have pastoralists insured their herds?
	Substitution	To what extent have pastoralists substituted goats for sheep?
	Migration	To what extent have pastoralists migrated to more favourable rangelands?
	Evacuation	To what extent have pastoralists evacuated their rangelands?
	Restoration	To what extent have pastoralists restored their rangelands?
	Health	To what extent have households followed the health recommendations?
	Nutrition	To what extent have households reduced their nutrition dependence on traditional livelihood?
	Credit	To what extent have households received credits from banks and financial institutions?
	Skill	To what extent have households participated in skill courses to learn handicraft, apiculture, and fish farming?

Source: Study findings.

households and rangelands in terms of health, nutrition, and ecology to external stresses (Amos, Akpan, and Ogunjobi 2014; Karimi, Karami, and Keshavarz 2018). In the adaptive capacity component, it was investigated to analyse to what extent households have had the necessary resources to engage in other income-earning activities in addition to pastoralism (Dang et al. 2014; Karimi, Karami, and Keshavarz 2018). Finally, the adaptation strategies evaluated the set of measures taken by households to adapt to climate change. From a theoretical point of view, each adaptation strategy must address a specific vulnerability or adaptation capacity issue. The adaptation strategies considered in this study are in line with the actual recommendations of the United Nations FAO smart agriculture adaptation (FAO 2021). For all questionnaire components, respondents were asked to answer the questions taking into account the conditions of the last 30 years. According to 7-point Likert scales from one (not at all) to seven (totally), the considered sub-components were arrayed and categorised. In addition, Cronbach's alpha coefficients for all sub-components were higher than 0.7, which confirmed the reliability of the scales used in the current study.

2.3. Evaluating livelihood vulnerability to climate change

To evaluate pastoralists' livelihood vulnerability to climate change, the following two steps were followed: (1) determining the weight of the sub-components using principal component analysis and (2) generating the livelihood vulnerability index based on weighted averaging.

Using the principal component analysis, the weights were calculated for the sub-components of the main components, including risk exposure, sensitivity, and adaptive capacity. The analysis applied for this weighing is adopted from a study by Karimi, Karami, and Keshavarz (2018). One of the advantages of principal component analysis is that it examines the maximum observed variance of the explanatory variables by using the least number of components (Hair et al. 2010). The principal component analysis was performed using IBM SPSS Modeler version 18.0. Table 2 indicates the weights of the sub-components. The obtained weights for almost all the sub-components indicate that the considered sub-components mostly contribute to their corresponding components. The explained variation for risk exposure, sensitivity, and adaptive capacity was calculated to be 0.71, 0.57, and 0.63, respectively.

After determining the weight of the sub-components, the three main components were calculated by weighted averaging (Equation 2):

$$\begin{aligned} \text{Risk exposure}_{\,i} &= \left(\frac{\sum_{j=1}^{2} w_j \text{Exposure}_{\,ij}}{\sum_{j=1}^{2} w_j}\right) \\ \text{Sensitivity}_{\,i} &= \left(\frac{\sum_{j=1}^{3} w_j \text{Sensitivity}_{\,ij}}{\sum_{j=1}^{3} w_j}\right) \\ \text{Adaptive capacity}_{\,i} &= \left(\frac{\sum_{j=1}^{3} w_j \text{Adaptation}_{\,ij}}{\sum_{j=1}^{3} w_j}\right) \end{aligned} \tag{2}$$

Table 2. Weighing the sub-components using the principal component analysis.

Main component	Sub-component	Weight	Proportion of explained variation
Risk exposure	Climate exposure	0.94	0.71
	Rangeland exposure	0.06	
Sensitivity	Health sensitivity	0.38	0.57
	Nutrition sensitivity	0.35	
	Ecology sensitivity	0.27	
Adaptive capacity	Time adaptation	0.60	0.63
	Budget adaptation	0.22	
	Skill adaptation	0.18	

Source**:** Study findings.

Accordingly, *i*, *j*, and *w* indicate pastoralists, sub-component, and weight, respectively. Furthermore, exposure includes climate exposure and rangeland exposure. Sensitivity consists of health sensitivity, nutrition sensitivity, and ecology sensitivity. Finally, adaptive capacity incorporates time adaptation, budget adaptation, and skill adaptation. After estimating the risk exposure, sensitivity, and adaptive capacity of each pastoralist, the integrated index was applied for evaluating pastoralists' livelihood vulnerability to climate change (Amos, Akpan, and Ogunjobi 2014; Hahn, Riederer, and Foster 2009). In this regard, LVI-IPCC indicates the definition of the livelihood vulnerability applied by IPCC in Equation (3).

$$\mathrm{LVI} - \mathrm{IPCC}_i = (\text{Risk exposure}_{\ i} - \text{Adaptive capacity}_i)(\text{Sensitivity}_i) \tag{3}$$

