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DPSIR framework priorities and its application to forest management: a fuzzy modeling

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Abstract The main aim of this research was to quantify the parameters related to forest situation (according to DPSIR framework) using decision-making processes and fuzzy methods in the Zagros forests of Iran. In this study, the situation factors (e.g., socioeconomic, biophysical, and environmental factors) were evaluated by fuzzy analytic hierarchy process (FAHP) using α-cuts in addition to the Chang method for fuzzy pairwise comparisons. The results of the study clearly illustrate that the decision-making process is the most important input in forest management planning in the Zagros forests, Iran. In such situations, decision-making techniques can be of great help in differentiating the factors influencing decision-making and policy-making for these forests. We found that α-cuts could improve the quality of the decision-making process, but only after secondary analysis. Initially, we did not find any significant difference in the results between α-cuts and research results, but using the differences in rankings, we could identify a significant difference. We propose that this method, which requires lengthy calculations to get the answer, should only be used by forest managers when the quality of the results and the difference between the parameters are very important to them; otherwise, they may be able to achieve the same desired results in a much easier way.

Keywords Fuzzy analytic hierarchy process (FAHP) · α-cuts · Decision making · Coppicing · Forest protection · Zagros forests

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Introduction

As the name implies, the DPSIR framework concentrates on driving forces, pressures, state, impacts, and responses. The DPSIR framework is used to determine the behavior of the ecosystem, its pressures, and the driving force on the ecosystem and to study the appropriate ecosystem responses to these driving forces and pressures (Jabbour & Hunsberger, 2014). In the forests' situation analysis, this framework can explain the situation of forest ecosystems to the managers on the basis of the pressures on them (Merwe et al., 2020; Scriban et al., 2019). Managers must develop coping strategies not only to driving forces, but also pressures, impact and state (see Fig. 1).

Fundamentally, in the DPSIR framework, socioeconomic development, which can exacerbate the creation of other consequences such as climate change and dust are considered as driving factors. Pressure factors refer to the rise of substances such as CO_2 emission and heat stress. As the name describes, state factors examine the quantity and quality of environmental and biological condition/state. The impact factors refer to human being and ecosystem health resulted by changes in environmental quality. Finally, response factors refer to managerial actions of the stakeholder groups to prevent the environmental degradation (Cooper, 2012; EEA, 2003). Potentially, the DPSIR framework is a strong and systematic model in introducing the effective factors and needs of ecosystems in ecosystem planning. Overall, therefore, if this framework is used correctly, it can be an effective guide for systematic planning in ecosystem management for ecosystem managers. The forests of Iran were declared national in 1963, but this process created many problems for local communities and the forests of the Zagros. The Forest Management Plans (FMPs) started at the same time (Ebrahimi Rostaghi, 2005). In Iran, FMP has been associated with many problems for the Zagros forests, which are located in the western and southwestern regions of Iran. Problems include over-grazing livestock of local communities in the forests, gathering fuel wood in some area, extensive and traditional harvesting of non-timber products by local people, coppicing, and the need for strong conservation to protect the forest (Valipour et al., 2014; Zandebasiri et al., 2020a).

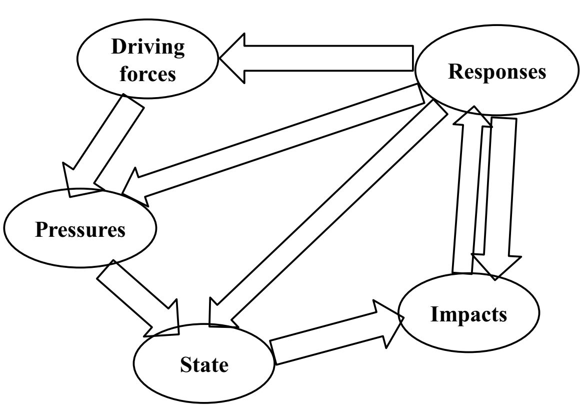

Fig. 1 Societal responses to driving forces, pressures, impact and state, adopted and modified from EEA (2003)

Some previous studies on the DPSIR framework in the Zagros forests, such as Heidari et al. (2016) in northern Zagros forests and Zandebasiri et al. (2017a) in central Zagros forests, were concentrated on a qualitative study in this framework. In spite the fact that the DPSIR framework is a qualitative approach, quantifying this framework could be helpful for the planners to determine the importance of the DPSIR factors (Mohammadizadeh et al., 2016; Wolfslehner & Vacik, 2008). After this quantification, assessing the factors, alternatives and management plans could be possible. In this context, situation analysis and quantifying the parameters related to the forests and FMPs achievements, as well as developing appropriate strategies for them, becomes doubly important.

Four specific goals arose from DPSIR framework quantifying the parameters related to forest conditions in this paper. (1) The assessment of the most important factors from DPSIR framework for the Zagros forests, Iran. Given the quantification of the DPSIR factors, our further aim is to investigate the most important factors. (2) Representing the guidelines in forest planning for the Zagros forests according to the quantification of the DPSIR framework. On the basis of the most important factors, it is possible to decide on strategic planning in these ecosystems. (3) In addition, we have another main objective: to broaden the methodology for decisions on forest management. We will also discuss the comparison of the FAHP (fuzzy analytic hierarchy process) method with regard to crisp rank that was achieved from fuzzy synthetic extent with the results of α-cuts in the quantification of the DPSIR framework. (4) Finally, we intend to analyze the strengths and weaknesses of the new method, as well as the opportunities and threats achieved from the strengths and weaknesses of the new method.

Considering the litter review studies (in the "Theoretical framework" sections), to the best of our knowledge, there is no study that has investigated α-cuts in the quantification of the DPSIR framework all around the world. However, Mohammadizadeh et al. (2016) proposed the fuzzy evaluation for the quantification of the DPSIR framework. Our paper contributes to this research gap by developing α-cuts in FAHP results in the DPSIR framework in forest management. However, α-cuts are mostly used in mathematical texts (Abbasi Shureshjani & Darehmiraki, 2013).

