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Scenario simulation in decision-making optimization: lessons from social coppice forests

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Abstract
In this study, three options for coppice management in Iran were developed. These management options include Traditional Coppicing (TC), modification of TC, and extreme conservation to convert them into high forest. Analytic Hierarchy Process (AHP) was used for modeling to select the optimal solution for managing these forests. Six different scenarios were simulated in which the importance of the criteria in decision-making process changed. The results show that each of the three management options has its own importance, which depends on the conditions of the region and the different importance of the decision criteria. Therefore, the selection of the management scenario for future forest planning depends on prioritizing the criteria from the perspective of the managers and stakeholders and is dependent on social, economic and ecological conditions in each management unit. The results of this study show that it is not possible to rely solely on the results of the AHP method for forest management decisions, as AHP model does not include constraints. In this context, reverse engineering can be very helpful in the final conclusion of the decision. The results of this study can make a valuable contribution to the global literature and support decision-making, especially in scenarios where stakeholder participation may be limited and modeling stakeholder behavior is essential to the decision-making process.

Keywords Traditional coppicing · Extreme conservation · Analytic hierarchy process · Sustainable forest management

Abbreviations

AHP	Analytic hierarchy process
EC	Extreme conservation
MTC	Modification traditional coppicing
SFM	Sustainable forest management
TC	Traditional coppicing

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Introduction

In the forest management literature, forests can be classified on the basis of method of regeneration on high forest, coppice and coppice with standards (Nicolescu et al. 2018; Heydari et al. 2021; Johann 2021). High forests are forests that originated through seeds and natural regeneration takes place in these forests. Several factors such as natural seed-dispersal processes and seedling development are effective for successful natural regeneration (Im et al. 2023). In contrast to high forests, coppice forests are forests that are reproduce by shoots and not by seeds. In these forests, the possibility of tree regeneration by seeds is very limited, and the trees use the formation and production of shoots for their survival. Depending on the species, the shoots originate from stumps or roots (Nicolescu et al. 2018; Johann 2021). The third category is coppice with standards, where there is a combination of trees from seeds and trees from shoots. In coppice with standards, a considerable number of seeds can be produced by the trees (Pourhashemi et al. 2018), but for various reasons, such as poor soil or problems with livestock grazing, it is not possible to establish these seeds. Coppices with standards have a greater diversity of production and

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can be used industrially, while a single coppice can only be used as fuel (Heydari et al. 2021). An introduction to coppice forests in western Iran (The Zagros forests) can be found in Appendix A.

Some scenario building and decision-making studies have been conducted in coppice forests in Europe and Asia, such as the study on modeling the impact of alternative scenarios on wood production and carbon storage by Bottalico et al. (2016), the study on abandoned coppice forests by Imamura et al. (2017), and the socio-economic assessment by Riccioli et al. (2020).

There are very large differences between conditions of Iranian Zagros forests from a perspective of socio-economic problems compared to previous studies. For example, there is no industrial timber production from oak forests in the Zagros forests of Iran, and the possible scenarios serve as a basis for all kinds of management plans, but not for wood harvesting. Other problems include livestock grazing, the dependence of local communities on forests, and the particular forms of harvesting in Zagros forests in Iran, which require a different form of forest management scenarios for these forests to plan the social coppice forests. Such scenarios can examine all aspects of different issues and priorities in coppice or coppice with standards management.

The important issue in policy making is that preferences and priorities in coppice forests have do far been less studied in terms of scenarios making and decision-making processes. Policy makers need to identify different models of forest management based on the priority of different criteria. By simulating and modeling different states, different scenarios can be designed for the continuation of activities in the future of the forest. Such scenario building could be unique for social coppice forests as it describes in detail the social conditions and impacts combination with the economic and ecological conditions.

Scenarios define the outline of foreseeable situations in an unknown future and can be selected for simulation (Creutzburg et al. 2017). In scenarios, all possible states can be predicted using concepts of probabilities and weightings for different states. In this way, this study aims to design different scenarios for the continuation of different activities in coppice forests and to determine the importance of each scenario. Finally, it aims to identify the best plans for forest continuity and the highest efficiency for the provision of functions and ecosystem services in coppice, as well as in coppice with standard socio-economic problems. Many previous studies in the field of forest management have attempted to involve multiple stakeholders in decision-making such as Pelyukh et al. (2021), who identified 15 stakeholders in forest management in the Yavoriv region, Ukraine. Another example is a web content-based method for stakeholder analysis in UK forestry (Raum et al. 2021). Given the difficulty and complexity of involving stakeholders in decision-making processes (Comino et al. 2016), this study can help to fill the gaps in this area. To the best of our knowledge, this study is unique in terms of the application of decision-making and scenario-building methods.

In general, the objectives of this study are as follows: (1) to generate scenarios to study coppice forests with socio-economic problems, (2) to investigate sustainability criteria weights in coppice forest management, and (3) to determine the preference and prioritization of different options in different scenarios for coppice forest management. Specifically, this study examines the following research questions:

1) What is the best scenario for the continuation of activities in the coppice and coppice with standard forests given the socio-economic problems?
2) What are the weights of sustainability criteria and ecosystem functions (as sub-criteria) for the management of coppice and coppice with standard in a case study in Iran?
3) How does the priority of the best options in coppice and coppice with standard forests management change by changing the importance of the criteria?
4) How is the application of the results of AHP method under the conditions of scenario building for criteria and reverse engineering to comment on the decision-making process and method?

Materials and methods

Study area

Zagros forests of Iran cover a vast area in the western provinces of Iran. The main objective of this study was to conduct surveys related to decision-making in all social coppice; however, one of the habitats of the Zagros forests in Lorestan province of Iran was selected as the study area. Lorestan province is located in the central part of Zagros vegetation area and the forests of this province have the general characteristics of Zagros forests. The study area is Ghelagol watershed (Ghelagol in the local dialect and flower castle in the official language), which is located 35 km south of Khorram-Abad city (The center of Lorestan province). Many characteristics of this region, such as socio-economic problems and the structure of forest stands, are similar to those of other areas of the Zagros forests. The minimum and maximum altitudes are 1500 and 2520 m above sea level,. The soil of the region is generally loamy and the climate is semi-humid and cold. The trees in the area are mainly coppice, and *Quercus brantii* Lindl. is the main species in the study area (Modaberi et al. 2018).

The study area, like other forest areas in the Zagros forests, suffers from weaknesses in wood production, poor soil composition, low density of trees per hectare, poor soil biodiversity, and poor overall habitat biodiversity. Furthermore, there are many opportunities for tourism in this area due to the beautiful landscape (Zandebasiri and Ghazanfari 2010). In addition to the ecological problems, there are also social pressures from livestock grazing, harvesting of wood and non-wood forest products, and various forms of forest degradation that affect the structural indices of these forests (Farhadi et al. 2014). Various forms of tree harvesting are carried out in coppice forests to harvest wood or produce fodder from the leaves. For example, pollarding is carried out in the forests of northern Zagros in Kurdistan province (Valipour et al. 2014; Plieninger et al. 2023). There are different forms of branch cutting and wood cutting in the study area. These forms are branching for the compilation of livestock, selecting from shoots, and in some situations (limited), full cutting in large trees to extract wood for fuel. Although these forests are protected from logging and cutting of trees in these forests is prohibited.

Methods

Designing management options

One of the most important issues in the Zagros forests is related to the management of forest by local communities and the formulation of principles and rules for sustainable management of these forests. Therefore, in order to identify the most appropriate program for Zagros forests, three management options were first defined, which are not independent of the local communities' perceptions. These three management options were (1) traditional coppice management (TC), which involves the continuation of traditional management by local communities and livestock grazing without severe management intervention, (2) modification of traditional coppice management (MTC) with the permission for some harvesting by local communities, and (3) extreme conservation (EC), which involves the complete prevention of harvesting by local communities and the conversion of coppice forests into high forests. Appendix B explains each of these management options in detail.

Criteria for decision-making

For the use of decision support systems, the goal, the management options and several decision criteria must be defined. The most important goal of forest management is forest sustainability, and in order to achieve this goal, a set of criteria and indicators are designed in terms of time and space (Lier et al. 2021). In this study, sustainable forest management (SFM) was chosen as the main goal using all three dimensions of economic, environmental and social aspects (Lier et al. 2021; Ananda & Herath 2003) as criteria.

Sub-criteria for criteria

Considering given the generality of the criteria, a number of sub-criteria were created for each criterion to describe the different dimensions in more detail. The ecosystem functions present in the study area were used for the sub-criteria (Zandebasiri et al. 2023 and originally by de Groot et al. 2002). Some ecosystem functions were combined to reduce the number of sub-criteria and some other sub-criteria were added to make the concept of sustainability more comprehensive. In this context, science and education; cultural, spiritual, and historical functions; and local management were defined as sub-criteria for the social sustainability criterion. The inclusion of local management as a sub-criterion of this criterion aims to consider the benefits of forests for social sustainability, the reduction of urban migration and the sustainability of local communities in the forest.