2.4. Detecting livelihood vulnerability patterns

To detect livelihood vulnerability patterns, a data mining process was used. The task of data mining is to mine and extract new knowledge from databases to reveal valuable information that is hidden in the vast amount of superficial information (Borodin, Mirvoda, and Porshnev 2016). The process aims at finding valid, useful, novel, and understandable patterns in the database (Rashid, Nohuddin, and Zainol 2017). Accordingly, Cross Industrial Standard Process for Data Mining (CRISP-DM), which is the most widely-used analytics model, was implemented in six steps as follows: (1) problem understanding in the form of detecting livelihood vulnerability patterns applying the sub-components, (2) data understanding in terms of acceptable range, missing data, outliers, and data consistency, (3) data preparation in the form of converting to binary data for association rules model, (4) modelling in the form of association rules to specify the relations among the considered sub-components, (5) evaluation in the form of adjusting results to address the detection of livelihood vulnerability patterns, (6) deployment in the form of offering patterns to policymakers to reduce pastoralists' livelihood vulnerability to climate change.

There is no limit to the minimum number of observations in using the data mining method (Smiti 2020). As the quality of the data is appropriate in terms of acceptable ranges, missing data, outliers, and data consistency, useful results have been obtained. Table 3 indicates the second step of the CRISP-DM. For all the sub-components, acceptable ranges of data were specified from one to seven according to seven Likert scales. No missing data and outliers were observed for the sub-components. However, in terms of data consistency, adaptation sub-components were not aligned with the two groups of exposure and sensitivity sub-components. Therefore, the inconsistency issue has been addressed in the data preparation step. For adaptation sub-components, the values in the range of were converted to 0, and the values in the range of were converted to one in the third step of the CRISP-DM. Conversely, for the two groups of exposure and sensitivity sub-components, the values in the range of were converted to one, and the values in the range of were converted to 0. In the fourth step of the CRISP-DM, the Apriori algorithm was used for frequent sub-component set mining and association rule solving on the livelihood vulnerability database. The algorithm proceeds by identifying the frequent individual sub-components in the database and extending them to larger

Table 3. Data understanding in terms of acceptable range, missing data, outliers, and data consistency.

Sub-component	Acceptable range	Missing data	Outlier	Data consistency
Climate exposure	[1, 7]	0	0	Higher values indicate more livelihood vulnerability
Rangeland exposure	[1, 7]	0	0	Higher values indicate more livelihood vulnerability
Health sensitivity	[1, 7]	0	0	Higher values indicate more livelihood vulnerability
Nutrition sensitivity	[1, 7]	0	0	Higher values indicate more livelihood vulnerability
Ecology sensitivity	[1, 7]	0	0	Higher values indicate more livelihood vulnerability
Time adaptation	[1, 7]	0	0	Higher values indicate less livelihood vulnerability
Budget adaptation	[1, 7]	0	0	Higher values indicate less livelihood vulnerability
Skill adaptation	[1, 7]	0	0	Higher values indicate less livelihood vulnerability

Source: Study findings.

and larger livelihood vulnerability sub-components as long as those sub-component sets appear sufficiently often in the database. In this regard, suitable patterns have been considered, and their support criterion was more than 10 households and their confidence criterion was 100%. Data mining was performed using IBM SPSS Modeler version 18.0.

2.5. Analysing the compatibility of adaptation strategies with livelihood vulnerability patterns

To analyse adaptation strategies adopted by pastoralists, the distribution of pastoralists was performed based on their adaptation strategies (Karimi, Karami, and Keshavarz 2018; Zorom et al. 2013). Furthermore, in each livelihood vulnerability pattern, a set of adaptation strategies that were adopted by Iranian pastoralists was arranged. Comparing the score of the LVI-IPCC in each livelihood vulnerability pattern with the LVI-IPCC of each County, it was specified to what extent the adoption of those adaptation strategies was appropriate. It means that the compatibility of adaptation strategies adopted by Iranian pastoralists with livelihood vulnerability patterns was evaluated.

3. Results

3.1. Descriptive statistics

A total of 393 pastoral households were surveyed in the current study (Table 4). As Table 4 shows, men are household heads in 97.7% of the sample households, and the age group of 51–60 years contains 30% of the household heads. More than 37% of pastoralists are illiterate, while 19.4%, 35.1%, and 7.9% of them have primary, secondary, and academic education, respectively (Table 4). According to Table 4, about 80% of the sample households raise sheep and goats; the main activity of pastoral households is based on traditional pastoralism. Less than 10% of the sample households engage in other activities such as grain cultivation (9.8%), gardening (3.7%), handicrafts (3.1%), and beekeeping (3.5%). As Table 4 shows, nearly 94% of sample pastoralists totally perceived climate impacts, such as drought, frost, and untimely floods.