Theoretical framework

Since the magnitude issue of the importance and priorities of the DPSIR factors are included in the quantitative DPSIR framework, in this section, we review the concept of this framework's quantification ("The application of quantitative DPSIR framework with MADM/MCDM" section), and then the fuzzy evaluation to quantify this framework is explained ("Fuzzy evaluation of the DPSIR framework" section).

The application of quantitative DPSIR framework with MADM/MCDM

The DPSIR model is a very important tool and has a qualitative aspect to determine the factors for ecosystem management; hence, multi-attribute decision making (MADM)/multi-criteria decision making (MCDM) could be used for quantifying the DPSIR factors. This quantification can formulate the strategy and determine the most important factors for ecosystem strategic planning. AHP (analytic hierarchy process) is one of the simple techniques in MADM/MCDM that is based on pairwise comparisons to evaluate the factors in multicriteria modeling (Kangas & Kangas, 2005; Ananda & Herath, 2009; Zandebasiri & Pourhashemi, 2016). The AHP method can be well adapted to the environmental problems of ecosystems, especially forests. The AHP method has a hierarchical structure and compares the pairs of factors of each level. For further information on MCDM methods and AHP method in forest management, see Kangas and Kangas (2005) and Ananda and Herath (2009).

Fuzzy evaluation of the DPSIR framework

Forest managers cannot remove the uncertainty in the results of their managerial observations; therefore, the best way to consider uncertainty is to include them in the process of ecosystem decision making. Suitable decision-making requires an assessment of the uncertainties of the decision solution as forest systems are inherently fraught with uncertainties. Depending on climate issues, high data volumes, long time plans, and time-varying societal demands may be the source of this uncertainty in forest systems (Zandebasiri et al., 2011). For a methodology to assess the uncertainty in ecosystem management, see Kangas et al. (2018). A way to investigate the uncertainty is to get help from the fuzzy numbers in decision-making processes. With fuzzy numbers, forest system experts can express many of the concepts of uncertainty (Mendoza & Prabhu, 2003; Zandebasiri et al., 2017b). This idea has also been used in the uncertainty plan in the forest management decision process (Kangas et al., 2018). The traditional AHP requires exact pairwise comparisons. One of the most important problems with MCDM methods is the exact evaluation of the data. Since uncertainty is usually typical for many MCDM decisions, a good MCDM framework allow for ambivalence or uncertainty (Zaerpour et al., 2008). While MCDM methods have been modeled under uncertainty conditions, fuzzy MCDM methods help to fix the ambiguity or vagueness contained in the criteria or factors for forest management (Mendoza & Prabhu, 2003; Grošelj et al., 2016).

The fuzzy analytic hierarchy process (FAHP) can be used to overcome these problems in forest evaluation and investigate the situation. Using fuzzy data is one way of dealing with these uncertainties. The use of fuzzy data leads researchers to various analyses. For example, different methods for ranking fuzzy data can be of different importance. Using different ranking methods can produce different results in fuzzy data analysis (Abbasi Shureshjani & Darehmiraki, 2013). This could affect the priorities of researchers and managers in forest planning. This is where the importance of the methodology in examining fuzzy or even non-fuzzy data is determined for their users. Thus, forestry experts need to identify these methods and conduct the necessary research on their selection or judgment on their results.

Material and methods

Study area

The Zagros forests are covered with a number of open and thin oak stands which are more similar to forest parks in the southwest and west of Iran (Jazirehi & Ebrahimi Rostaghi, 2013; Valipour et al., 2014). For the present study, we selected the Tang-e Solak landscape area as a Forest Management Unit (FMU) (a managed local forest area in the Zagros forests in western Iran, 15 km south of the city of Likak). The boundaries of the FMU were defined by the province of Kohgilouye and Boyerahmad through a forest management planning process. The FMU is known for its native *Cupressus sempervirens*, tourism and recreational activities. Natural *Cupressus sempervirens* forms a unique forest type of the oak-cypress. In addition, the FMU has agricultural and horticultural areas (Zandebasiri et al., 2017c).

Data collection and analysis

This paper proposes a fuzzy quantitative DPSIR methodology based on α-cuts to assess the overall environment of forest decline in the Zagros forests. In this paper, the concept of the FAHP is introduced into the DPSIR model to construct a quantified DPSIR framework. Our application consists of the following steps (see Fig. 2.)

Zandebasiri et al. (2017a) presented a simple and qualitative DPSIR framework in the forest management of the central Zagros forests briefly and generally. Initially, we modified this framework, and then a novel fuzzy tool was used, which takes into account the elements that influence the situation of the forest landscape.

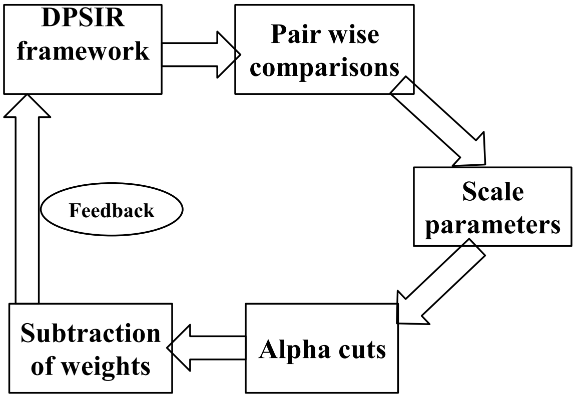

Fig. 2 The schematic structure of the multi-steps approach of fuzzy quantified DPSIR

Since the most important problem in the central Zagros in recent years has been the issue of forest decline (Zandebasiri et al., 2017a, b, c), the discussion of driving force, pressure, state, impact, and responses have focused on this issue. The overview of the DPSIR factors for Zagros forests is presented in Table 1. The experts who helped us with weighting DPSIR factors had complete and comprehensive knowledge of the problems of the Zagros forests. However, to complete the pairwise comparison questionnaires, the researcher of the research team provided a supplementary interview to explain the content and questions. Experts were asked to weigh the three factors (by pairwise comparisons) in all the five groups mentioned in Table 1. Data collection was conducted from March 2018 to January 2019.