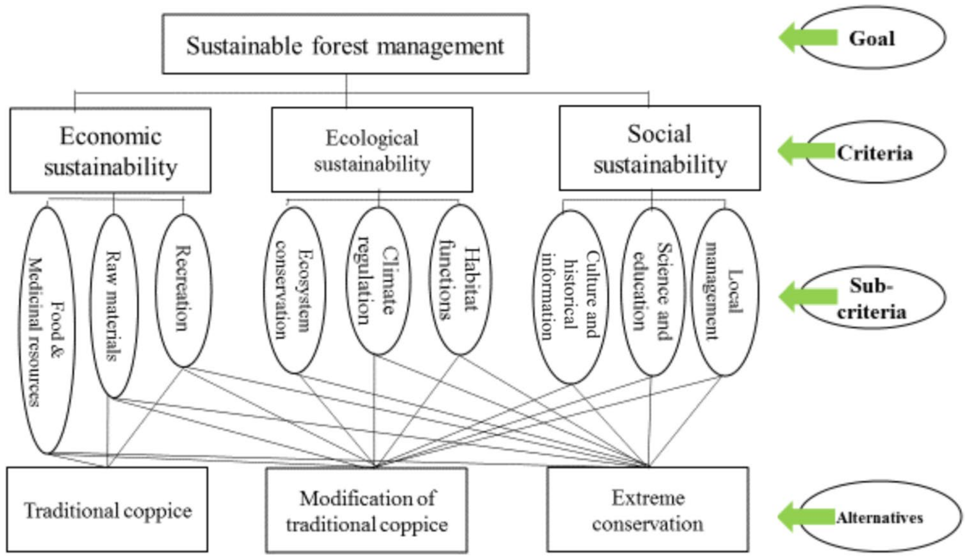
Food and medicinal resources, raw materials, and recreation were defined as sub-criteria for economic sustainability criterion. Food and medical resources were defined as edible products, food collection, forest fruits, medicinal plant products, and non-wood products, while raw materials were defined as wood obtained from the forest in various forms, wood for construction materials, wood for fences, etc.

Ecosystem conservation, habitat functions, and climate regulation were defined as sub-criteria for ecological sustainability. Ecosystem conservation encompasses all the functions of water supply, soil conservation, and soil formation. Habitat functions include a range of factors relating to regulatory functions for wildlife, fauna and flora, nursing roles (Maintenance functions) and shelter for wildlife, biological control, and the regulation of nutrient recycling in the ecosystem. Climate regulation also includes gas regulation and prevention of disturbance from storm dust. Figure 1 shows the hierarchy of the decision-making process for the goal, criteria, sub-criteria, and management options.

Evaluation of the scenarios with AHP method

There are many different Multi-Criteria Decision-Making (MCDM) methods that are used in the context of decision-making. One of the simplest and at the same time most logical and widely used methods is the Analytic Hierarchy Process (AHP). AHP provides a hierarchical framework for selecting the best option and ranking other options by forming a hierarchy of goals, criteria and options (Ghodsipour 2019; Kucuker and Giraldo 2022). Once the hierarchy is formed, pairwise comparisons are made to compare the importance of the elements at each level of the

Fig. 1 The hierarchy of the decision-making process from goal to management options



hierarchy relative to the higher level using the 1–9 scale described in Table 1.

In the last part of the AHP method, a sensitivity analysis is performed to show how sensitive the results are to a change in the importance of different criteria, to test the model (Bhadra et al. 2022) and to check the applicability of the AHP method for this study. There are several methods for sensitivity analysis, including dynamic, performance, gradient, head to head, and two-dimensional sensitivity analysis (Ghodsipour 2019). The graphical efficiency sensitivity analysis was used in this study. Dynamic sensitivity analysis with 10 and 20 percent changes in the weights of the criteria was also used to investigate how changes in the importance of the criteria affect the weights of the management options (Zandebasiri et al. 2010). For each of the decision levels, a square pairwise comparison matrix (A_i) is defined. The source of formulas 1 to 4 is Saaty (1990).

$$A_i = \begin{bmatrix} 1 & a_{12} & a_{13} & \dots & a_{1n} \\ a_{21} & 1 & a_{23} & \dots & a_{2n} \\ a_{31} & a_{32} & 1 & \dots & a_{3n} \\ \dots & \dots & \dots & 1 & \dots \\ a_{n1} & a_{n2} & \dots. & \dots & 1 \end{bmatrix} \tag{1}$$

In Eq. 1, the elements on the main diagonal (a_{11} to a_{nn}) are all equal to 1, because the result of comparing each element with itself is always equal to 1. A reciprocal condition as in Eq. (2) applies to the other elements of this matrix.

$$a_{ij} = \frac{1}{a_{ji}} \tag{2}$$

The geometric mean was used to aggregate experts' pairwise comparison matrices into a group pairwise comparison matrix, using Expert choice software. The consistency of pairwise comparisons is measured by the consistency ratio of the pairwise comparison matrix as described in Eq. 3 (Also see the source Arshad et al. 2023 in addition to Saaty 1990)

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \tag{3}$$

In Eq. (3), CR is the consistency ratio, CI is the consistency index which is calculated according to Eq. 4

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{4}$$

where $\lambda_{\max}$ is the principal eigenvalue and n is the matrix size, and RI is the random index.

It is necessary to check that CR is less than 0.1 for pairwise comparison matrices in AHP to be acceptably consistent. In this study, there were two very minor inconsistencies (there was no need to change prioritization) that

Table 1 Ratio scale of element importance in each level for pairwise comparison

Scale	1	3	5	7	9	2, 4, 6, 8
Definition: Severity of importance	Equally	Moderately	Obviously	Particularly	Absolutely	Values between the above numbers

Modified from Savari et al. 2022 and originally published by Saaty 1977 & Saaty, 1990 were resolved by a minor change in one of the pairwise comparisons.

Scenario building

The importance of social, economic, and ecological criteria in forest management can be assessed in different ways. The history of preparing forest management plans in the Zagros forests also shows that each of the criteria can be prioritized (Zandebasiri et al. 2021 and originally by Ebrahimi Rostaghi 2005). Recently, forestry officials in this region have attempted to define social forestry projects where social criteria appear to have more weight (Isna students, news agency 2022). For this reason, the pairwise comparisons in the criteria section were not conducted in the usual way. In contrast to group decision-making (Grošelj and Dolinar 2023) and stakeholder analysis with the AHP method (Blagojević et al. 2023), the scenarios for different stakeholder decisions are created in this study. In the criteria section, six scenarios were developed to assess their importance, with two scenarios representing the highest preference for each criterion. In each of these six scenarios, the preference for each criterion was simulated independently. Such scenarios can predict different situations for future management and policymaking. The description of the characteristics of the scenarios for the Zagros forests in Iran can be found in Appendix B.

Table 2 shows the types of preference simulation for the criteria. The results of the pairwise comparisons of the sub-criteria were determined by experts and the results of the pairwise comparison of the criteria were formulated as 6 scenarios. In addition, the weights of the management options compared to the sub-criteria were calculated based on the concepts designed in the management options.

Based on Table 2, the calculations were performed six times for one scenario each. At the end of the results, the reverse engineering method was used to interpret the results. Reverse engineering is a problem-solving process that starts with answers (Raja 2008) and searches for the appropriate combination of questions and answers. In this study, reverse engineering was used to determine the issues and conditions in coppice and coppice with standard for which each of the results obtained in the different simulations is suitable.

Results and discussion

Table 3 shows the weights of sub-criteria based on the results of the expert opinions.

The results of Table 3 show that local management has the highest weight among the social sustainability sub-criteria. This is due to the role of the local population in the participatory management of social coppice forests. Recreation is the most important sub-criterion among the economic sustainability factors, which is due to the role that recreation plays in the local economy and the reduction of pressure on timber harvesting due to the increase in tourism revenues. Among the ecological sustainability factors, ecosystem conservation has the highest weight, because the mountain coppice forests are in a sensitive position and need to be protected (Table 4).