3.2. Pastoralists' livelihood vulnerability to climate change

Table 5 shows the scores of pastoralists' livelihood vulnerability to climate change. The higher values in terms of risk exposure, sensitivity, adaptive capacity, and LVI-IPCC score show that pastoralists are highly at risk, highly sensitive, very adapted, and rather vulnerable, respectively. The score of risk exposure was 6.92, 5.65, and 5.60 in the three counties of Eghlid, Sepidan, and Shiraz, respectively. There is a significant difference in the component of risk exposure for Eghlid County compared to Sepidan and Shiraz based on the Duncan test. Therefore, pastoralists' revenue has been further affected by the threat of climate change and degraded rangelands in Eghlid. The sensitivity scores for Eghlid, Sepidan, and Shiraz were computed to be 2.45, 1.83, and 2.26, respectively. The component of sensitivity for Sepidan is significantly lower than those of Eghlid and Shiraz based on the Duncan test. According to the scores of the sub-components, the ecological sensitivity of rangelands in Eghlid (4.70) and Shiraz (3.97) was significantly higher than Sepidan (1.64). Therefore, the climate impacts have caused more damage to rangelands' ecology in Eghlid and Shiraz. However, in terms of the nutritional sensitivity of households, Sepidan (2.68) was significantly more sensitive than Eghlid (1.92) and Shiraz (2.17). The households' nutrition in Sepidan compared to Eghlid and Shiraz has been more dependent on traditional pastoralism. Moreover, the scores of the adaptive capacity for Eghlid, Sepidan, and Shiraz were 2.22, 1.52, and 2.17, respectively. There is a significant difference in the component of adaptive capacity for Eghlid and Shiraz counties compared to Sepidan based on the Duncan test. According to the adaptive capacity in terms of time, households' adaptation was lower in Sepidan (1.81) compared to Eghlid (2.74) and Shiraz (2.81). Households have had less

Table 4. Summary statistics of household characteristics.

Socioeconomic characteristics	Description	Percentage of household: Eghlid	Sepidan	Shiraz	Total sample
Gender	If the household head is a man	98.2	97.3	97.4	97.7
	If the household head is a woman	1.8	2.7	2.6	2.3
Age	If the age of the household head is between 15 and 30 years old	3.0	8.7	1.3	4.6
	If the age of the household head is between 31 and 40 years old	19.6	22.2	14.5	19.2
	If the age of the household head is between 41 and 50 years old	27.4	16.8	27.6	23.1
	If the age of the household head is between 51 and 60 years old	27.4	28.8	32.9	30.0
	If the age of the household head is more than 60 years old	22.6	23.5	23.7	23.1
Education	If the household head is illiterate	31.5	44.3	34.2	37.6
	If the household head has primary education	23.8	13.4	21.1	19.4
	If the household head has secondary education	39.9	31.5	34.2	35.1
	If the household head has academic education	4.8	10.8	10.5	7.9
Type of farmer	If the main activity of the farmer is grazing sheep and goats	71.4	87.2	70.8	79.9
	If the main activity of the farmer is grain cultivation	16.7	1.3	11.9	9.8
	If the main activity of the farmer is gardening	7.1	4.0	5.3	3.7
	If the main activity of the farmer is handicrafts	1.2	4.7	6.7	3.1
	If the main activity of the farmer is beekeeping	3.6	2.8	5.3	3.5
Knowledge	If the household head perceived climate impacts totally	95.2	93.2	90.8	93.6
	If the household head perceived climate impacts at a very high level	4.8	4.0	6.6	4.8
	If the household head perceived climate impact at a relatively high level	0	2.0	2.6	1.3
	If the household head perceived climate impacts at a middle level	0	0.8	0	0.3
	If the household head perceived climate impacts at a relatively low level	0	0	0	0
	If the household head perceived climate impacts at a very low level	0	0	0	0
	If the household head did not perceive climate impacts at all	0	0	0	0

Source**:** Study findings.

time to engage in other income earning activities in Sepidan. In addition, the scores of the budget adaptation for Eghlid, Sepidan, and Shiraz were computed to be 1.32, 1.07, and 1.24, respectively. Thus, households have not had enough cash capital to engage in other income earning activities

Table 5. Livelihood vulnerability scores.

Main component	Sub-component	Eghlid	Sepidan	Shiraz
Risk exposure		**6.92**	5.65	5.60
	Climate exposure	**6.92**	5.64	5.60
	Rangeland exposure	**6.90**	5.75	5.55
Sensitivity		**2.45**	1.83	**2.26**
	Health sensitivity	1.33	1.19	1.13
	Nutrition sensitivity	1.92	**2.68**	2.17
	Ecology sensitivity	**4.70**	1.64	**3.97**
Adaptive capacity		**2.22**	1.52	**2.17**
	Time adaptation	**2.74**	1.81	**2.81**
	Budget adaptation	1.32	1.07	1.24
	Skill adaptation	1.59	1.11	1.18
LVI-IPCC score		**11.51**	7.56	7.75

Bold values indicate that there is a significant difference in vulnerability score between counties based on the Duncan test.
Source: Study findings.

in the three counties. Furthermore, the adaptive capacity score in terms of skill was 1.59, 1.11, and 1.18 in the three counties of Eghlid, Sepidan, and Shiraz, respectively. Thus, households have not had high skills to engage in other income earning activities. The LVI-IPCC of Eghlid (11.51) was significantly higher than Sepidan (7.56) and Shiraz (7.75), because of the higher scores for the risk exposure and sensitivity. Hence, pastoralists at high risk, more sensitive, and relatively intolerant to climate change should be care to the effects of these changes.