For more explanation about the factors of Table 1, see Appendix. The main considerations in the DPSIR factors in Table 1 are as follows: (1) the driving force category has been focused on the factors, which could be considered as a starting point for other factors to design DPSIR model, particularly for the pressure factors. To formulate the driving forces, the current study examined the factors dealing with development plans in societies. Due to the relationship between socio-economic developments with climate change, the concept of climate change has been selected to represent such developments. Also, decision making in forest policy-making could be a major driving force in the Zagros forests, Iran (Zandebasiri & Ghazanfari, 2010), and this factor (decision making) has been selected as another driving factor. The system theory approach in environment (Danehkar & Zandebasiri, 2020) has been considered to investigate DPSIR. To have a better understanding about the system boundary, "dust" has been proposed as a factor to explore external socio-economic developments. Dust can be harmful to oak trees given their leaf sensitivity. (2) To determine the pressure factors, emission of substances (e.g., CO_2 emission) into the Zagros forest were considered. To study these factors, grazing in the forests and lack of protection as a driving factor for loss in carbon sequestration and the increase of CO_2 were examined. (3) To determine the state factors, the main quantity and quality factors of the Zagros forest ecosystem's conditions were considered. (4) To identify the impact factors, the impacts of environmental changes on the Zagros

Table 1 The DPSIR factors in the central Zagros forests, Iran (Modified from Zandebasiri et al., 2017a)

DPSIR groups	The DPSIR factors
Driving forces	
D_1	Climate change as a representative factor for driving force originated from social and economic developments
D_2	Decision making
D_3	The dust that enters from western countries to the Zagros ecosystems as a factor for external socioeconomic development
Pressures	
P_1	Livestock grazing pressure on the forest ecosystem
P_2	Heat stress and pressure on oak trees due to their sensitivity to the aridity stress and drought
P_3	CO_2 emission resulted from lack of protection and deforestation
States	
S_1	Forest state in terms of forest regime (coppice stands)
S_2	Forest state in terms of soil surface and rock outcrops
S_3	Quantity state in terms of forest species and biodiversity sources
Impacts	
I_1	The impact of oak ecosystems about oak decline on social welfare (both local people and the whole society)
I_2	The impact of ecosystem sustainability and social welfare of future generations (by lack of natural regeneration)
I_3	The impact of creating weakness in various production and environmental capabilities as well as reducing social welfare by soil weakness
Responses	
R_1	Precipitation storage
R_2	Forest conservation
R_3	Local community participation

ecosystems were examined. (5) Finally, to determine the response factors, main managerial interventions (i.e., precipitation storage, forest conservation and mitigating oak decline), and local communities' participation were considered.

The mean of the responses factors is the factors that could be considered as policies or targets from the management of the Zagros forests. Three factors are presented according to related policies for the Zagros forests (Zandebasiri et al., 2017a, b, c, 2019, 2020a, b). The factors are as follows: (1) precipitation storage including methods for saving rainfall for drought and aridity stress to prevent the mortality of oak trees; (2) forest conservation including methods to build a fence to prevent from grazing in the forests; and (3) local community participation including set of local community's collaboration to control oak decline and the collaboration in the Zagros ecosystem management.

Fuzzy AHP

The FAHP technique is an ordered way of thinking about the parameters and complex questions (Mendoza & Prabhu, 2003), which makes use of the ideas of hierarchical decision making (Wang & Chen, 2007). In classical AHP model (Kangas & Kangs, 2005 and originally by Saaty, 1977) which has n factors at a hypothetical level, pairwise comparison is presented with the fundamental scale from 1 to 9 (Ananda & Herath, 2009). Therefore, a pairwise comparison matrix A can be built (Fig. 3).

$$\text{where } a_{ji} = \frac{1}{a_{ij}}. \tag{1}$$

In this section, some definitions, equations (as well Fig. 4) in fuzzy numbers for fuzzy calculations are reviewed by different authors (Ataei, 2016; Bojadziev

$$A = \begin{bmatrix} 1 & a_{12} & \ldots.. & a_{1n} \\ a_{21} & 1 & \ldots.. & a_{2n} \\ \ldots. & \ldots & \ldots. & \ldots. \\ a_{n1} & a_{n2} & \ldots.. & 1 \end{bmatrix}$$

Fig. 3 Pairwise comparison matrix (Modified from Ananda & Herath, 2009)

& Bojadziev, 2007; Chang, 1996; Wang & Chen, 2007; Zaerpour et al., 2008; Zandebasiri et al., 2012; Zanjirche, 2015):

A fuzzy set is a collection of vagueness and uncertainty data/information phrases with a specific degree of membership. The membership function has a range from 0 to 1 and quantifies the levels to which each linguistic phrase belongs. The fuzzy set is represented by the set Eq. 2:

$$\tilde{A} = \{(x, \mu_A(x)) | x \epsilon X\} \tag{2}$$

Triangular fuzzy number (TFN) is utilized for characterizing the ambivalence of the factors of verbal phrases. A TFN $\tilde{A} = (a, b, c)$ is presented in Fig. 4.

