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ORIGINAL PAPER

Valuing the role of key stakeholders in modelling forest cooperative game: a case study of Iranian forests

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Abstract

The aim of this study was to investigate the issues of forest stakeholders with regard to their role in forest management. For this aim, the theory of calculating Shapley value was used for modelling a cooperative game for participatory management in Iranian forests. Four scenarios were used to examine different perspectives, including the perspectives of the academic, research, and management departments as well as the average results of the three mentioned scenarios. For these scenarios, Shapley value relations and calculations were used in game theory. The results showed among the stakeholder values, the local community had the highest normalized Shapley value with a value of 0.41. Then forest management stakeholder with a value of 0.37 has the second priority. Finally, the research and education section has the last priority with a value of 0.22. Accordingly, the main column of creating participatory management is the participation of local communities in forest management plans. The role of local communities in forest management is more prominent than other main stakeholders. These Shapley values can be a good guide for budget distribution in forest management based on the role of players.

Keywords Forest policy-making · Shapley value · Local communities · Negotiation model · Decision-making

Introduction

The Zagros forests of Iran exist in the west and southwest of the country which has various socio-economic issues (Imani Rastabi et al. 2015). Local communities in these forests use the fodder produced in the ecosystem for cattle grazing. The cattle are important for locals in this region. Locals use the forest for resource utilizations such as looping for producing leaves for grazing cattle, utilizing non-timber forest products, producing fuel wood in some areas (Valipour et al. 2014; Soltani et al. 2016). The regeneration regime in these forests considerably includes combined coppice and standard trees or an approximate pure coppicing regime (Jazirei & Ebrahimi Rostaghi 2013; Pourhashemi et al. 2015). A regeneration regime is a method that ensures the trees' survival and future. The main regeneration regimes in the Zagros forests are high forests (regeneration by seeds), coppice forests (regeneration by shoots), and a combination of high and coppice regimes (regeneration by seeds and shoots) (Marvi Mohajer 2005). Forest conservation objectives in these forests are very significant so that future generations can use various ecosystem services for their livelihoods (Zandebasiri et al. 2017b; Imani Rastabi et al. 2020). The objectives of Zagros forests can be related to local communities, forests

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managers, NGOs (Non-Government Organizations), environmental organizations, the public, forest research institutes and centres, or other stakeholders (Zandebasiri et al. 2017a). Hence, different interests of stakeholders could be presented by these stakeholders. A game can be formed from the relations among these stakeholders in the management of Zagros forests (Soltani et al. 2016; Zandebasiri et al. 2017a; Zandebasiri et al. 2020a, b). From the competition in the game between main stakeholders, forest management, and local communities (Soltani et al. 2016), we need to move towards a cooperative game between them so that these forests remain sustainable. Considering the interests of stakeholders is one of the problems of these forests to provide a framework for Cooperative Game Theory (CGT) to resolve interactive participation among the stakeholders to achieve sustainable forest management.

Coalition among stakeholders/players and its influence on CGT forming is one of the important issues in CGT. In cooperative games, the stakeholders create a coalition according to fair allocation of the resources (Alvarez et al. 2019). Hence, the measurements of the roles and the importance of each stakeholder in the total coalition are significant. Shapley value approach is an instrument to determine the role and the importance of all stakeholders in creating coalition among themselves. The Shapley value presented by Shapley in 1953 represents the quantity of the effect and the performance of a player in achieving coalition in a cooperative game. The players with more Shapley value have more power in creating a cooperative game (Abdoli 2019b; Lipovetsky 2020). This value can have different viewpoints. This value may be presented from the viewpoints of managers, experts, scientists, etc. The role and the importance of each stakeholder are related to the viewpoint which focuses on the issue, and based on this viewpoint (from the perspective of different stakeholders), a different Shapley value for a game is expected.

While a wide range of stakeholders are included in forest management, only two or three players were considered in forest management. In this regard, national forest policy in the USA was modeled with two key players including the United States Forest Service (USFS) and environmentalists (Carlson & Wilson 2004). In another study, forest owners and non-forest owners were modelled in the issue of carbon sinks (Andrés-Domenech et al. 2015). In another study by Lee et al. (2018), illegal logging was considered by forest managers and the locals. Accordingly, in this study, we embedded three stakeholders including managers, local communities, and researchers in the Zagros forests as the key players.