3.3. Livelihood vulnerability patterns

Figure 3 shows the association rules among the sub-components of livelihood vulnerability in the three counties. More than 95% of pastoral households were vulnerable in Eghlid County according to four sub-components including climate exposure, rangeland exposure, ecology sensitivity, and budget adaptation. Association rules of livelihood vulnerability in Sepidan County indicate that the frequency of households was above 95% in the three sub-components of climate exposure, budget adaptation, and skill adaptation. Finally, above 95% of pastoralists were vulnerable in Shiraz County according to the sub-components of climate exposure, rangeland exposure, ecology sensitivity, and skill adaptation.

The outcomes of the Apriori algorithm indicate the existing separate patterns of livelihood vulnerability in the counties of Eghlid (10 vulnerability patterns), Sepidan (nine vulnerability patterns), and Shiraz (eight vulnerability patterns) (see Table 6, the third column). For example, the first pattern of livelihood vulnerability shows that there was a relationship between "climate exposure" and "rangeland exposure". In other words, the first pattern indicates that the high frequency of occurrence of "climate exposure" and "rangeland exposure" caused the livelihood vulnerability for pastoralists in Eghlid County. The LVI-IPCC score of the first pattern was also calculated at a relatively high level (11.61) while the corresponding value for Eghlid was lower (11.51). Similarly, the livelihood vulnerability status of other patterns can be interpreted.

3.4. Compatibility of adaptation strategies with livelihood vulnerability patterns

Adaptation strategies adopted by pastoralists under the changing climate are illustrated in Figure 4. The most used adaptation strategies in Eghlid County included following health recommendations, improving nutrition, and reducing herd size, which was adopted by 85%, 82%, and 72% of households, respectively. In Sepidan, 90% of pastoralists reduced their herd size to adapt to climate

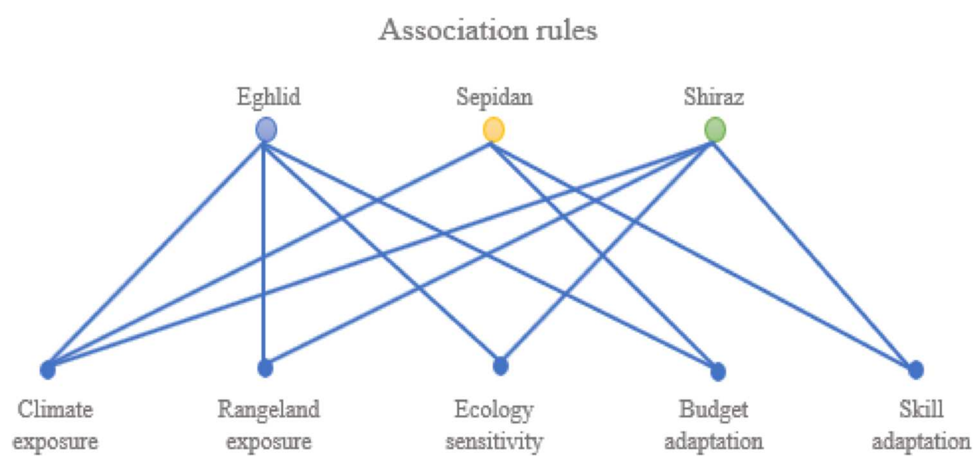

Figure 3. Association rules of livelihood vulnerability sub-components in the three counties.

Table 6. Compatibility of adaptation strategies adopted by pastoralists with livelihood vulnerability patterns.