In Fig. 4, quantities that are smaller than the quantity a, or larger than the quantity c are no longer described in this fuzzy variation. A function for a membership at TFN is used as follows:

$$\mu_A(x) = \begin{cases} 0 & x \le a \\ \frac{x-a}{b-a} & a \le x \le b \\ \frac{x-c}{b-c} & b \le x \le c \\ 0 & x > c \end{cases} \tag{3}$$

Assume $\tilde{m} = (m_1, m_2, m_3)$ and $\tilde{n} = (n_1, n_2, n_3)$ as two fuzzy numbers, TFNs arithmetic operation laws are described by Eqs. 4–6:

$$\tilde{m} \oplus \tilde{n} = (m_1 + n_1, m_2 + n_2, m_3 + n_3) \tag{4}$$

$$\tilde{m} \otimes \tilde{n} = (m_1 n_1, m_2 n_2, m_3 n_3,) \tag{5}$$

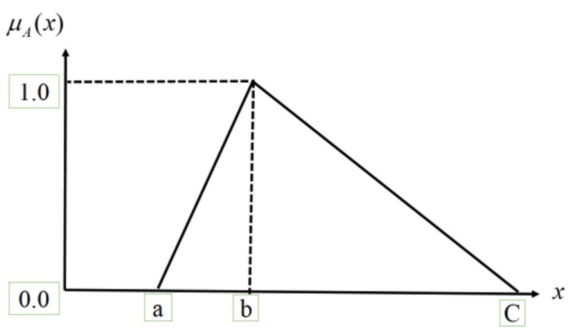

Fig. 4 Display of a TFN

Table 2 The linguistic verbal scale and corresponding TFNs (Modified from Erensal et al., 2006)

Linguistic verbal scale	Equal	Moderate	Strong	Very strong	Demonstrated
TFN	(1, 1, 1)	(1, 3, 5)	(3, 5, 7)	(5, 7, 9)	(7, 9, 11)

$$\tilde{m} \oslash \tilde{n} = \left(\frac{m_1}{n_3}, \frac{m_2}{n_2}, \frac{m_3}{n_1}\right) \tag{6}$$

Fuzzy judgments between DPSIR factors

After the formation of DPSIR framework, pairwise comparisons are made between DPSIR factors within each of the five groups of this framework. For this purpose, we used fuzzy pair comparisons as part of the FAHP method. Table 2 shows the linguistic scale which we used for the FAHP method.

Pairwise comparisons using the linguistic verbal scale between DPSIR factors are performed between factors in all DPSIR groups, and the corresponding TFNs are collected in five fuzzy pairwise comparison categories. There are several approaches to derive weights from a fuzzy pairwise comparison matrix (Groselj & Zadnik Stirn, 2018). Chang's technique is used to calculate fuzzy weights, called fuzzy synthetic extent (FSE). In this research, we applied Chang's technique and extent analysis method to calculate weights from the fuzzy pairwise comparison categories (Chang, 1996; Wang et al., 2008). In this study, these methods were used only for the calculations and processing of pairwise comparisons. Chang's formula for processing pairwise comparisons is as follows (Eq. 7) (Chang, 1996):

$$S_i = \sum_{j=1}^{m} Mg_i^j \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} Mg_i^j\right]^{-1} \tag{7}$$

In Eq. 7, Mg_i^j refers to TFNs within the pairwise comparison matrices. In fact, when the matrix S is calculated, the components of the fuzzy data are added together and the sum of this collection is multiplied by the fuzzy inverse. This process is similar to the calculation of normalized weights in the conventional AHP method, but with fuzzy numbers (Ataei, 2016). In this study, we have used a weighted mean (Eq. 7), instead of Chang's method, to simplify the results of the final ranking. We have used this approach because it is simpler than other FAHP techniques. Let $\tilde{m} = (m_1, m_2, m_3)$ be an FSE. To obtain the mean value of FSE, perform Eq. 8 (Bojadziev & Bojadziev, 2007):

$$x = \frac{m_1 + 4m_2 + m_3}{6} \tag{8}$$

where x is the mean of the fuzzy number $\tilde{m}$, which is obtained from the processing of pairwise comparisons. Based on the results in this section, the most important factors for all DPSIR groups are selected and presented in Table 8. These factors are scaled parameters for the DPSIR framework. The results of this section can introduce the scale parameters (Kurttila et al., 2000). With regard to the aims of the study, we focused on calculating the factor weights according to the α-cuts instead of continuing the processes on the scale parameters.

Calculating the factor weights according to the α-cuts

The α-cut concept that is first proposed by Zadeh (1971) is one of the most important and widely used concepts in both theory and applications of the fuzzy set theory. By α-cuts, we can specify the elements of a fuzzy set $\tilde{A}$ that their membership values (degree of belonging) are bigger than or equal to alpha. Mathematically, we can define the α-cut of a fuzzy set $\tilde{A}$ as follows:

$$\tilde{A}_a = \left\{ x \in X \mid \mu_A(x) \geq \alpha, \alpha \epsilon [0,1] \right\} \tag{9}$$

where $\mu_{\tilde{A}}(x)$ is the membership function of $\tilde{A}$. So, α -cuts are non-fuzzy (crisp) sets, and they can be used to convert a fuzzy problem into a non-fuzzy one. This approach is applied in a significant number of fuzzy studies (e.g., Hemmati-Marbini et al., 2011; Pourabdollah et al., 2020) to solve real-world problems.

Depending on the size of uncertainty, the α-cut method can lead to different results. FAHP based on α-cuts allows analysts to categorize the results at different ranges of quantitative uncertainty such as low ($\alpha = 0.9$), medium ($\alpha = 0.5$) and high uncertainty ($\alpha = 0.1$) with respect to a particular problem, and thus to compare the results of high uncertainty with low uncertainty. In other words, α-cuts in FAHP represent the wide range of weights proportional to the uncertainty of the decision situations. Let $\tilde{A} = (a, b, c)$ be the TFN. In the α-cuts method, the wide range of the weights is defined as Eq. 10 (Basirzadeh & Abbasi Shureshjani, 2008; Zandebasiri et al., 2012; Abbasi Shureshjani & Darehmiraki, 2013). In this paper, we used Eq. 10 for only three different $Q_a : Q_{0.1}, Q_{0.5}, Q_{0.9}$.

$$Q_a = 2b(1-\alpha) + \frac{(c-b)-(b-a)}{2}\left(1-\alpha^2\right) \tag{10}$$

Investigating the subtraction of the factor weights

In this step, the subtraction of the factor weights in each group of the DPSIR was calculated in order to better differentiate between the results of the DPSIR factors. For this purpose, the factor weights w_j were ranked according to their size. For instance, w_1 is the parameter with the highest priority. Finally, the subtraction of w_i and w_{i+1} was calculated and called $w_i - w_{i+1}$. These subtractions were analyzed using Friedman's Sign test in SPSS software.