Table 3 The weights from the pairwise comparisons of the sub-criteria based on the results of the expert opinions

Criteria	Sub-criteria	Weights
Social sustainability		
	Local management	0.558
	Science and education	0.320
	Culture and history	0.122
Economic sustainability		
	Recreation	0.745
	Raw materials	0.099
	Food & medicinal resources	0.156
Ecological sustainability		
	Habitat functions	0.179
	Climate regulation	0.113
	Ecosystem conservation	0.709

Table 2 Six scenarios, constructed on the ranking of the criteria

Scenario 1	Ranking*	Scenario 2	Ranking	Scenario 3	Ranking
Social sustainability	1	Social sustainability	1	Economic sustainability	1
Economic sustainability	2	Ecological sustainability	2	Ecological sustainability	2
Ecological sustainability	3	Economic sustainability	3	Social sustainability	3
Scenario 4	**Ranking**	**Scenario 5**	**Ranking**	**Scenario 6**	**Ranking**
Economic sustainability	1	Ecological sustainability	1	Ecological sustainability	1
Social sustainability	2	Social sustainability	2	Economic sustainability	2
Ecological sustainability	3	Economic sustainability	3	Social sustainability	3

*Ranking based on the importance of criteria

Table 4 The weights of criteria management options in scenario 1 based on scenario analysis

Criteria				Overall inconsistency
	Social sustainability	Economic sustainability	Ecological sustainability	
Weight	0.625	0.238	0.136	
Management options				
	Traditional coppicing	Extreme conservation	Modification of traditional coppicing	
Weight	0.369	0.366	0.265	0.02

Table 5 The weights of criteria and management options in scenario 1 and dynamic sensitivity analysis

Criteria	Criteria weights	Management options	Management options weights
Original weights in scenario 1			
Social sustainability	62.5%	Traditional coppicing	36.9%
Economic	23.8%	Extreme conservation	36.6%
Ecological	13.6%	Modification of traditional coppicing	26.5%
10% increase in the weight of economic sustainability			
Social sustainability	54.4%	Traditional coppicing	35.3.%
Economic	33.8%	Extreme conservation	38.1%
Ecological	11.9%	Modification of traditional coppicing	26.6%
20% increase in the weight of economic sustainability			
Social sustainability	46.2%	Traditional coppicing	33.8%
Economic	43.8%	Extreme conservation	39.5%
Ecological	10.0%	Modification of traditional coppicing	26.7%
10% increase in the weight of ecological sustainability			
Social sustainability	55.3%	Traditional coppicing	33.9%
Economic	21.1%	Extreme conservation	40.1%
Ecological	23.6%	Modification of traditional coppicing	26.0%
20% increase in the weight of ecological sustainability			
Social sustainability	48.2%	Traditional coppicing	31.1%
Economic	18.2%	Extreme conservation	43.4%
Ecological	33.6%	Modification of traditional coppicing	25.5%

Scenarios with social sustainability as the most important criterion

Based on the scenario analysis, the weights of the criteria and management options in scenario 1 are shown in the first part of Table 5. Figure 2 shows the efficiency sensitivity analysis for the goal (sustainable forest management) for scenario 1 and Table 5 shows the results of the dynamic sensitivity analysis for this scenario.

The explanation for Figs. 2, 3, 4, 5, 6 and 7*: Obj% is percentage of objective changes, Alt% is percentage of alternatives changes, Social susta is the abbreviation for social sustainability, Economic sus for the economic sustainability, and Ecological for the ecological sustainability.*

The results of the sensitivity analysis in Table 5 and Fig. 2 show that the superiority of traditional coppice over extreme conservation is completely unstable, because as soon as the importance of other criteria changes, the extreme conservation option becomes more important.

According to scenario 1, traditional coppice can be a suitable option for the management of Zagros forests

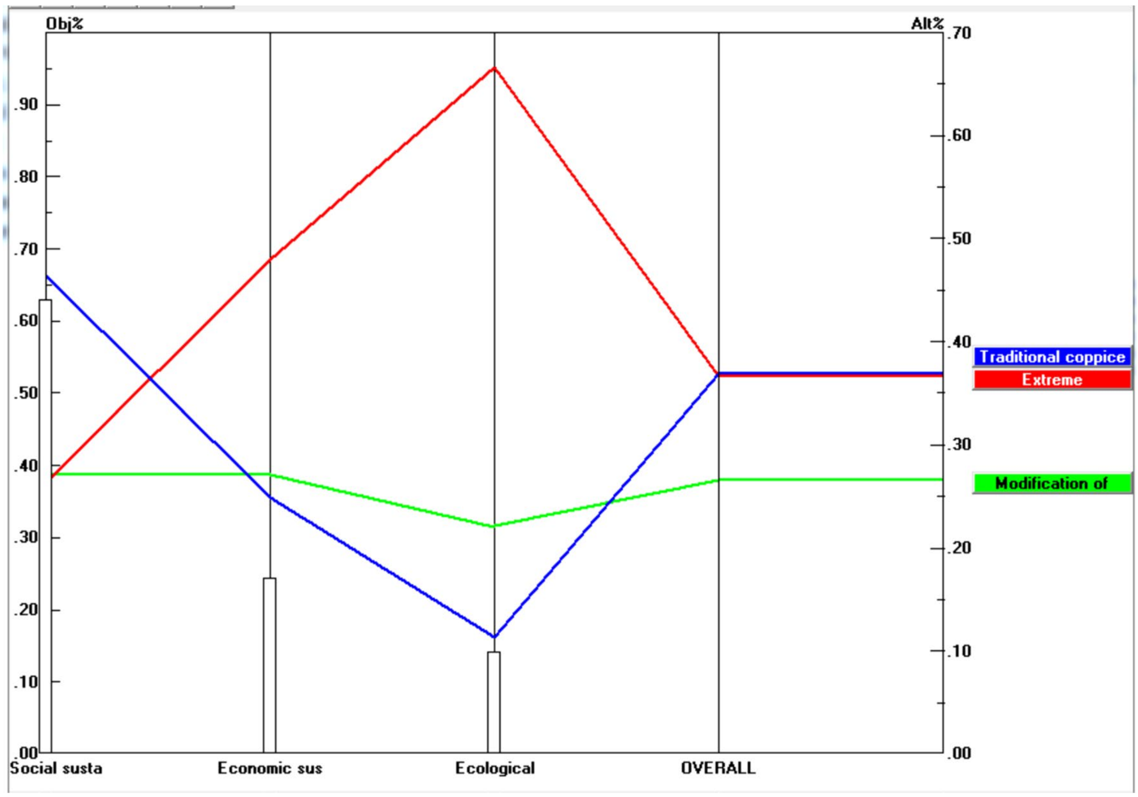


Fig. 2 Efficiency sensitivity analysis for the goal (Sustainable forest management) in scenario 1

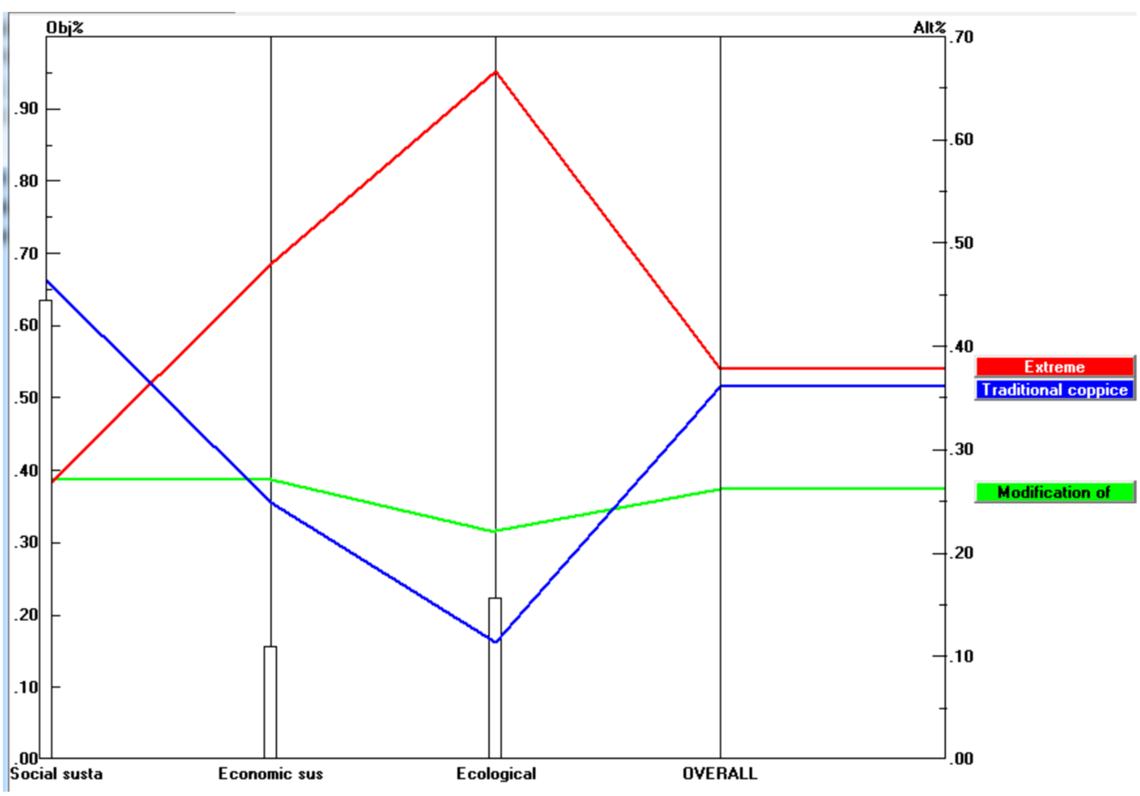


Fig. 3 Efficiency sensitivity analysis to the goal (sustainable forest management) in scenario 2