The key players are the main stakeholders who have different interests in the forests. They use different strategies in cooperative or non-cooperative games and generally have disagreements on some issues about forest management (Andres-Domenech, et al. 2015; Kumar and Kant 2016). For instance, the extraction of natural common resources could be represented as a non-cooperative game (Fesselmeyer and Santugini 2013). Guidelines for reducing these irreconcilable demands were presented in Joint Forest Management (JFM) and Community-Based Forest Management (CBFM) models such as Kumar and Kant (2016) and Lee et al. (2018). On the other hand, in the forest management context, designing cooperative games can help sustainable forest management (Andres-Domenech et al. 2015).

In this study, three stakeholders (managers, locals, and researchers) were embedded in the Zagros forests as the key players. This is because the main motivation for conducting this study is to provide valuation models for the role of key stakeholders in forest management. This motivation is doubled when this valuation can be a guide to allocate funds to stakeholders and build participatory management capabilities among the stakeholders. Therefore, the main innovation of this research is to present Shapley values (i.e. values used to determine the role of each stakeholder/player in forming a coalition to create a cooperative game) for the key stakeholders involved in forest management. The meta-main goal of this study was to investigate the issue of participatory management in the Zagros forests of Iran. In participatory management, it is necessary to determine the role and position of various stakeholders. The subject of participatory management is an extensive system that can have several subsystems such as participatory goal setting, participatory planning, and organization (Zandebasiri et al. 2010). One of these subsystems is the coalition between forest management stakeholders. Totally, the main goal of this study is to valuate the role of key stakeholders in forest management, and another objective of this study is to valuate the coalition between forest management stakeholders.

Recently, some researchers (Usman et al. 2021; Usman and Balsalobre-Lorente 2022) have focused on valuation topics such as agriculture value addition, energy utilization, tourism and environment (Usman et al. 2021), or connections between financial development, renewable energy, and natural resources (Usman and Balsalobre-Lorente2022). These studies have been designed at the international level, mostly with the aim of combining values in ecological calculations and combining them with economic issues. On the other hand, this study tried to discuss forest management issues and their valuation in particular to achieve the CGT model.

There are limited reviews on CGT in forest management, such as Andres-Domenech et al.'s (2015) research on cooperation for sustainable forest management, Lee et al.'s (2018) research on profit sharing for reducing illegal logging, and Alvarez et al.'s (2019) research on the role of forest use in river flooding risk prevention. There are some studies in other branches of the game theory about forest management, forest policy-making, and forest management (Carlson and Wilson 2004; Corato 2012; Kumar and Kant 2016). However, to the best of our knowledge, the measurement of Shapley value from different stakeholders' viewpoints has not been investigated in forest management. Effective and meaningful results have been obtained from the application of game theory in these models; however, in these models (the models mentioned in the review of the above sources), the values were not calculated for the role of each of stakeholder/player in creating coalition among stakeholders. Therefore, there seems to be a gap in these reviews and that is the issue of examining creating a coalition between different players. This study can respond to this gap by examining the Shapley values for each of the stakeholders. Accordingly, the aim of this research was to identify the role and the importance of key stakeholders in the forest management game in Zagros forests, Iran. The key questions of this study are as follows: (1) Which stakeholders have higher Shapley values in the viewpoint of the stakeholders? (2) Which stakeholder coalition is more important in forming cooperative game modelling? For these aims this study is carried out from January 2021 to April for the Zagros forests, Iran.

General outline for the stakeholders, MCDM (MultiCriteria Decision-Making), and game theory issues

Forest ecosystems have various ecosystem functions (climate regulation, water regulation, food production, and cultural and artistic information), and four well-known ecosystem functions are regulating, production, habitat, and information functions (Costanz et al. 2017). Ecosystem functions construct a framework for representing the ecosystem services (Potschin & Haines-Young 2016). An expanding spectrum of ecosystem services will be extracted from the ecosystem functions (Costanz et al. 2017). In the forestry context, the expanding spectrum originated from the stakeholders' viewpoints. Hence, towards monitoring for sustainable forest management, forest ecosystems are presumed to have various interests among different forest stakeholders (Hickey et al. 2007; Raum 2018). Different irreconcilable demands are therefore presented in the goal-setting of forest management plans (Carlson & Wilson 2004; Raum 2018). This is expected to increase conflict and inconsistency among the stakeholders' interests in forest ecosystem planning. Due to this inherent inconsistency, forest managers and policy-makers represent models and simulations for managing and adapting these services/requests (Schwaiger et al. 2019).