No	County	Livelihood vulnerability pattern	Adaptation strategies	LVI-IPCC score
1	Eghlid	(Climate exposure, Rangeland exposure)	Health, Nutrition, Herd size	11.61
2	Eghlid	(Climate exposure, Skill adaptation)	Health, Herd size, Credit	11.69
3	Eghlid	(Rangeland exposure, Budget adaptation)	Nutrition, Herd size, Skill	11.85
4	Eghlid	(Rangeland exposure, Skill adaptation)	Diversification, Fodder, Skill	**9.69**
5	Eghlid	(Climate exposure, Rangeland exposure, Skill adaptation)	Health, Nutrition, Credit	11.78
6	Eghlid	(Rangeland exposure, Budget adaptation, Skill adaptation)	Health, Nutrition, Diversification	10.89
7	Eghlid	(Climate exposure, Rangeland exposure, Time adaptation, Budget adaptation)	Health, Nutrition, Herd size	12.48
8	Eghlid	(Climate exposure, Rangeland exposure, Time adaptation, Skill adaptation)	Health, Nutrition, Insurance	12.66
9	Eghlid	(Climate exposure, Rangeland exposure, Ecology sensitivity, Time adaptation, Budget adaptation)	Health, Nutrition, Fodder	14.51
10	Eghlid	(Rangeland exposure, Ecology sensitivity, Time adaptation, Budget adaptation, Skill adaptation)	Health, Nutrition, Herd size	14.59
11	Sepidan	(Climate exposure, Rangeland exposure)	Herd size, Nutrition, Fodder	7.73
12	Sepidan	(Climate exposure, Budget adaptation)	Herd size, Nutrition, Health	7.95
13	Sepidan	(Climate exposure, Skill adaptation)	Nutrition, Health, Fodder	8.43
14	Sepidan	(Rangeland exposure, Budget adaptation)	Diversification, Evacuation, Credit	**5.68**
15	Sepidan	(Rangeland exposure, Skill adaptation)	Herd size, Diversification, Skill	**4.68**
16	Sepidan	(Rangeland exposure, Time adaptation, Budget adaptation)	Nutrition, Herd size, Health	7.92
17	Sepidan	(Rangeland exposure, Time adaptation, Skill adaptation)	Nutrition, Herd size, Fodder	7.12
18	Sepidan	(Climate exposure, Rangeland exposure, Budget adaptation)	Health, Nutrition, Insurance	8.56
19	Sepidan	(Climate exposure, Rangeland exposure, Skill adaptation)	Herd size, Health, Fodder	8.14
20	Shiraz	(Climate exposure, Rangeland exposure)	Herd size, Nutrition, Health	7.88
21	Shiraz	(Rangeland exposure, Budget adaptation)	Evacuation, Diversification, Credit	**6.01**
22	Shiraz	(Rangeland exposure, Skill adaptation)	Nutrition, Fodder, Health	7.28
23	Shiraz	(Climate exposure, Rangeland exposure, Budget adaptation)	Herd size, Health, Skill	8.01
24	Shiraz	(Rangeland exposure, Budget adaptation, Skill adaptation)	Nutrition, Fodder, Health	8.21
25	Shiraz	(Rangeland exposure, Time adaptation, Budget adaptation, Skill adaptation)	Herd size, Health, Insurance	8.69
26	Shiraz	(Climate exposure, Ecology sensitivity, Time adaptation, Budget adaptation, Skill adaptation)	Herd size, Nutrition, Fodder	9.03
27	Shiraz	(Rangeland exposure, Ecology sensitivity, Time adaptation, Budget adaptation, Skill adaptation)	Nutrition, Herd size, Health	9.39

Bold values indicate that there is a significant difference in vulnerability score between each pattern and corresponding county based on the Duncan test.
Source: Study finding.

change. Next, adaptation strategies such as improving nutrition and following health recommendations were adopted by 78% and 75% of households, respectively. The most common adaptation strategies in Shiraz included reducing herd size, improving nutrition, and feeding fodder, which was adopted by 92%, 86%, and 74% of households, respectively. In contrast, a few numbers of households participated in training courses related to handicrafts, apiculture, and fish farming (20% in Eghlid, 9% in Sepidan, and 16% in Shiraz). In addition, pastoral households insured their herds (10% in Eghlid, 23% in Sepidan, and 13% in Shiraz), or received credits for increasing mutton production from banks and financial institutions (22% in Eghlid, 12% in Sepidan, and 19% in Shiraz).

Table 6 shows the compatibility of adaptation strategies adopted by pastoralists with livelihood vulnerability patterns. Comparing adaptation strategies with livelihood vulnerability patterns shows that pastoralists have only adopted a set of adaptation strategies to help reduce vulnerability in four vulnerability patterns (including credit, diversification, evacuation, fodder, herd size, and skill).