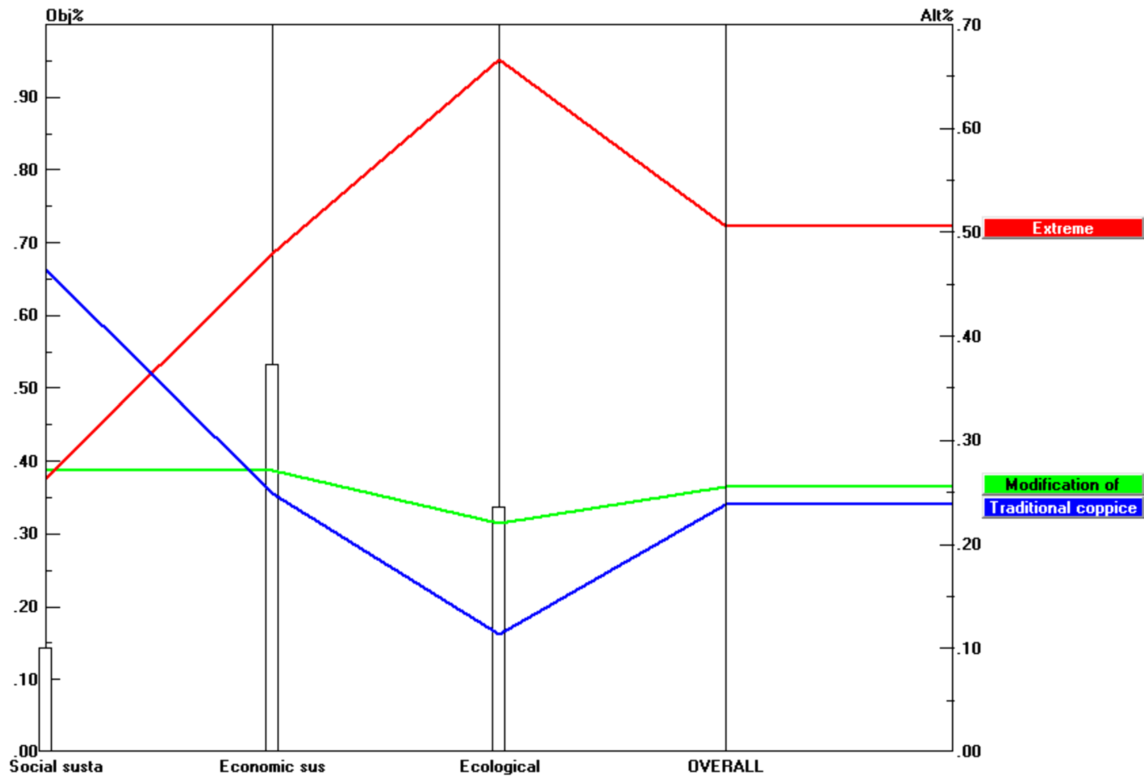


Fig. 4 Efficiency sensitivity analysis to the goal (sustainable forest management) in scenario 3

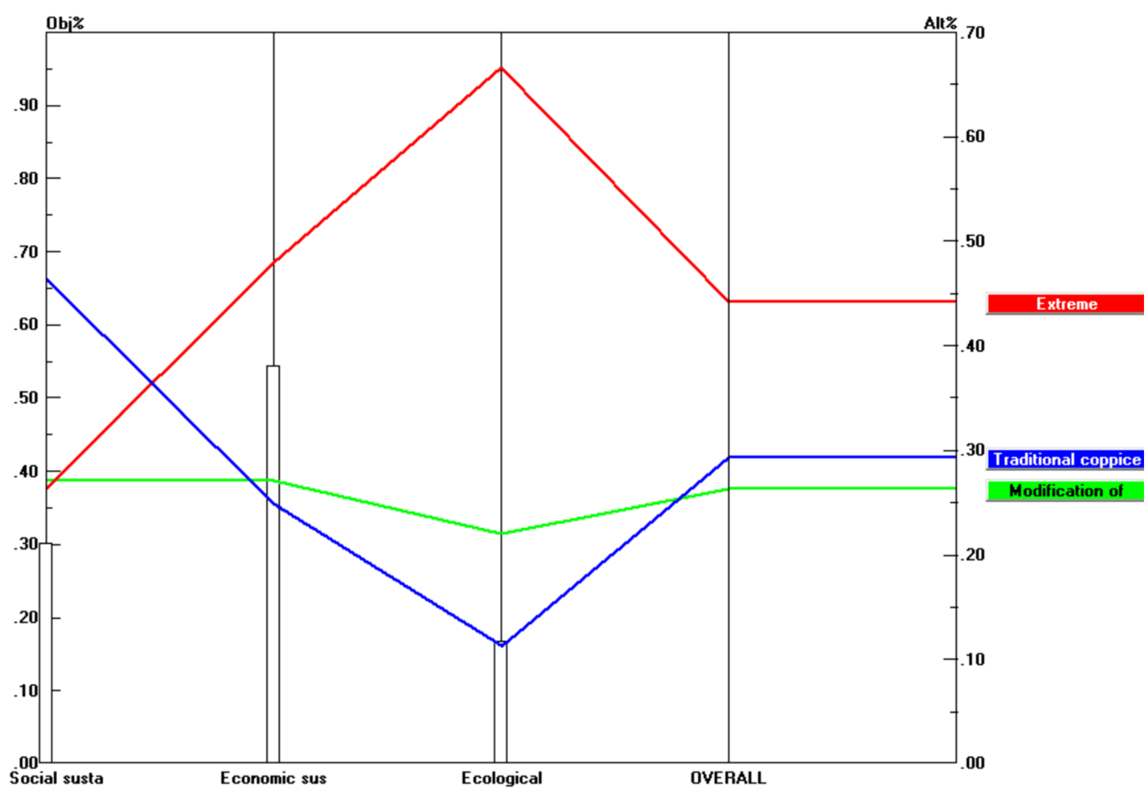


Fig. 5 Efficiency sensitivity analysis to the goal (sustainable forest management) in scenario 4

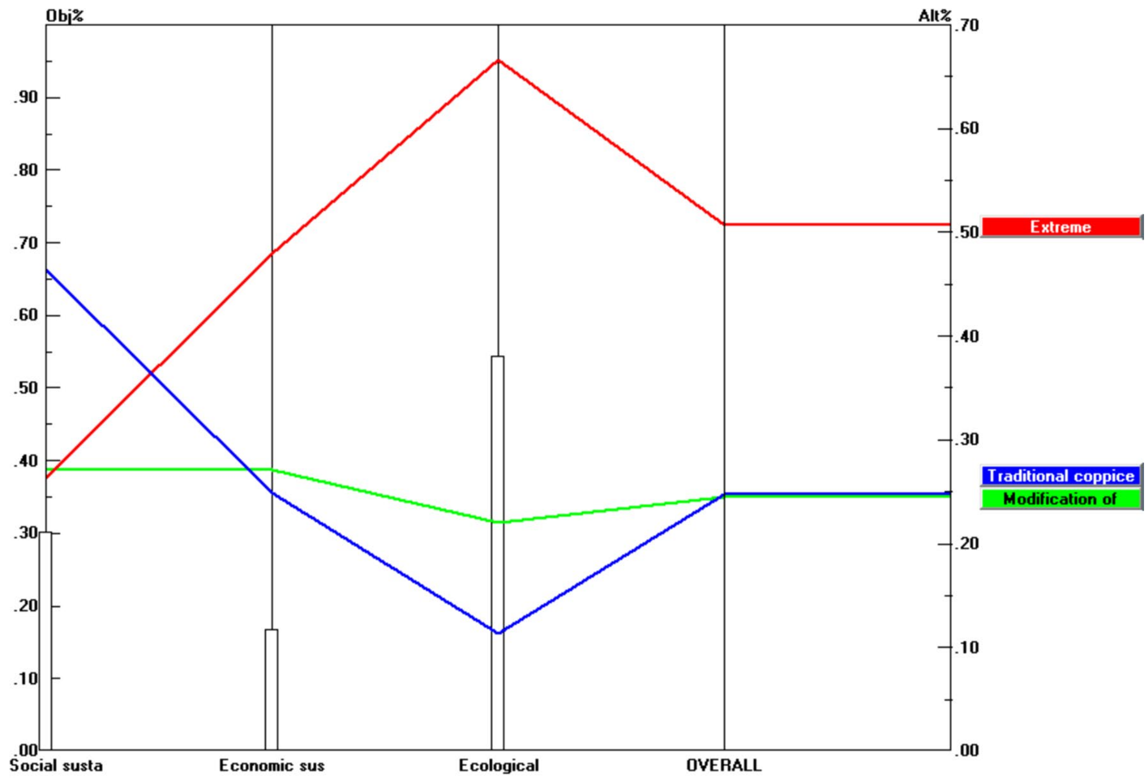


Fig. 6 Efficiency sensitivity analysis to the goal (sustainable forest management) in scenario 5