Forest stakeholders (based on their interests and demands) could be classified into several social groups such as forest owners and non-owners, or forest services managers and environmentalists (Carlson and Wilson 2004; Andres-Domenech et al. 2015; Raum 2018), as well as local people and forest managers (Lee et al. 2018). The request of a stakeholder (from one ecosystem service) may be irreconcilable with other stakeholders' requests (from other services), and this issue could be considered as stakeholders' conflict. A considerable debate may be created about timber production accompanied by regulation functions such as climate change. Presenting and modelling the ways to trade-offs (Schwaiger et al. 2019) between ecosystem services aims to reduce the conflicts among the stakeholders (Hichey et al. 2007; Langemeyer et al. 2018). However, some researchers (Huber et al. 2019 or Zandebasiri et al. 2019) represent some methods for considering stakeholders' interaction with a few stakeholders involved, along with expert consultation. However, some researchers (Huber et al. 2019 or Zandebasiri et al. 2019) represent methods for considering stakeholders' interaction with a few stakeholders along with expert consultation.

MCDM methods were utilized by forest researchers to study various forest aspects and decide on the alternatives (Balana et al. 2010; Nordstrom et al. 2010; Huber et al. 2019). The MCDM methods have become increasingly relevant topics in forest management which considered multiple aspects of forests as the criteria with regard to different alternatives (Huber et al. 2019). A challenge of using MCDM methods for stakeholder analysis in the analyst team is that they could not consider stakeholder interactions for combining their strategies (Zandebasiri et al. 2017a). Decisions of one forest stakeholder influenced the other stakeholders' decisions as well as the next decision of the same stakeholder. Fundamentally, in most situations, the role of MCDM methods in forest management is selection, assessment, and evaluation among the alternatives by criteria (Balana et al. 2010; Huber et al. 2019). One decision from a stakeholder lonely cannot scrutinize optimal forest conservation (Corato 2012), and forest management decision-making requires the relationship between the decisions of the stakeholders (Carlson & Wilson 2004; Zandebasiri et al. 2020a). For instance, if one of the stakeholders encourages increasing the upstream water retention, the other stakeholders' responses will be very significant, and the next decision of this stakeholder is based on other stakeholders' responses as well (Alvarez et al. 2019). Stakeholders may be wanted to increase/decrease timber production or they would concentrate on upstream water retention. In game theory, it makes a few questions about the players/stakeholders. What can be done by a stakeholder who wants to increase the upstream water retention after these decisions (increase/decrease timber production by another stakeholder)? Do these decisions have impacts on this stakeholder decision? And what impacts? According to these decisions, what strategy should be made by this stakeholder? Another challenge is what the best agreement between these stakeholders is.

Totally, the MCDM methods do not have the potential for resolving these debates in these situations. In spite of the MCDM theories, game theory is intended to model conducts/behaviours of social groups that can be affected by other stakeholder strategies (Abdoli 2019a). In this theory, presenting adequate strategies depends on other stakeholder strategies (Zandebasiri et al. 2020a, b a). In game theory, each decision of a stakeholder (first stakeholder) can be an incentive for responses from other stakeholders. Similarly, these responses can act as a response to the first stakeholder (Alvarez et al. 2019). A game is therefore formed from the stakeholder strategies that attempt to first describe the situation of stakeholders, sequence of decisions, complete or incomplete information, cooperative or non-cooperative, etc. (Abdoli 2019a). Second, this theory determines substantive or weakened agreements/equilibriums among the stakeholders' interactive behaviours.