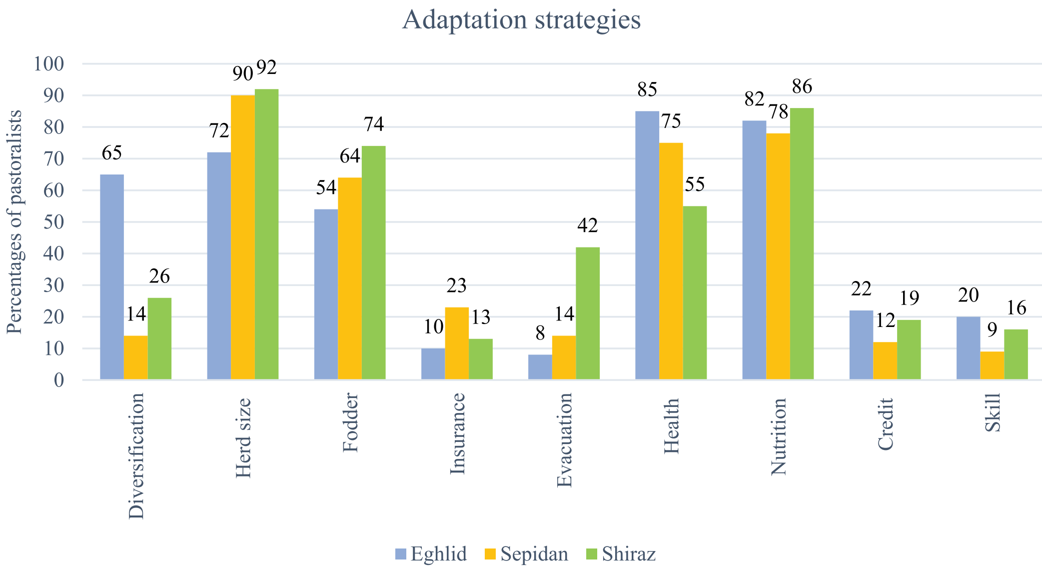

Figure 4. Adaptation strategies adopted by pastoralists.

Households in the fourth pattern were vulnerable due to the relationship between "rangeland exposure" and "skill adaptation". Accordingly, pastoral households have been able to reduce "rangeland exposure" by adopting a diversification strategy to diversify income-earning activities and increase "skill adaptation" by participating in skill courses in learning handicrafts, apiculture, and fish farming. In pattern 14, a relationship was detected between "rangeland exposure" and "budget adaptation". The set of adaptation strategies has also included diversification, evacuation, and credit, which were perfectly able to reduce the livelihood vulnerability of this pattern. In pattern 15, pastoral households were vulnerable due to the relation between "rangeland exposure" and "skill adaptation". Thus, pastoralists decreased their vulnerability by reducing their herd size, diversifying their revenue source with various income-earning activities, and participating in skill courses for learning other activities. Finally, pastoralists were vulnerable due to the relation between "rangeland exposure" and "budget adaptation" in pattern 21. Households reduced "rangeland exposure" by evacuating rangelands and engaging in various income-earning activities, and increased "budget adaptation" by receiving credits.

4. Discussion

4.1. Livelihood vulnerability to climate change in the northern Fars province

The results of the current study show that the sample pastoralists are generally vulnerable to climate change. The two main reasons for the high vulnerability of pastoralists are high-risk exposure and low adaptive capacity (Table 5). According to Table 5, the main barrier to pastoralists' low adaptive capacity is budget constraints. The compatibility of the results of the current study with previous studies can confirm the strength of this paper. Such a comparison showed that the sub-components in the main vulnerability components were properly selected. In this regard, various scholars, such as Adu et al. (2018), Gerlitz et al. (2016), Panthi et al. (2015), and Toufique and Islam (2014), examined livelihood vulnerabilities with respect to three components of risk exposure, sensitivity, and adaptive capacity, and their results confirm the findings of the current study.

The findings of the livelihood vulnerability to climate change indicate that of pastoralists in Eghlid (11.51) were the most vulnerable based on the LVI-IPCC score. The reason for the high livelihood vulnerability of pastoralists in the County was that their revenue has been strongly affected by climate change (6.92) and degraded rangelands (6.90). During the last 30 years, climatic variables such as reduced rainfall (Figure 2), climate impacts such as frost, and degraded rangelands in the form of reduced forage quality (Table 4) have been more tangible in Eghlid County. In this regard, Ashok and Sasikala (2012), Biazin and Sterk (2013), Gerlitz et al. (2016), Ghazali and Zibaei (2018), Sietz, Mamani Choque, and Lüdeke (2011), and Toufique and Islam (2014) showed that livelihoods based on traditional pastoralism put farmers at risk of climate change and increased their vulnerability. The second reason for the high livelihood vulnerability of pastoralists in Eghlid was the high ecological sensitivity of their rangelands (4.70). This is because their rangelands' ecology has been severely affected by climate impacts such as frost and untimely floods. In addition to the mentioned reasons, the adaptive capacity in terms of cash (1.32) was at a low level in the County. This means that households did not have enough cash to engage in other income-earning activities. In contrast, several researchers, such as Adu et al. (2018), Antwi-Agyei et al. 2013(), Biazin and Sterk (2013), Ghazali and Zibaei (2018), and Morzaria-Luna, Turk-Boyer, and Moreno-Baez (2014) discussed that households that did not rely on one activity and diversified their livelihoods were able to adapt to external stresses. Therefore, they reduced their livelihood vulnerability to climate change and were resilient.

In Shiraz, the score of LVI-IPCC (7.75) was relatively moderate. The main reason for the livelihood vulnerability of pastoralists in this County was the exposure risk (5.60) of their revenue from external stresses such as climate change and degraded rangelands. Furthermore, the ecological sensitivity of rangelands (3.97) to climate impacts was relatively high. The major natural phenomenon that has recently been observed in Shiraz has been the occurrence of spring floods. The third reason for the livelihood vulnerability of pastoralists in this County was the fact that their households have low skills (1.18) for engaging in various income-earning activities.