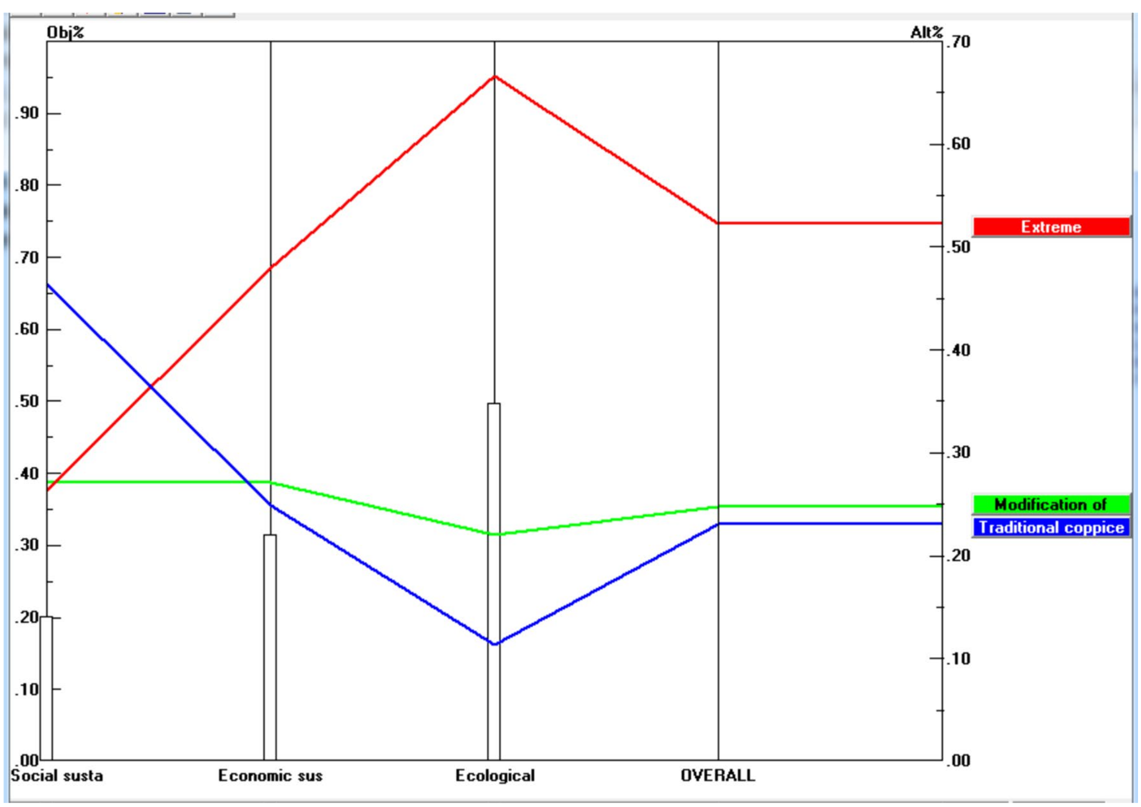


Fig. 7 Efficiency sensitivity analysis to the goal (sustainable forest management) in scenario 6

Table 6 The weights of criteria management options in scenario 2 based on scenario analysis

Criteria				Overall inconsistency
	Social sustainability	Economic sustainability	Ecological sustainability	
Weight	0.630	0.151	0.218*	
Management options				
	Traditional coppice	Extreme conservation	Modification of traditional coppice	
Weight	0.361	0.378	0.261	0.05

*Due to the presence of decimal numbers, in some cases of the tables related to the weights in the same level, it may be 0.1 more or less than the number 1 in these tables

in Iran. Based on the results of this scenario, it can be expected that if the weight of the social sustainability criterion is high, the weight of traditional coppice option will also increase, although its weight is not much higher than that of extreme conservation (Table 5). This shows that the traditional coppice option can be seen as the best management option if policy makers want to weight social sustainability higher than other criteria.

For other scenarios (scenarios 2 to 6), a series of criteria weights, weights of management options and efficiency and dynamic sensitivity analyses are carried out below.

The results of scenario 2 (Table 6) with social sustainability as the most important criterion and ecological sustainability as the second criterion show that in this case extreme conservation is the first option for the management of Zagros forests in Iran. The sensitivity analysis of scenario 2 also shows a higher weight for extreme conservation compared to the traditional coppice option (Fig. 3 and Table 7).

Table 7 Dynamic sensitivity analysis of scenario 2

Criteria	Criteria weights	Management options	Management options weights
Original weights in scenario 2			
Social sustainability	63.0%	Traditional coppicing	36.1%
Economic	15.1%	Extreme conservation	37.8%
Ecological	21.8%	Modification of traditional coppicing	26.1%
10% increase in the weight of ecological sustainability			
Social sustainability	55.0%	Traditional coppicing	32.9%
Economic	13.2%	Extreme conservation	41.4%
Ecological	31.8%	Modification of traditional coppicing	25.6%
20% increase in the weight of ecological sustainability			
Social sustainability	47.0%	Traditional coppicing	29.8%
Economic	11.2%	Extreme conservation	45.1%
Ecological	41.8%	Modification of traditional coppicing	25.1%
10% increase in the weight of economic sustainability			
Social sustainability	55.6%	Traditional	34.8%
Economic	25.1%	Extreme conservation	39.0%
Ecological	19.3%	Modification of traditional coppicing	26.3%
20% increase in the weight of economic sustainability			
Social sustainability	48.2%	Traditional coppicing	33.4%
Economic	35.1%	Extreme conservation	40.2%
Ecological	16.7%	Modification of traditional coppicing	26.4%

Table 8 The weights of criteria management options in scenario 3 based on scenario analysis

Criteria				Overall inconsistency
	Social sustainability	Economic sustainability	Ecological sustainability	
Weight	0.140	0.528	0.333	
Management options				
	Traditional coppicing	Extreme conservation	Modification of traditional coppicing	
Weight	0.238	0.506	0.256	0.03

Scenarios with economic sustainability as the most important criterion

In scenario 3 when economic sustainability is most important, extreme conservation is considered the first management option, and modification of traditional coppice is considered the second option (Table 8).

The results of the sensitivity analysis for scenario 3 show that if the weights of the second and third criteria are increased, extreme conservation will be the first option. Traditional coppice only with an increase in the importance of the social sustainability criterion could be considered the second option (Fig. 4 and Table 9).

The results of scenario 4 show that if economic sustainability is the first and social sustainability the second criterion, the traditional coppice can be the second option, with a slight difference to the third option (Table 10). The results of the sensitivity analysis show that even a change in the importance of the second and third criteria cannot lead to extreme conservation not being the first management option in this situation (Table 11 and Fig. 5).

Table 9 Dynamic sensitivity analysis of scenario 3

Criteria	Criteria weights	Management options	Management options weights
Original weights in scenario 3			
Social sustainability	14.0%	Traditional coppicing	23.8%
Economic	52.8%	Extreme conservation	50.6%
Ecological	33.3%	Modification of traditional coppicing	25.6%
10% increase in the weight of ecological sustainability			
Social sustainability	11.9%	Traditional coppicing	21.9%
Economic	44.9%	Extreme conservation	53.0%
Ecological	43.3%	Modification of traditional coppicing	25.0%
20% increase in the weight of ecological sustainability			
Social sustainability	9.6%	Traditional coppicing	20.1%
Economic	37.1%	Extreme conservation	55.4%
Ecological	53.3%	Modification of traditional coppicing	24.5%
10% increase in the weight of social sustainability			
Social sustainability	24.0%	Traditional coppicing	26.5%
Economic	46.6%	Extreme conservation	47.8%
Ecological	29.4%	Modification of traditional coppicing	25.7%
20% increase in the weight of social sustainability			
Social sustainability	34.0%	Traditional coppicing	29.1%
Economic	40.5%	Extreme conservation	45.0%
Ecological	25.5%	Modification of traditional coppicing	25.9%

Table 10 The weights of criteria management options in scenario 4 based on scenario analysis