CGT can be helpful for forest management by sharing the gain of cooperation among the agents, especially for forest modelling in impeding deforestation (excessive logging), and world's biodiversity problems, as well as problem of greenhouse gases (Andres-Domenech 2015). Furthermore, it is important to identify the role of stakeholders/players in the CGT to determine the profit-sharing rate (Lee et al. 2018). By using CGT, forest managers can plan for the finances and resources in fair allocations among forest stakeholders. Designing the CGT and determining the profit-sharing rate can represent suitable decisions by forest policymakers.

Materials and methods

Case study: The Zagros forests, Iran

The Zagros forests ecosystem is located in the west of Iran, which is very important in terms of water and soil conservation in the region. In addition, the livelihood of locals has also very noticeable importance in these forests (Jazirei & Ebrahimi Rostaghi 2013). The geographical position of the Zagros forests is located between east longitude 45.12 to 54.92 and north latitude 27.63 to 36.54. However, these positions are presented for the map of this study, and to find the formal position, it is better to ask the official mapping authority in Zagros forestry and executive management. In these forests, the diversity of species has been significantly lost, and oak trees are the main species of these forests (Pourhashemi et al. 2015). Oak is the dominant species of this ecosystem and the ecosystem has significantly lost its diversity, and in most areas, such oak species have occupied about 70% of the stands (Jazirei & Ebrahimi Rostaghi 2013). The location of the Zagros forests in Iran is shown in Fig. 1, and Fig. 2 is a general view of the trees in these forests.

In Fig. 2, the lines that are created parallel to the contour line on the soil are in fact the path of the movement and footprints of local communities' cattle. In these forests, the issue of livestock grazing in forests is very important. Brown soils, chestnut soils, litho soils, Rendzinas, and alluvial soils are the main soils in these forests. The soil of these forests is weak and these forests are threatened by biodiversity decrease (Jazirei & Ebrahimi Rostaghi 2013). In the Zagros forests of Iran, the issue of examining the various strategies of forest stakeholders is very significant (Zandebasiri et al. 2017a). The issue of sustainability of these forests has particular importance (Zandebasiri et al. 2017b). Socio-economic issues of these forests, such as the dependence of local communities (including villagers, nomads, forest-related farmers, etc.), have made the issue of management of those involved in these forests very significant (Imani Rastabi et al. 2015; Zandebasiri et al. 2019). The issue of forest protection can be considered by the forest managers. The local community demands to livestock grazing, using of non-timber products, and utilizing the resources for the livelihood needs (Valipour et al. 2014; Imani Rastabi et al. 2015; Soltani et al. 2016). In this way, the issue of the various demands of those stakeholders is very important; each of these stakeholders/players can play a role in forming a coalition for greater cooperation in ecosystem management. In this research, an attempt will be made to define a cooperative game for the management of these forests in order to discuss the role of power and the influence of each of the key stakeholders on the formation of different coalitions.

Methods

In game theories, some games between different players are examined with competitive issues. According to the result of this competition, players are content with the equilibrium point that is called Nash equilibrium in the game theory literature (Bonanno 2018). On the other hand, in some other games (cooperative games), the relationship of the players is based on cooperative behavior. Basically, the cooperative game is identified by two characteristics including the number of stakeholders/players (typically called N) and the worth of coalition (typically called v(S) for $S \subseteq N$). The cooperative game is formed by $n \geq 2$, in which N is the number of players and $N = \{1, 2, 3, \ldots, n\}$ (Parrachino et al. 2006; Abdoli 2019b; Alvarez et al. 2019).

In general, in a game there exist competitions between the game players, and these competitions may be created by inheriting the deficiency of the resource or competition on the allocation of the resource (Bonn 2018; Abdoli 2019a). In a non-cooperative game (with competition between players), a zero-sum game between players could be formed. In a zero-sum game (assuming 2 players), one of the players wins the game and another loses it at the same quantity and