The lowest livelihood vulnerability to climate change based on the LVI-IPCC score was obtained in Sepidan County (7.56). The first reason for livelihood vulnerability in this County was the occurrence of climate change in the form of reduced rainfall and dried springs and its effect on pastoralists' revenue (5.64), as well as the degradation of natural rangelands and its effect on pastoral livelihood (5.75). The second reason for livelihood vulnerability in Sepidan was the nutritional sensitivity of households (2.68). Pastoralists' livelihood in this County has highly relied on traditional pastoralism, and it has been the main source of households' nutrition. Furthermore, the vulnerability study of Panthi et al. (2015) on pastoralists in central Nepal showed that nutrition security, health conditions, and health services were important components in terms of sensitivity component. Nutrition insecurity and unfavourable health conditions had led to high livelihood vulnerability to climate change. In addition to those reasons, households' adaptive capacity in terms of cash (1.07) and skills (1.11) to engage in other income-earning activities was very low.

4.2. Livelihood vulnerability patterns according to data mining

Using data mining, 27 livelihood vulnerability patterns based on the relationship among sub-components were detected. In Eghlid County, the number of 10 separate patterns were extracted. The first vulnerability pattern (LVI-IPCC score: 11.61) indicates that pastoralists were vulnerable caused by high climate exposure and rangeland exposure. The second to eighth patterns (LVI-IPCC score: from 9.69 to 12.66) indicate that pastoral households were vulnerable caused by high exposure and low adaptation in different vulnerability sub-components. Moreover, the ninth and tenth patterns of livelihood vulnerability (LVI-IPCC score: 14.51 and 14.59) indicate the relations among the sub-components of high exposure, high sensitivity, and low adaptation. The results of other researchers such as Karimi, Karami, and Keshavarz (2018), and Pandey and Bardsley (2015) on vulnerability patterns were clustered in different vulnerability levels (low, medium, and high). Karimi, Karami, and Keshavarz (2018) discovered low, medium, and high vulnerability patterns of livestock keepers in southwest Iran, which were principally extracted by cluster analysis on risk exposure, sensitivity, and adaptive capacity. According to their results, the high vulnerability pattern had a high score in the components of risk exposure and sensitivity, and a low score in the component of adaptive capacity. The study findings of Pandey and Bardsley (2015) revealed significant levels of risk exposure to climate change and sensitivity to extreme weather events, but low adaptive capacities to adapt to climate change resulted in very high vulnerability. However, there were variations in the vulnerability levels among the households in Nepal. Considering the limited capacities of the country, they stated that the country needs to consider the policy of "poor people prior". Therefore, households that were in the high vulnerability pattern should be considered prior.

In Sepidan, nine separate patterns of livelihood vulnerability were obtained. Pastoral households of the County were vulnerable due to the various relationships between exposure and adaptation. The first livelihood vulnerability pattern (LVI-IPCC score: 7.73) in the County was detected according to the relation among the exposure sub-components. Other vulnerability patterns (LVI-IPCC score: from 4.68 to 8.56) were extracted from the relations among the sub-components of exposure and adaptation. Furthermore, eight separate patterns were also detected in Shiraz. In the first livelihood vulnerability pattern (LVI-IPCC score: 7.88) of the County, pastoralists were only vulnerable due to high exposure in terms of climate change and degraded rangeland. Pastoral households were vulnerable to climate change due to high exposure and low adaptation in five livelihood vulnerability patterns (LVI-IPCC score: from 6.01 to 8.69). Livelihood vulnerability was detected in the last two patterns (LVI-IPCC score: 9.03 and 9.39), according to high exposure, high sensitivity, and low adaptation in their different sub-components. Moreover, the clusters that were detected by Kok et al. (2015) were labelled as vulnerability profiles. Those profiles reported different typical groupings of conditions and processes that caused the vulnerability of farmers in drylands. Their results incorporated eight separate vulnerability profiles in the study area. The analysis of vulnerability profiles was used as a base to identify appropriate methods to reduce vulnerability.

4.3. Compatibility of pastoralists with livelihood vulnerability patterns through adopting appropriate adaptation strategies

As the results show, four adaptation strategies in the form of herd size, nutrition, health, and fodder have been adopted by more than 50% of pastoral households. Almost 12% of pastoralists have not taken any adaptation measures due to a lack of financial liquidity and limited budget resources. Other studies on the adaptation of farmers and pastoralists to climate change in Iran have obtained similar results. In Hamadan province, Jamshidi et al. (2020) stated that most farmers have adopted three adaptation strategies, i.e. new irrigation methods, drought-tolerant varieties, and diversifying income resources. In Fars province, based on a study by Karimi, Karami, and Keshavarz (2018), a large number of livestock producers used three adaptation strategies, e.g. rotational grazing, raising mixed herds, and purchasing fodder. In this context, Keshavarz, Maleksaeidi, and Karami's (2017) study showed that farmers followed the adaptation strategies of farm management, financial management, and income diversification. Accordingly, it can be concluded that the diversification of income-generating activities and non-reliance on traditional livelihoods are effective measures taken in the face of climate variability and change.