Table 3 SWOT analysis for the α-cut-based new approach in FAHP

Strengths	**Weaknesses**
Takes into account uncertainty	Needs more calculation volume
Easy to use because of the verbal scale	Does not have the proper and accurate software
Opportunities	**Threats**
The convenience of the respondents	Time of the analysis
A more logical and complete result	Possible errors in calculations

SWOT analysis

Finally, we have prepared the SWOT (Strengths, Weaknesses, Opportunities, and Threats) framework to investigate the strengths and weaknesses as well as opportunities and threats of this new approach presented in this article (Kurttila et al., 2000; Zandebasiri & Hoseini, 2019). This analysis can explore new situations and methods so that decision-makers can understand the weaknesses and threats when they choose the new method. Our goal in conducting this analysis was for the readers of the α-cuts in FAHP to understand what threats they should anticipate if they were to benefit from the method. Table 3 presents the SWOT analysis based on the α-cuts in the FAHP in quantifying the DPSIR framework.

Results

Results of FAHP and the scale parameters

The factors within groups of DPSIR model were evaluated by the FAHP model and Chang's FSE technique. The local weights and pairwise comparisons of the DPSIR factors are given in Table 4.

The results in Table 4 (D lines) clearly illustrate that the decision-making process is the most important driving force in forest management planning in the Zagros forests, Iran. The results from the P lines indicate that lack of protection is the most effective pressure for these ecosystems. The results in S lines show that coppicing and the need of forest stands for natural regeneration has become a most important issue for the management of the Zagros forests, which can affect other issues such as forest stands stability and sustainable forest management. This may be because coppicing plays an important role in reducing the quality of the forest structure. The present results regarding the ecosystem impacts indicate that soil weakness is the most important ecosystem impact (I lines) and the results in R lines illustrate that precipitation storage is the most important response for these forests based on driving forces, pressures, and their state. The elements with the maximum priority (scale parameters) of each DPSIR category are presented as reported in Table 5. These factors can be considered as the

Table 4 Local factor weights and FSE for the factors of the DPSIR framework

		FSE		Local weights	Crisp rank
Driving forces					
D_1	0.2540	0.3503	0.4844	0.3566	2
D_2	0.4053	0.5771	0.8145	0.5880	1
D_3	0.0595	0.0725	0.0923	0.0736	3
Pressures					
P_1	0.1833	0.2370	0.3112	0.2404	2
P_2	0.1377	0.1724	0.2198	0.1745	3
P_3	0.4331	0.5906	0.7950	0.5984	1
State					
S_1	0.3406	0.4610	0.6218	0.4677	1
S_2	0.0995	0.1263	0.1650	0.1282	3
S_3	0.3065	0.4126	0.5525	0.4182	2
Impacts					
I_1	0.1807	0.2632	0.4243	0.2763	3
I_2	0.2213	0.3158	0.4539	0.3231	2
I_3	0.2367	0.4211	0.6875	0.4347	1
Responses					
R_1	0.4515	0.6076	0.8086	0.6150	1
R_2	0.1298	0.1646	0.2125	0.1668	3
R_3	0.1744	0.2278	0.3024	0.2313	2

main elements in the management of the Zagros forests, Iran.

The result of calculating α-cuts

The FSE within the groups of DPSIR model was evaluated by the α-cuts, which allows for managing uncertainty in the weighting of the DPSIR factors. The results for three different α-cuts for the ranking of the DPSIR factors are presented in Table 6.

The results in Table 6 show that the rankings of the DPSIR factors are the same for all the α-cuts. A question is asked whether the ranking of the factors remains unchanged, and what is the added value of the α-cuts? The answer is that in $\alpha = 0.1$, the uncertainty is high and the differences are reduced, and in the conclusive states ($\alpha = 0.9$), the difference in weights is increased.

The result of the subtractions of the weights

Since the α-cuts could not present a different ranking for the priority of factors (Table 6), the subtractions of the DPSIR factor's weights are given in Table 7.

Figure 5 shows the subtractions of the DPSIR factor's weights in Excel diagram. This chart provides more clarity to display the differences.

In Fig. 5, the subtractions of the DPSIR factors are shown on the y-axis, and D, P, S, I, and R factors are respectively shown on the x-axis and each one has two diagrams: w_1-w_2 and w_2-w_3. As shown in Fig. 5, the biggest differences in the $\alpha = 0.1$ are noticeable. The results of Fig. 5 show the large pressure forces as well as the required responses for the oak decline in the Zagros forests. The Friedman test results for $w_1 - w_2$ and $w_2 - w_3$ of the α-cuts ($N=6$, Chi-square$=8$, df$=4$) indicate 0/092 Asymp. Sig. To further investigate the results of the α-cuts, the differences between w_1 (scale parameters), w_2, and also between w_3 and w_2 in each group were analyzed accordingly. The results of the Friedman test in SPSS software show that the difference between the weight difference of rank 2 and rank 1 and also rank 3 and rank 2 (see Table 7) is significant in each group. In Table 7, for $\alpha = 0.1$, the distance between the weights is very large, but in c and the opposite is true, i.e., the distance between the weights is very small. This issue was extracted from the uncertainty.