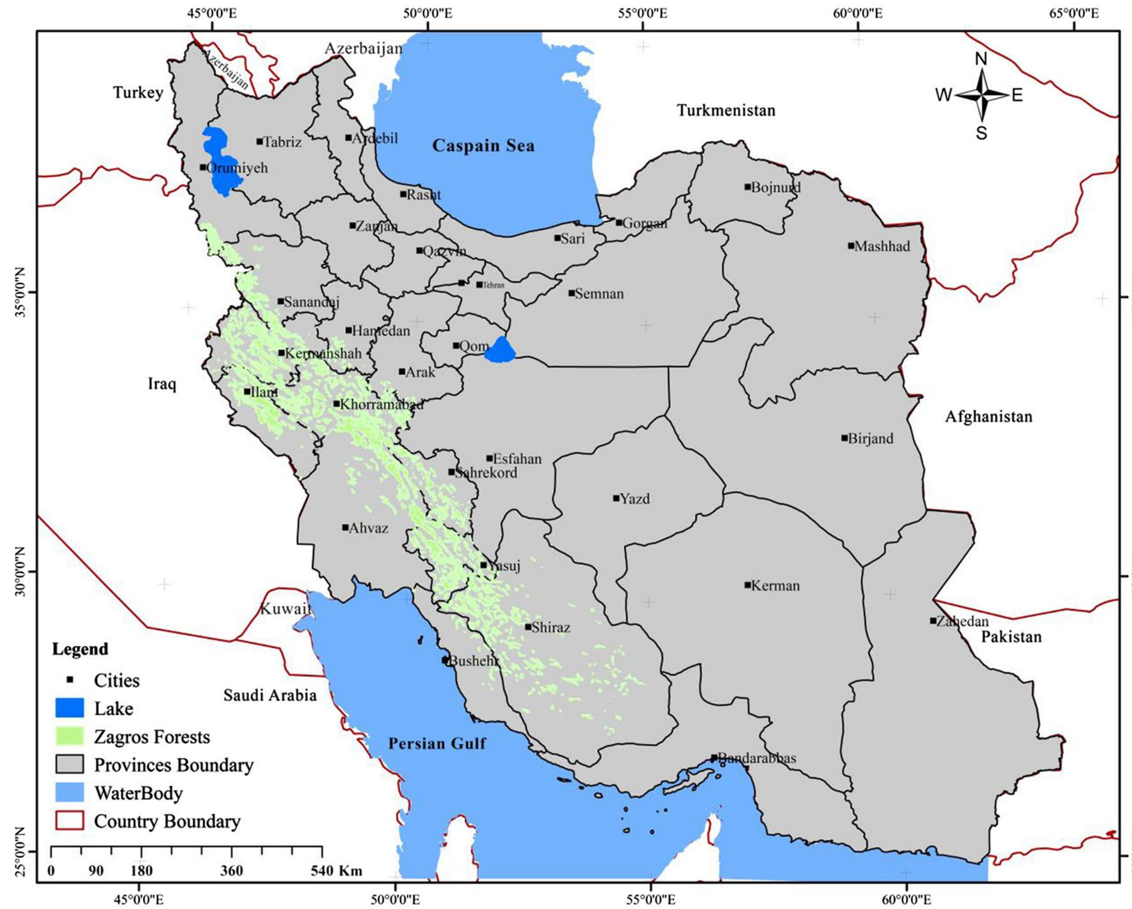

Fig. 1 The location of Zagros forests (green regions) in Iran in the west of Asia

simultaneously. Generally, in a cooperative game, the aim is cooperation instead of competition. It should be a necessity that a situation is formed according to profit sharing, cooperation, and positive interaction. In this condition, a win–win game will be organized instead of a zero-sum game (Abdoli 2019b; Lipovetsky 2020). In real life, the aim of the CGT is a selective allocation admissible for the players according to stable and fair allocations (Alvarez et al. 2019). If 3 players (A, B, C) are presumed for a collaborative game and every one of them has 1 or 2 strategies; the payoffs in this game can show as follows in Table 1. In the coalition between players B and C, the payoffs change as follows in Table 2.

In Table 1, three players have been introduced to play with names A, B, and C. The numbers a_{11}, a_{12}, and a_{13} are the payoffs of the coalition between players A (when payer A adopts strategy 1) and B (when player B adopts strategy 1), while player C adopts strategy 1. These strategies are a set of decisions made by each player, taking into account the decisions of the other player. In this situation, if player C adopts strategy 2, payoffs of the coalition are provided in e_{11}, e_{12}, and e_{13} forms. The other indices are defined for calculating the payoffs of coalitions. In Table 1, b_i (which is marked in red in the corresponding cell shape) shows the payoffs between the coalition of players A and B (when player A adopted strategy 1 and player B adopted strategy 2) if player C adopts strategy 1. In the same way, f_i shows the payoffs between the coalition of players A and B (when player A adopted strategy 1 and player B adopted strategy 2) if player C adopts strategy 2 which is marked in green in the corresponding cell shape.