Criteria				Overall inconsistency
	Social sustainability	Economic sustainability	Ecological sustainability	
Weight	0.297	0.540	0.163	
Management options				
	Traditional coppicing	Extreme conservation	Modification of traditional coppicing	
Weight	0.294	0.442	0.264	0.09

Table 11 Dynamic sensitivity analysis of scenario 4

Criteria	Criteria weights	Management options	Management options weights
Original weights in scenario 4			
Social sustainability	29.7%	Traditional coppicing	29.4%
Economic	54.0%	Extreme conservation	44.2%
Ecological	16.3%	Modification of traditional coppicing	26.4%
10% increase in the weight of social sustainability			
Social sustainability	39.7%	Traditional coppicing	31.8%
Economic	46.3%	Extreme conservation	41.7%
Ecological	14.0%	Modification of traditional coppicing	26.5%
20% increase in the weight of social sustainability			
Social sustainability	49.7%	Traditional coppicing	34.2%
Economic	38.6%	Extreme conservation	39.2%
Ecological	11.7%	Modification of traditional coppicing	26.6%
10% increase in the weight of ecological sustainability			
Social sustainability	26.1%	Traditional coppicing	27.2%
Economic	47.5%	Extreme conservation	46.9%
Ecological	26.3%	Modification of traditional coppicing	25.9%
20% increase in the weight of ecological sustainability			
Social sustainability	22.6%	Traditional coppicing	25.1%
Economic	41.1%	Extreme conservation	49.6%
Ecological	36.3%	Modification of traditional coppicing	25.3%

Table 12 The weight of criteria management options in scenario 5 based on scenario analysis

Criteria				Overall inconsistency
	Social sustainability	Economic sustainability	Ecological sustainability	
Weight	0.297	0.163	0.540	
Management options				
	Traditional coppicing	Extreme conservation	Modification of traditional coppicing	
Weight	0.247	0.507	0.245	0.02

Table 13 Dynamic sensitivity analysis of scenario 5

Criteria	Criteria weights	Management options	Management options weights
Original weights in scenario 5			
Social sustainability	29.7%	Traditional coppicing	24.7%
Economic	16.3%	Extreme conservation	50.7%
Ecological	54.0%	Modification of traditional coppicing	24.5%
10% increase in the weight of economic sustainability			
Social sustainability	26.1%	Traditional coppicing	24.7%
Economic	26.3%	Extreme conservation	50.4%
Ecological	47.5%	Modification of traditional coppicing	24.9%
20% increase in the weight of economic sustainability			
Social sustainability	22.6%	Traditional coppicing	24.8%
Economic	36.3%	Extreme conservation	50.1%
Ecological	41.1%	Modification of traditional coppicing	25.2%
10% increase in the weight of social sustainability			
Social sustainability	39.7%	Traditional coppicing	27.8%
Economic	14.0%	Extreme conservation	47.3%
Ecological	46.3%	Modification of traditional coppicing	24.9%
20% increase in the weight of social sustainability			
Social sustainability	49.7%	Traditional coppicing	30.9%
Economic	11.7%	Extreme conservation	43.8%
Ecological	38.6%	Modification of traditional coppicing	25.3%

Table 14 The weight of criteria management options in scenario 6 based on scenario analysis

Criteria				Overall inconsistency
	Social sustainability	Economic sustainability	Ecological sustainability	
Weight	0.196	0.311	0.493	
Management options				
	Traditional coppicing	Extreme conservation	Modification of traditional coppicing	
Weight	0.230	0.522	0.248	0.03

Scenarios with ecological sustainability as the most important criterion

In scenario 5, ecological sustainability has the highest weight, and for this reason, extreme conservation was again chosen as the best management option (Table 12). The sensitivity analysis in these scenarios shows only minor changes in weights of all management options, with extreme conservation having the highest weight (Table 13 and Fig. 6).

In scenario 6, ecological sustainability is the most important criterion and extreme conservation was again selected as the best management option (Table 14). The sensitivity analysis shows that the weight of management options change only slightly when we change the weights of the criteria (Table 15 and Fig. 7).

The potential risks and uncertainties associated with implementing different management scenarios in social coppice forests were examined in this study on the basis of changes in the ranking of different criteria (Table 2) and other changes in the weights of criteria, as well as a ten or twenty percent increase in the weight of social, economic or ecological sustainability criteria. The potential for risk and uncertainty assessment in this study is shown in Tables 5, 7, 9, 11, 13 and 15.

Discussion

The main results of the study

This study examines the conditions under which the scenarios can be implemented and which characteristics should be prioritized in each scenario. Accordingly, the results of various scenarios shows that the choice of traditional coppice as

Table 15 Dynamic sensitivity analysis of scenario 6

Criteria	Criteria weights	Management options	Management options weights
Original weights in scenario 6			
Social sustainability	19.6%	Traditional coppicing	23.0%
Economic	31.1%	Extreme conservation	52.2%
Ecological	49.3%	Modification of traditional coppicing	24.8%
10% increase in the weight of social sustainability			
Social sustainability	29.6%	Traditional coppicing	26.0%
Economic	27.3%	Extreme conservation	49.0%
Ecological	43.1%	Modification of traditional coppicing	25.1%
20% increase in the weight of social sustainability			
Social sustainability	39.6%	Traditional coppicing	28.9%
Economic	23.4%	Extreme conservation	45.8%
Ecological	37.0%	Modification of traditional coppicing	25.4%
10% increase in the weight of economic sustainability			
Social sustainability	16.7%	Traditional coppicing	23.3%
Economic	41.1%	Extreme conservation	51.6%
Ecological	42.2%	Modification of traditional coppicing	25.1%
20% increase in the weight of economic sustainability			
Social sustainability	13.9%	Traditional coppicing	23.6%
Economic	51.0%	Extreme conservation	51.0%
Ecological	35.1%	Modification of traditional coppicing	25.4%

a proposed option for forests with socio-economic problems depends on the following points. First, the main criterion for the future management of forests is social sustainability followed by economic sustainability and ecological sustainability. Considering the large scale of degradation in the Zagros forests, such a scenario, i.e. the low importance of ecological sustainability, cannot be applied on a broad scale. Therefore, the traditional coppice can only be used for limited areas.

The management of coppice and coppice with standards is very complex and requires a precise knowledge and understanding of the management requirements of these forests. Monitoring and restoration of these forests is also very important (Chirici et al. 2020). Most studies on SFM refer to high forests, and the criteria and indicators developed in the context of SFM also apply to them (Cutini et al. 2021). As coppice forests make up a significant proportion of the world's forests, it is necessary to carry out appropriate management planning for them. On the European continent, for example, about 14% of forests are coppice, which corresponds to about 23 million ha of European forests (Unrau et al. 2018).

Studies (e.g., Bottero et al. 2022; Plieninger et al. 2023) conducted in the area of coppice forests show that coppice forests can provide various ecosystem services. Some coppice forests could be useful for the provision of services such as roe deer browsing (Bottero et al. 2022) or grazing by goats and sheep (Plieninger et al. 2023).

The complete weakness of forest stands (Pourhashemi et al. 2015), the absence of elite trees, the collection of seeds by local people for various reasons (Iranmanesh et al. 2022), the cutting of trees for coppice and branch cultivation (Plieninger et al. 2023), and the need for conversion of these forests show that the modification of traditional coppice is strongly favoured over other options in decision-making for these forests. However, it should be noted that in none of the scenarios was the modification of traditional coppice the best management option (Tables 4, 6, 8, 10, 12, and 14).

Two categories of factors influence decision-making in the management of social coppice in Zagros forests. One category of factors includes ecosystem sustainability factors, including social, ecological and economic sustainability, whose components are described in Fig. 1, and the other category is the constraints of decision-making. Based on the model in Fig. 1, the constraints for this problem have not yet been included in the model, but this would be possible if a different decision-making method was chosen (e.g., data envelopment analysis (Zhou et al. 2023)). In addition, there are other constraints in the model design of this study, including environmental regulations, resource availability, budgetary constraints, and other relevant restrictions that need to be considered for a comprehensive decision-making process. By eliminating the options that contradict the constraints the best option could be defined based on compatibility with the conditions of each forest management unit in forest ecosystems. The indigenous knowledge of local communities in these forests has been demonstrated (Valipour et al. 2014; Iranmanesh et al. 2022) and can be the basis for a change in the management system (modification of traditional coppice) as an important option for the sustainability of local communities and better communication with forest ecosystems (Zandebasiri et al. 2023). Modification of traditional coppice was not the best option in our scenarios as it is associated with both economic and social constraints, and problems in coordination with local communities. On the one hand, there are restrictions on the use of traditional coppice in some areas and it is not possible to adapt this system to ecological conditions. On the other hand, due to social pressure in some areas, it may not be possible to implement the extreme conservation system, as some interests of local communities may be in strong conflict with extreme conservation. Thus, if extreme conservation is not possible in some scenarios due to the aforementioned constraints, the modification of traditional coppice may also be the best management option. Since there are many constraints of this type in the Zagros forests of Iran, the results of the study do not mean that modification of traditional coppice is excluded from the best management options.