Table 5 The scale parameters of the DPSIR groups

DPSIR groups	Scale parameters
Driving force	Decision making
Pressure	Lack of protection
State	Coppice stands
Impact	Soil weakness
Response	Precipitation storage

Table 6 The ranking of the DPSIR factors with α-cuts

	Local weight,$\alpha = 0.1$	Local weight,$\alpha = 0.5$	Local weight,$\alpha = 0.9$	Rank
Driving forces				
D_1	0.6494	0.3645	0.0735	2
D_2	1.0712	0.6017	0.1216	1
D_3	0.1339	0.0750	0.0151	3
Pressures				
P_1	0.4367	0.2375	0.0493	2
P_2	0.3166	0.1787	0.0355	3
P_3	1.0864	0.6081	0.1225	1
State				
S_1	1.0318	0.4761	0.0960	1
S_2	0.2332	0.1307	0.0264	3
S_3	0.7595	0.4252	0.0857	2
Impacts				
I_1	0.5127	0.2926	0.0600	3
I_2	0.5942	0.3174	0.0883	2
I_3	0.8092	0.4595	0.0939	1
Responses				
R_1	1.1161	0.6244	0.1257	1
R_2	0.2963	0.1694	0.0341	3
R_3	0.4261	0.2398	0.0485	2

Discussion

Table 3 presents a set of simultaneous strengths and weaknesses of the α-cuts method in quantifying the PSIR framework. According to these descriptors, it seems that the α-cuts can be more specific about the priorities, but this requires a lot of time to do different analyses on the results. These results are dependent on the type of problem analysis of the team analysis. Accordingly, the α-cuts offer an attractive alternative for forest managers and especially for those dealing with models based on fuzzy set theory, but the

Table 7 The subtractions of the DPSIR factor's weights in α-cuts methods

The groups	The subtraction of the weights	The subtraction, α = 0.1	The subtraction, α = 0.5	The subtraction, α = 0.9
Driving forces	W_1-W_2	0.4213	0.2372	0.0481
	W_2-W_3	0.5160	0.2895	0.0584
Pressures	W_1-W_2	0.6496	0.3706	0.0732
	W_2-W_3	0.1201	0.0588	0.0138
State	W_1-W_2	0.2723	0.0509	0.0103
	W_2-W_3	0.5263	0.2945	0.0593
Impacts	W_1-W_2	0.2150	0.1421	0.0056
	W_2-W_3	0.0815	0.0248	0.0283
Responses	W_1-W_2	0.6900	0.3846	0.0772
	W_2-W_3	0.1298	0.0704	0.0144

application of the α-cuts has also some limitations. These findings evaluate the potential of the FAHP based on the α-cuts in the solution of the DPSIR quantification for forest condition assessment. When choosing a method, however, it is important to bear in mind that each method has not only a number of strengths and opportunities but also some weaknesses and threats, and it should not be analyzed based on one strength/opportunity or weakness/threat alone. Quantifying these strengths and weaknesses (Kurttila et al., 2000) may be inevitable for future research, and it could also be treated as a problem for future scenarios in natural resource modeling. It is expected that such upgrading will extend the use of fuzzy decisions based on the α-cut method in forest planning decisions. In this study, we identified the most effective ways to adopt management strategies and decided on this issue. We also developed a research methodology by designing α-cuts in the final conclusion. In addition, we determined the extent to which the topic of α-cuts can be used in managerial decisions for forest managers. Nowadays, researchers in the field of mathematics, especially in the field of operational research, have presented different ranking methods (Shakouri et al., 2020). Exploring alternative methods for fuzzy ranking and comparing these approaches with α-cuts can help identify more strengths and weaknesses of this approach. According to Table 3, the main strength of FAHP, which is primarily based on α-cuts, is the use of verbal terms; however, the weakness is that this approach has a lot of calculations. At the same time, although the work of respondents is comfortable

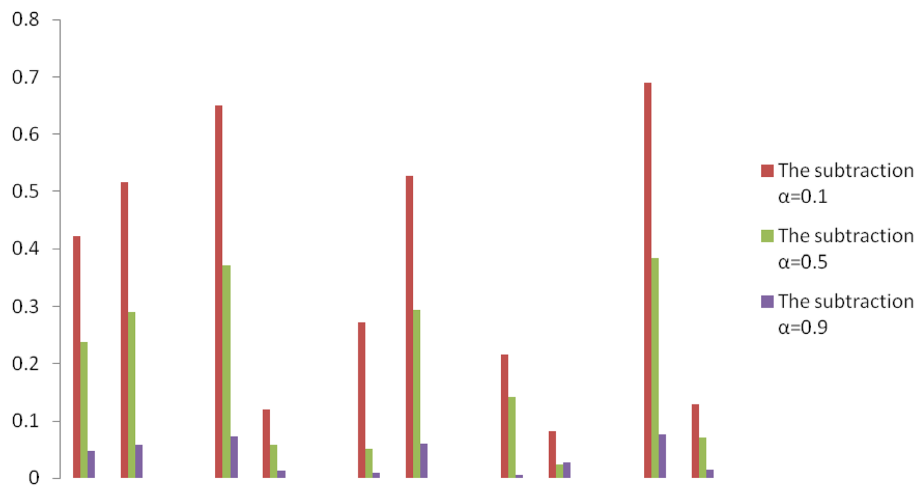

Fig. 5 Subtractions of the DPSIR factor's weights in Excel diagram

(Opportunity), the work of the analyst team will be difficult under threats. The respondents' convenience means that the experts can answer questions in a shorter time for pairwise comparisons. In pairwise comparisons, according to fuzzy methods, it is enough for the expert to use a verbal concept to compare pairs and not the exact number and can be considered as a strong point for analysis. In addition, the time of the analysis refers to a period of time for examining pairwise comparison results considering the α-cuts in fuzzy calculations. In this regard, due to the use of different values for the α-cuts, the time analysis of this fuzzy model is increased and can be considered as a weakness for the analysis.

Wolfslehner and Vacik (2008) arranged the indicators of sustainability in a pressure–state–response model of management unit in the North-Eastern Limestone Alps in Austria. They used ANP (analytic network process) for PSR quantification. In this study, we have used the AHP method, but in a fuzzy form. In this method, the respondents are given more freedom to make choices. In addition, in this study, the α -cuts were also designed. However, in our case, the α -cuts designs did not show any difference in the ranking of the factors. These results show that the α-cuts, despite the weaknesses that this method may have, can be used for the ranking of the factors in order to improve the understanding of the ranking.