Based on the assumed payoffs (Table 1) and according to Table 2, the payoffs increase with creating a cooperative game. The Shapley value which was first presented by Shapley in 1953 allocates a value for each player that contributes to the coalitions (Alvarez et al. 2019; Lipovetsky 2020). This value is the role and importance of the presumed player in creating a coalition in a cooperative game. Mathematically (as a simple formula in this concept), the Shapley value is defined as follows (Parrachino et al. 2006; Abdoli 2019b; Lipovetsky 2020):

$$\phi_i(V) = \sum_{\substack{S \subset N \\ i \in S}} \frac{(|s| - 1)!(n - |s|)!}{n!}[V(s) - V(s - i)] \quad (1)$$

Fig. 2 A general view of the trees (*Quercus brantii* Lindl and *Pistacia atlantica* Desf. stand) in dry habitats of Zagros forests, Iran. (Photograph was taken by the corresponding author, summer of 2021, in Chaharmahal and Bakhtiari province, Lordegan forests)

where $\phi_i(V)$ is the Shapley value for player i, $|s|$ is the number of coalition s, n is the number of the players, $V(S)$ is the value of the coalition s, id $[V(s) - V(s - i)]$ is the value added for adding the player i for the coalition s, and N is a collective coalition of all players. The goal of this formula is to calculate the role and importance of each player in the game. Therefore, the basic assumption of this equation is to calculate the sum of all coalitions for modelling a cooperative game.

Table 1 The assumed payoffs for players in strategies 1 and 2 for player C. *Source*: Modified from Abdoli (2019b)

Player C and strategy 1		Player B	
		1	2
Player A	1	(a_{11}, a_{12}, a_{13})	(b_{11}, b_{12}, b_{13})
	2	(c_{11}, c_{12}, c_{13})	(d_{11}, d_{12}, d_{13})
Player C and strategy 2		Player B	
		1	2
Player A	1	(e_{11}, e_{12}, e_{13})	(f_{11}, f_{12}, f_{13})
	2	(g_{11}, g_{12}, g_{13})	(h_{11}, h_{12}, h_{13})

Recent studies in the management of the Zagros forests of Iran show that a wide range of stakeholders can be involved in the management of the Zagros forests. These stakeholders include (1) forest managers and personnel of departments of natural resources and Forest, Range, and Watershed Management Organization (FRWO); (2) local communities (villagers, nomads, forest-related farmers, pastorals, etc.); (3) forest-related organizations of management such as environment organization; (4) research centers and institutions; (5) ecotourism management organization; (6) the nomadic affairs organization; (7) universities and agriculture organizations (such as horticulture and livestock production departments); (8) NGOs; (9) local government units; (10) institutions related to development; and (11) media and

Table 2 The payoffs for players in the coalition between players B and C. *Source*: Modified from Abdoli (2019b)

Coalition between B and C					
		(1,1)	(1,2)	(2,1)	(2,2)
Player A	1	(a_{11}, $a_{12}+a_{13}$)	(e_{11}, $e_{12}+e_{13}$)	(b_{11}, $b_{12}+b_{13}$)	(f_{11}, $f_{12}+f_{13}$)
	2	(c_{11}, $c_{12}+c_{13}$)	(g_{11}, $g_{12}+g_{13}$)	(d_{11}, $d_{12}+d_{13}$)	(h_{11}, $h_{12}+h_{13}$)

other forest-related social groups (Zandebasiri et al. 2017a). Although all of the above are very important for Zagros forestry, reducing the number of stakeholders in formulating planning and policy-making can help us focus more on adopting optimal strategies. There may be a pre-game before the game is defined (Carlson & Wilson 2004; Zandebasiri et al. 2017a). In this research, a pre-game among different players can be considered and it is assumed that in the initial game, the role of all these players is examined and then the strategies of key players are focused on.