Thus, the final solution for the implementation of the models of this study is that the management of Zagros forests in Iran prepares plans with a macro perspective, but the implementation of the plans takes place in the local management units. In the management units where ecological, social, and economic constraints exist, these constraints should be applied and the appropriate management option should be selected after their application. Therefore, the division of Zagros forests into parts with severe social problems or parts with high ecological protection and support needs is an essential measure for these forests. By recognizing and addressing the different challenges and requirements in different parts of the forest, it is possible to implement targeted measures and strategies that can effectively address these specific problems. This approach allows for a more comprehensive and balanced management of the Zagros forests, ensuring the well-being of local communities while preserving the ecological integrity of the area. It is therefore essential to harmonize the process of special planning with the social and ecological characteristics of these forests. In this framework, identifying synergies and conflicts in land use becomes crucial, especially in addressing the social challenges faced by local communities. Finnish research, such as that by Kangas et al. (2022), provides illustrative examples of decisions related to land use synergies and conflicts. In some parts, it is not possible to present ecological plans (due to the social pressure and constraints from local communities), so the goals and limitations of forest management plans should be discussed before developing scenarios. In parts where there are social tensions, the previous plans have not been able to solve the social problems. Moreover, in parts with livelihood dependence on forest, it is necessary to restrict one or more options. In addition, in these models, the constraints of degraded land are not included in the problem. If the constraints of degraded areas are entered in scenario 1, the traditional coppice cannot be included in the problem and the best option will change again. In this way, it is necessary to plan separately for each part of the land, and each scenario should be planned for separate management units. In the area of land division, there are suitable patterns in the study of Núñez Godoy et al. (2022).

This study can contribute to the analytical framework for decision-making in the field of ecosystem management. The decision-making process in this study was formulated differently than in other studies. The scenario building was carried out with the aim of broadening the vision of the future of the forest ecosystem, with 6 scenarios and 6 outcomes instead of only one result in a decision-making process. The number of these processes depended on the number of criteria in this study. Only three criteria were defined in this study. By increasing the number of criteria, more branches can be considered for the decision-making process and more situations can be discussed. However, reducing and generalizing the criteria as in this study has the advantage that the number of scenarios is also defined within a reasonable and feasible framework. In order not to lose the components of these macro criteria (social, economic, and ecological sustainability), sub-criteria were defined instead, so that the small components of this large system can be well identified. This type of decision-making can have a global impact on decision-making theories in the field of natural resource and environmental management. The only weakness of the presented method may be the larger volume of calculations, but in return, many strengths can be imagined, such as observing different states that may occur in the future, preparing for different states and predicting the necessary preparations for them.

Which is the best option for coppice management?

In scenarios 2 to 6, the extensive conservation option is the best management option for Zagros forests in Iran. It may therefore be the best option in most cases, unless social constraints stand in the way of this option. Due to heavy rock outcropping, reduction of soil surface, excessive harvesting of trees by local communities, irregular grazing of livestock, incompatibility of some development activities with the principles of forest ecosystem conservation, and wrong decision-making, these forests are now destroyed in many cases and need to be strictly protected. Therefore, many factors contributing to forest degradation need to be eliminated.

The controversial point in the results of this study is the difference between the results of the ideal optimal option (extreme conservation) and the actual optimal option (modification of traditional coppice). In the results of this study, the extreme conservation is considered the ideal option in many scenarios, but in the real world, this option may not be feasible due to social constraints, and then modification of traditional coppice is the real optimal option.

Compared to other studies, wood harvesting in the coppice forests of Iran differs from other places, including also Europe. Wood harvesting in the Zagros forests, Iran is limited and intended for local communities, as these forests are legally protected forests, while there are plans to harvest wood from Europe's coppice forests (Pyttel et al. 2015; Bottalico et al. 2016).

A very important concept for the future of Iran's Zagros forests is the combination of different roles for coppice forests and hybrid planning to utilize all the good features of the different coppice alternatives, as well as the comprehensive conservation and modification of traditional coppice forest. This means that when planning all the different functions that can be applied to them, so that the issues of ecological, economic and social sustainability are taken into account for them, and we can provide combined programs for them according to the conditions of the management units.

One of the models of scenario formation in the study of coppice forests is the study by Imamura et al. (2017), which presents three scenarios for modelling oak coppice forests in Japan, including (a) the traditional forest management scenario, (b) the biodiversity-rich forest scenario, and (c) the productive coniferous forest scenario. Their study shows that people expect abandoned Japanese oak forests to be protected and enriched in terms of biodiversity. The results of this study in the Zagros forests of Iran can also provide a kind of compatibility with the results in the upper part of the extensive conservation option in the context of the importance of conservation and enrichment in the coppice forests around the world.

Another study on scenario building in coppice forests is the study by Bottalico et al. (2016) in the Molise region (Central Italy). They present three scenarios, including business-as-usual, nature conservation, and wood production, and four management systems, including simple coppice, coppice with standards, coppice in conversion to high forest, and high forest. They concluded that ecosystem services are reduced by 85% in the nature conservation scenario and 82% in the wood production scenario compared to the first scenario. In this study, conducted in Zagros forests, it can also be concluded that the value of ecosystem services for coppice forests depends on a combination of the options studied and the social and ecological conditions of each management unit. Furthermore, Riccioli et al. (2020) in the Tuscany region, Italy, using a plan with three options, coppice, conversion, and natural development, show the need of communities for multifunctional management of forests. In that research, the results showed that each of the options should be used in its place, depending on the forest activities and integration in the communities. In this way, the results of this study in Zagros forest, Iran, can confirm the results of previous studies, especially the study by Riccioli et al. (2020) on the value of each option in forest management depending on the situation. This study also had some limitations. Increasing the number of criteria can be a problem in calculations related to scenarios. For this reason, the number of criteria in this study was reduced to 3. However, an appropriate number of sub-criteria for these criteria were provided. The next problem was the limitation related to different views of the experts. Different ranges of stakeholders, each having different roles and impacts in the forest ecosystem, may lead to a variety of viewpoints for which mere averaging may not be an appropriate solution, as each category of stakeholders may have its own weight. Stakeholders perceive and prioritize social coppice management objectives based on their interests and desires. The effects of decision-making can be changes in the ecological and socio-economic conditions in forest areas.

The impact of management structures and institutional arrangements on decision-making processes in social coppice forests is reflected in the prioritization of policy making and management of these forests. The decision to maintain the status or to convert it to modified coppice management or to high forest is an important decision in this area, that depends on the institutional arrangements and decisions of the forest policy section. The conversion of coppice forest into high forest requires greater protection of seeds, especially from livestock grazing. This conversion may be accompanied by some social resistance from local communities because in some areas the local population uses the forest area for livestock grazing.

Conclusion

The main results of this study show that all management options can be considered the best, and this result is considered a major innovation in the knowledge of social forestry decision-making. Although this study is a case study, its results can be used for all coppice forests in the world with socio-economic problems or social forests. The results of this study guide decision-making at the ecosystem level, taking into account the overall ecological, economic and social conditions, and the need to plan for the large landscape level of the Zagros forests, but implement it for very small and local units, i.e. forest management units. The extreme conservation option can be the superior option, as it is presented as the top-ranked option in many scenarios. The traditional coppice option can be a superior option for situations where the social criterion is very important for policy makers in forest ecosystems and at the same time the importance of the ecological sustainability criterion in the decision-making process is low compared to other criteria (social and economic sustainability). The option of modification of traditional coppice can be considered in areas where there are ecological or social constraints, i.e. one of the criteria is a requirement for decision makers. Accordingly, in a situation where one of the management options must be ruled out (e.g., the extreme conservation option due to social constraints), this option must be ruled out from the beginning, so that the modification of traditional coppice may be the best option for these scenarios.

There is an urgent need to identify local people's behavior, especially their indigenous knowledge, and to focus on the role of local communities in forest management decisions, as optimizing decision-making in social coppice forests has implications for local communities, forest-dependent livelihoods, and ecosystem resilience. The results of this study have a practical meaning and each problem in forest ecosystems requires its own conditions. It is very difficult to use one result in general and for a habitat with an area of about 6 million hectares (i.e., the area of Zagros forests); although some ecological and social conditions are similar in this habitat, only one of the scenarios can occur in each management unit. In general, it is better to follow the results of each scenario for a single management unit than for very large landscapes. In this way, the issues and problems of forest management in areas with socio-economic problems generally need to be studied from a systemic perspective, and it is also necessary to implement them with a local attitude and make them different for management units whose social conditions are different from each other. The implementation of land use planning and forest land use planning can be a good way to solve these issues.