Compared to the FAHP without α-cuts, the α-cuts provide a really complete method for distinguishing several ranks that best represent the priority factors of forest management. This study also identified a significant difference between the subtractions of weights (Table 7). Hence, it could be concluded that depending on the different processing of the data, more interpretable results can be provided than the α-cuts. The impact factors are very closely related, especially in $\alpha = 0.9$ (Table 6), so the importance of the rank among the impact factors cannot be very decisive. In contrast, differences in rank are tangible in the group of driving forces, pressures, and responses. D_2 in the driving forces group is a very important factor and has a significant difference in all the α-cuts (D_2 line in Table 6). If the α-cuts can change the ranking for the factors (different from the crisp results), there would be more distinctive results in this section. However, in this paper, the ranking remained constant but we recommend using α-cuts for other studies. In other situation if the ranking changes, a comparison can be made between the crisp and uncertain results.

Compared to other studies that have provided a quantitative measurement for the DPSIR framework, the research of Mohammadizadeh et al. (2016) is much more pronounced in our study. Mohammadizadeh et al. (2016) used the FAHP method to quantify DPSIR framework. In this study, we improved this quantification using the α-cuts method. In addition, we used the DPSIR framework to build appropriate strategies. At a time, when a landscape (Zagros forests, Iran) is also experiencing socio-economic issues, it is in dire need of protection and conservation. It is important to focus on the DPSIR scale parameters in order to concentrate on strategic management. Accordingly, the scale parameters for the DPSIR framework in the Zagros forests (Table 5) determine the focus on decision-making in the Zagros forest management plans, the implementation of modern forest protection practices, the focus on rootstock management, the review of soil management practices, and the implementation of precipitation storage methods as the most important strategic issues in the forests.

In the context of the DPSIR framework proposed for the Zagros landscape in Iran, the evaluation of the drivers provides the identification of the main driving forces influencing the Zagros landscapes: decision-making, climate change, and the dust that enters from western countries to the Zagros ecosystems in Iran (Table 1). Compared to qualitative studies on the DPSIR framework in the Zagros forests, Heidari et al. (2016) presented some qualitative factors such as lack of fodder for animals, climate change in driving force, the development of agriculture in forest, and traditional pastoral in pressure, soil erosion in impact, lack of regeneration in state factors in northern forests of Zagros ecosystems which could be compatible in some factors with this research. However, some factors related to traditional lopping and copying strategies in northern Zagros forests is totally different from central Zagros forests. Furthermore, in this study, based on quantifying and presenting priorities in the DPSIR framework, it is possible to guide forest management toward the most important factors (according to Tables 4 and 6). This quantification and prioritization can be utilized in forest policy-making as well as some economic distribution such as the prioritization of funding distribution. As for the first factor (decision-making in Table 5), previous decisions in Zagros forest management have often not led to perfect results due to the low social acceptance of local communities. The issue of decision-making in the Zagros forestry FMPs is very important and vital in these projects (Ebrahimi Rostaghi, 2005; Valipour et al., 2014; Zandebasiri & Ghazanfari, 2010). Pressures contain elements that could change the situation of Zagros forest landscapes, i.e., medium pressures generated by all entropy components. The local inhabitants of these forests are highly dependent on their pastoralism, and of course, cattle can prevent natural regeneration in the forest. The main issue resulting from these pressures and states is soil weakness. The combination of soil weakness with the dying of crown cover and basal emergence hole (such as Fig. 8.) requires precipitation storage to prevent oak decline. The purpose is to apply some methods to save the rainfall, such as constructing holes in the soilto be useful for drying trees, especially oak trees, and strengthening the soil in droughts. After the nationalization of Iranian forests in 1963 (Jazirehi & Ebrahimi Rostaghi, 2013) , the status of the local communities and the status of the management and conservation of the Zagros forests have always been problematic (Valipour et al., 2014). Hence, lack of protection is the main pressure for the Zagros landscapes (line P_3 in Table 4). The main social responses of the management to the conditions of these sites are the storage of precipitation and the forest conservation. This issue is also linked to the participation of the local population (Ghazanfari et al., 2004). In the state group, the coppicing has the highest rank (Table 5). In these situations, coppice stands, rock outcrops, and low biodiversity are the main issue which have created soil weakness, failure of regeneration, and oak decline impacts. In this way, the assessment of the impacts caused by anthropogenic activities is quantified. The coppicing of oak has caused the general structural weakness of the forest (Pourhashemi et al., 2015), but the power of oak shooting has resulted in the oak's survival to this day. In such a situation, it is logical to follow the strategies for protecting these forests instead of the strategies of turning coppice forests into high forests ones. In this case, opportunities such as the improvement of specific habitats and forest diversity levels (Vacik et al., 2009) can be used in the forest strategies. In many Zagros areas, natural regeneration is very limited. The grazing of the cattle, the weakness of the soil, and the stretched rock are the reasons for the natural regeneration. Although the forest management carries out many activities for the forest management of Zagros, we can divide them into two categories. In this respect, the forest management emphasizes two strategies: (1) forest conservation and (2) precipitation storage. Precipitation storage is one of the solutions to forest decline in the Zagros forests. In this method, drilling of holes can be used to store rainwater (Zandebasiri et al., 2020a, b). The most important response to these situations is the storage of precipitation for these landscapes (Table 5). The role in this issue arises from the concept of forest declineand heat stress as well as drought in these forests. Forest protection has been one of the main strategies of natural resources personnel in the face of oak decline. In these forests, not only the vegetation of the Zagros ecosystems must be rehabilitated, but also the participation of the communities must be considered. In fact, they need participatory management in order to seize opportunities and prevent threats to forest use by the local population (Zandebasiri et al., 2019).