In the current study, the herd size strategy has been adopted by pastoralists in 16 livelihood vulnerability patterns. Only in the livelihood vulnerability pattern 15, pastoralists were able to reduce their livelihood vulnerability by reducing their herd size. In fact, diversifying activities along with reducing the herd size has led to a reduction in the dependence of pastoralists' revenue on rangelands. The nutritional strategy to reduce nutrition dependence on traditional livelihood and the health strategy to follow health recommendations have been adopted by pastoral households in more than 15 livelihood vulnerability patterns. Therefore, none of the patterns were vulnerable in terms of nutrition sensitivity and health sensitivity. While the fodder strategy has been adopted by pastoral households in nine vulnerability patterns, this strategy could significantly reduce the LVI-IPCC score (9.69) in the fourth pattern. In addition to the mentioned adaptation strategies, three adaptation strategies of evacuation, credit, and skill in combination with others were appropriate to reduce livelihood vulnerability. Pastoralists in the 4th, 14th, 15th, and 21st patterns were compatible with livelihood vulnerability sub-components by adopting the appropriate set of adaptation strategies. Considering that pastoralists took appropriate decisions to adopt the adaptation strategies in only four livelihood vulnerability patterns, the compatibility of pastoralists with the extracted patterns is low.

5. Conclusion

Considering the first research question, pastoralists have high livelihood vulnerability in terms of risk exposure in the northern Fars province. Only nearly 5% of the sample households have a head of household in the age range of 15–30 years, the distribution of pastoral households in other age groups is almost. As the component of risk exposure contains the subcomponent of revenue, pastoralism revenue that has fundamentally gained from traditional pastoralism has decreased due to climate change and degraded rangelands. In addition, the ecological sensitivity of rangelands to climate change is high in Eghlid and Shiraz. The ecology of those rangelands has been degraded by climate impacts in recent years. Furthermore, the low adaptive capacity in terms of cash and skill has increased the livelihood vulnerability of Iranian pastoralists. To address the second research question, it should be noted that 27 livelihood vulnerability patterns were detected with respect to the sub-components of exposure, sensitivity, and adaptation, and patterns indicate the relationships among the sub-components. Thus, the cause of pastoralists' vulnerability can be considered as a combination of sub-components of climate exposure, rangeland exposure, ecological sensitivity, time adaptation, budget adaptation, and skill adaptation. The third research question was addressed by comparing the vulnerability score of each pattern with the related County; pastoralists have adopted an appropriate set of adaptation strategies to reduce their livelihood vulnerability in only four livelihood vulnerability patterns. Therefore, pastoralists reduced their vulnerability to a low level by adopting adaptation strategies. In fact, the livelihood vulnerability score in each pattern is high compared to the corresponding score of the related County. This means that pastoralists in each vulnerability pattern (excluding the 4th, 14th, 15th, and 21st patterns) have not adopted a set of adaptation strategies to reduce vulnerability.

Lack of attention to reducing the vulnerability of Iranian pastoralists to climate change leads to instability in their livelihoods. In line with the mentioned implication, the negligence of authorities in determining adaptation strategies to help reduce vulnerability does not reduce the livelihood vulnerability of pastoralists to climate change. In addition, the adoption of strategies without training or support by Iranian pastoralists increases their vulnerability. The results of the current study can assist pastoralists to adopt an appropriate set of adaptation strategies. Thus, the adoption of the diversification strategy in the form of diversifying income-earning activities is recommended for pastoralists who were exposed to climate change and degraded rangelands. It is also suggested to improve the quality of rangelands by adopting the herd size strategy in the form of reducing herd size, the fodder strategy in the form of feeding the herd with purchased fodder, and the evacuation strategy in the form of evacuating natural rangelands. Increasing the adaptive capacity is recommended for pastoralists who were vulnerable: firstly, by granting the production credits to start complementary activities, and secondly, by organising training workshops for those pastoralists.

Almost none of the pastoralists has adopted adaptation strategies, such as herd insurance, the substitution of goats for sheep, more favourable rangeland migration, and rangeland restoration. Future studies can examine why pastoralists are reluctant to adopt adaptation strategies, or how policymakers can encourage pastoralists to change the composition of their herd and migrate to more favourable and safer rangelands. In addition, by identifying the sub-components of vulnerability in the current paper, future studies can focus on finding adaptation strategies to reduce vulnerability. To direct future studies, diversifying income-generating activities seems to be an important issue for pastoralists. Such studies can reduce the vulnerability of pastoralists by increasing their adaptive capacity.

Disclosure statement

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