This study provides valuable insights into how the AHP results can inform and influence policy decisions at the international level. Although the AHP method has many strengths, such as simplicity in use or broad applicability to different areas of ecosystem management, this method cannot interact much with the concepts related to constraints in the decision-making process. The option of modification of traditional coppice could be among the best options if ecological constraints were included in the decision-making process, but due to the lack of constraints, it is still dominated by the extreme conservation option.

The continuation of studies on scenarios and multi-criteria decision-making in forest management and natural ecosystems can help to identify the best option selection strategies; especially under conditions of uncertainty, decisions for different ecosystems such as protected forests or reserved forests and decisions for the future of forests can have a major impact on climate change. It is proposed to continue research on networks and the possibility of increasing decision branches in their interconnectedness in the next study, as well as to design solutions to reduce the number of situations in networks according to scenario building and to increase the decision space.

Some important lessons for the management of Zagros forests in Iran and other social forests in the world can be drawn from the results of this study. Under the current conditions, in most parts and in different situations, the strategic plan for forest management should be extreme conservation along with the social needs of local communities. The novel contributions of this study are (1) the development of scenarios to see all different forms in the decision space, (2) the appreciation of all management options simply because of their existence as an option, and (3) the dependence of decisions on different conditions in an ecosystem.

In some of the world's forests, the issue of coppice management is controversial. Practical recommendations and policies for sustainable forest management in other regions can give coppice forests a place and also highlight the importance of social issues for these forests. The need to protect and care for the forests and to pay attention to the local communities in these forests is very important.

Appendix A: Introduction to Zagros coppice forests in Iran

Some of the forests in Iran are coppice, especially in western Iran, which refers to the vegetation area of Zagros; forests are managed as coppice or coppice with standards. Oaks are the main species in the vegetation zone of Zagros (Heydari et al. 2021). There are three types of oak, *Quercus brantii* Lindl., *Quercus infectoria* Oliv., and *Quercus libani* Oliv. in the Zagros forests of Iran. In addition to these oak species, *Prunus* spp., *Pyrus* spp., *Astragalus* spp., *Pistacia* spp., *Crataegus* spp., etc. are also present in these forests (Jazirei, & Ebrahimi Rostaghi 2013). The role of these forests in preventing soil erosion and water supply is of great importance due to the mountainous and steep forest areas in the Zagros region. Due to the presence of local communities in these forests and livestock grazing in forest areas, the supply services and livestock breeding in these forests are of great importance. This problem may lead to disruption of some regulatory services such as waste treatment and biological control for these forests (Zandebasiri et al. 2023).

Local management is very effective for the functions of these forests because of the high level of human disturbance; therefore, mitigating global warming and carbon sequestration depends entirely on optimizing the relationship between local management and the local community with these forests (Safari & Sohrabi 2019). In general, the ecosystem of these forests and their local management are very important for the country of Iran, and it is necessary to carry out the planning processes for these forests with great precision and care. Studies show that the stand structure of these forests is highly degraded

(Pourhashemi et al. 2015). Farhadi et al. (2014) consider human intervention by local communities to be effective in this area. Considering the situation of local communities, these coppice forests are a type of social forest.

Coppice forests have several disadvantages compared to high forests. These include unstable firewood prices, high cutting/harvesting costs, and lower market flexibility with less product diversification potential (Unrau et al. 2018). Other problems include weak forest soil, low tree height and lower biomass production, as well as the loss of some ecosystem functions and services (Zandebasiri et al. 2023). Moreover, despite its numerous disadvantages, this system can provide ecosystem benefits to local communities as these communities are highly dependent on Iranian forests. This issue may lead to some conflicts between the executive management and local communities in these forests (Soltani et al. 2016). Changes to the forest structure or decisions to convert these forests into high forests can have a significant impact on local communities, and in this context, managers may face opposition to such decisions from the local communities. According to the above issues, there are challenges in coppice or coppice with standard forests.

The continuation of activities in coppice forests requires a decision-making process that considers a comprehensive range of ecological, social, and economic criteria. However, it appears that researchers tend to focus on certain aspects of these criteria in their decision-making rather than considering them all together. As each group of stakeholders has different preferences on the criteria mentioned, scenario building in this area is important to examine all the different preferences. So far, different approaches have been proposed in different studies based on management research topics for these forests. For example, Ghazanfari et al. (2004) and Valipour et al. (2014) proposed traditional coppicing in a silvopastoral system as a management approach for Zagros forests, Iran. Iranmanesh et al. (2022) called for a revision of coppice management to maintain economic production, especially in the area of acorn production for local communities. Zandebasiri et al. (2023) considered the management of ecosystem functions of coppice forests in context of long-term planning, where some provisioning functions can be fully explored in short-term planning, but in the long term, they should be gradually replaced by regulatory functions. However, in the area of decision-making, no decisions were made based on different scenarios and simulations of their criteria preferences in social coppice forests.

Appendix B: The description of the scenarios designed for the Zagros forests of Iran

Different forms of local communities' management can be observed in different parts of Zagros forests in Iran (Zandebasiri and Ghazanfari 2010). As stated in the section on the studied area, there are different forms of timber harvesting by local communities in Zagros forests in Iran depending on the local communities and forest ecosystem such as complete pollarding of trees (Valipour et al. 2014; Plieninger et al. 2023), selecting a shoot for cutting (Iranmanesh et al. 2021) or cutting branches and dropping leaves to allow to graze the livestock underneath, etc. This form of forest tree management has weaknesses such as lower tree growth (Saeidizadeh et al. 2015) and lack of sexual regeneration for trees (Ghazanfari et al. 2004). The importance of continuing TC on coppice trees in this study is that they are managed without management interventions and using only the traditional methods of local communities. The advantages of this option for local communities include local economic stability and social participation of local communities in forest management, while the disadvantages of this option for the environmental sustainability include sexual regeneration, permanent coppicing of forest stands, and excessive cutting of forest trees.

The MTC in this study means implementation of a set measures to accept some harvests in the present and reduce the intensity of harvests for the future (Zandebasiri et al. 2023), regular grazing of livestock and the introduction of some silvopastoral systems (Valipour et al. 2014) that correspond to the ecological capacity (Zandebasiri and Pourhshemi 2019) and socio-economic capacity, while making a contract on the responsibility of local communities for the protection of young trees. The MTC method means that local communities are given the authority and responsibility for the powers they find in the forests together. For example, if the local communities are allowed to graze livestock in some months of the year or harvest fodder, they should also be responsible for the individual protection of established seedlings or new shoots. Individual conservation of newly established shoots (Valipour et al. 2009) can be part of the necessary reforms to improve TC. Systematizing the perceptions of local communities is one of the main issues in this option. How these reforms are implemented depends on the conditions of the forest ecosystems. The drastic reduction of underground cultivation, livestock grazing based on the forestry plan and according to the criteria established by social forestry experts, and individual conservation are the most important criteria of this option. This management option is costly and very complex from a social point of view.

The third option is EC and conversion to high forest as a part of a long-term plan for the Zagros forests, which in this study means that EC prevents livestock from entering the forest and seeds and seedlings are planted to strengthen the cover on the ground. Conservation of tree seeds in forest lands is another issue that is very important in these forests to become high forests. Such a measure is difficult and requires the removal of the activities of local communities from the forest, especially the removal of livestock grazing to establish seeds and the creation of seedlings.

Extreme conservation and conversion to high forest is to carry out all the necessary activities to convert from coppice to high for these forests. Planting seeds and in some parts planting seedlings, removing livestock from forests, and removing branching to strengthen large trees and maintain large trees can be other activities that belong to this management option.

The impact of the first scenario (Traditional coppicing) on ecosystem services, increases the level of provisioning services and at the same time poses a threat to regulatory services. The impact of the second scenario (Modification of TC) leads to a gradual reduction of provisioning services and restoration of regulating services. The effect of the third scenario (Extreme conversation) is sever reduction in the provisioning services and stabilization of regulatory and support services. It is possible to harvest culturall services in all these scenarios; however, in the first and second scenarios, this possibility is more facilitated. Based on these descriptions, trade-offs are possible to switch between ecosystem services when moving from one scenario to another. The interests of local communities are more secured in the first scenario, while technical and silvicultural aspects take the place of social demands in the second and third scenarios.

The integration of scenarios can be a form of decision making to continue the planning processes for the future management of coppice forests. The combination of all scenarios can lead to land use planning systems for forestry systems. In this issue, decision making depends on the combination of ecological and socioeconomic conditions for a forest ecosystem. In some areas where there are many social problems in the forest, traditional coppicing systems should be used. The lower the socio-economic problems are, the more protection options can be used; this is like this the modification of the traditional coppice system, and finally the conversion to high forests.

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Declarations

Conflict of interest There is no conflict of interest.

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