Overall, the DPSIR framework can be a way to identify and describe a system. The findings of this survey indicate that the Zagros forests in Iran have special conditions, such as coppice oak forests, the occurrence of oak decline, and socio-economic problems. Socio-economic problems in the Zagros forests consist of a set of local community dependencies on the forests such as utilizing forests by local communities for non-timber forests products, gathering fuel wood, grazing of livestock in the forest and agriculture under the forest in some areas could be considered as the origination of forest depletion. Nevertheless, local communities have traditional forest-related knowledge in the harvesting application (Ghazanfari et al., 2004; Valipour et al., 2014; Zandebasiri & Pourhashemi, 2019). Accordingly, the preparation of social forestry with participation in the decision-making level of the local population and also the control of oak decline are the main issues that are relevant for decision-making in Zagros forestry.

Conclusion

According to the conducted modeling of this paper, we understood significant issues regarding the application of the DPSIR framework in the Iranian forestry. Local communities play an important role in the Zagros forests of Iran who are the cause of livestock grazing and traditional harvesting of timber and non-timber forest products. Managing these ecosystems has many complexities. The issue of decision-making is very important for the FMPs, thus trial and error methods should not be the focus of decisions for the Zagros management projects. Paying attention to local communities and their participation in forest management as well as focusing on oak decline, and concentrating on precipitation storage can play the most important role in preventing the destruction of these forests. If the wrong decisions are made, they can be the most destructive driving forces for Iran's Zagros forestry. In decisions related to the management of Zagros forests, the challenges between the management of local communities and the need to protect coppicing forests and restore the condition of forest soils should be considered simultaneously. In such situations, decision-making techniques can be of great help in differentiating the factors influencing decision-making and policy-making for these forests. Given the uncertainty of forestry projects, fuzzy decision-making methods can have benefits of addressing this uncertainty. We found that $\alpha-$cuts could improve the quality of the decision-making process, but only after secondary analysis. Initially, we did not find any significant difference in the results between alpha cuts and research results, but using the differences in rankings, we could identify a significant difference. In this way, we establish a general rule: $\alpha-$cuts can be used to manage the forest in fuzzy decisions, but this requires a lot of information processing. We propose that this method, which requires lengthy calculations to get the answer, should only be used by forest managers when the quality of the results and the difference between the parameters are very important to them, otherwise they may be able to achieve the same desired results in a much easier way. The results also highlight the effect of fuzzy type processes on their performance. A critical feature for the DPSIR framework is the relationship between the factors and the effects of factors on the other factors. It would be important to consider the design of network analysis between different factors and the effect of these connections on the priorities and the planning process. That could help discover a more profound understanding of the DPSIRS framework's roles in forest planning. Another recommended topic of future study is to compare the results of $\alpha-$cuts with other fuzzy ranking methods to determine whether other fuzzy ranking methods can shift the ranking of the preference of the DPSIR framework parameters.

Abbreviations AHP: Analytic hierarchy process; DPSIR: Driving forces, pressures, state, impact, responses; FMP: Forest management plan; FSE: Fuzzy synthetic extent; MCDM: Multi criteria decision making; SWOT: Strengths, weaknesses, opportunities, threats; ANP: Analytic network process; FAHP: Fuzzy analytic hierarchy process; FMU: Forest management unit; MADM: Multi attribute decision making; NGOs: Non-governmental organizations; TFN: Triangular fuzzy number

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Data availability For further information, please contact the corresponding author (mehdi.zandebasiri@yahoo.com).

Declarations

Competing interests The authors declare no competing interests.

Appendix

Livestock grazing in the forest is one of the problems of Zagros forests in Iran. This issue causes both soil weakness and the elimination of sexual reproduction in the forest. Nowadays, the Zagros forests of Iran are mainly coppice forests (such as show in Fig. 6). Coppice forests can reduce the tree species richness (Vacik et al., 2009), but the problem in the Zagros forest is that the possibility of turning these forests into high forests is low due to socioeconomic problems (Ghazanfari et al., 2004; Valipour et al., 2014; Imani Rastabi et al., 2015). In some areas, there is a combination of coppice with standard tree species richness, but many single stems are the oldest shoots of the past.

One of the visible conditions in the Zagros forests is rock outcrops and soil erosion. In some cases, the ground is barely covered by forest trees and there are many pebbles on the ground of oak stands (such as shown in Fig. 7). This specifies the need for protection in such areas.

Soil weakness is the main impact of these pressures and drivers. In this paper, "soil weakness" consists of loss of microorganisms in soil (such as earthworm), lack of surface cover, and lack of stability. This impact involves weakness in various productions, lack of stability and environmental capabilities, and reducing social welfare which originated from the lack of soil productivity. This can be attributed to the importance of soil for seed regeneration, an issue that Zagros forests suffer from. The weakness of the soil can also be caused by the grazing of the cattle, the lack of crown cover, and the dryness of the air. For about 10 years, the decline of the oak has been an issue. The rise in temperature, climate change, external dusts, and the general weakness of the forest structure could be the reason for this. After declining at the tree crowns, the basal emergence hole appears on oak trunks (Fig. 8).

Fig. 6 Coppice trees at Tange-Solak local area in the Zagros region

Fig. 7 Little ground covers for the trees at Tange-Solak local area in the Zagros region

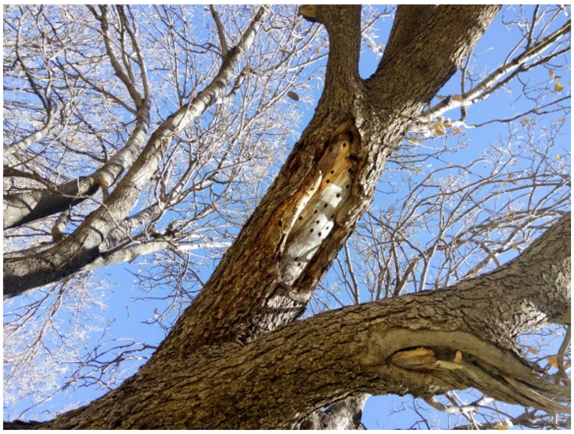

Fig. 8 Basal emergence holes in the topper parts of the branches in Tange-Solak local area in the Zagros region

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