After a preliminary review of previous studies in game theory in Zagros forests, such as those by Soltani et al. (2016), Zandebasiri et al. (2017a), and Zandebasiri et al. (2020a), three key players were identified for the Zagros forests, Iran. According to the available documents, one of the most important actors/stakeholders in the management of Zagros forests is definitely the local community of these forests (Valipour et al. 2014; Zandebasiri et al. 2020a, 2020b). This community includes villagers in the forests, forest-related ranchers and farmers, nomadic locals, semi-nomadic locals, and various spectrums of local people, each of whom is affected by forest management plans. Another key player in the Zagros forests is forest managers and employees of the natural resources section. The importance of this group of stakeholders was related to various strategies for the conservation of these forests (Jazirei & Ebrahimi Rostaghi 2013; Soltani et al. 2016; Zandebasiri et al. 2020b). Another stakeholder in forestry programs was the research section. This section includes agricultural and natural resources research centers, and the research institute of forests and rangelands (Zandebasiri et al. 2017a). In addition to the research section, another section that can be important in producing information on the forests of Zagros is the university section. Universities can be an integral part of Zagros forestry programs by educating students of forestry and natural resources and environment, as well as by presenting research projects on Zagros forests. In this study, due to the similarity of the tasks of research and universities sections, these two sections were combined and were introduced as the research section.

Therefore, following these stakeholders and their strategies, some important questions will be raised. The interaction of different strategies may be proposed in this way: If afforestation is done, what is the response from the locals? Does this answer require a management strategy? If the forests are enclosed, what response will be received from the local people? Does this answer require a management strategy? What is the best response from executive management if local people cooperate in one of the management strategies adopted, such as planting seedlings in the forest? Does this answer require a management strategy? What is the best response of the executive management if the local people do not cooperate in one of the adopted management strategies such as not exploiting non-wood products? Does this answer require a management strategy? Decisions and strategies related to these questions can create a game in forest ecosystem management.

In this study, we sought to find the Shapley values for the stakeholders/players of the Zagros forests involved in creating coalition and cooperation in the forest management game. Since the presentation of these values can depend on different opinions of different experts, we have created four different scenarios (based on a managerial viewpoint, an academic perspective, a research viewpoint, and finally, average results of the previous three scenarios) to calculate the Shapley value. Accordingly, four different forms can be proposed to provide the results of Shapley value for key stakeholders:

1- Presenting the Shapley value in order to form a coalition in the cooperative game of forest management based on a managerial viewpoint.

2- Presenting the Shapley value in order to form a coalition in the cooperative game of forest management based on an academic viewpoint.

3- Presenting the Shapley value in order to form a coalition in the cooperative game of forest management based on a research viewpoint.

4- Presenting the Shapley value in order to form a coalition in the cooperative game of forest management based on the mean and average of the above various viewpoints.

In addition to Shapley values, the value of the pair-pair coalitions among the three key players was calculated based on the same scenarios. Accordingly, a stakeholder-based questionnaire was applied to determine the importance of key players' data in forming a cooperative game. In this research, firstly, the power, role, and position of key actors were evaluated with a Likert scale of 5 parts, and

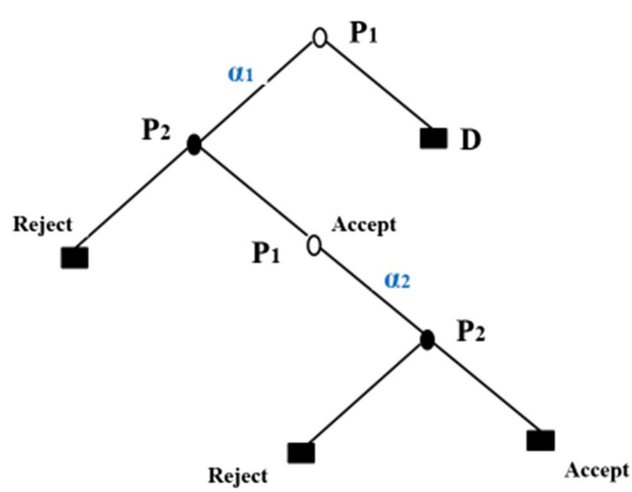

Fig. 3 Game Tree of the two-stage bargaining/negotiation model *Source*: Summarized and modified from Yan et al. (2011)

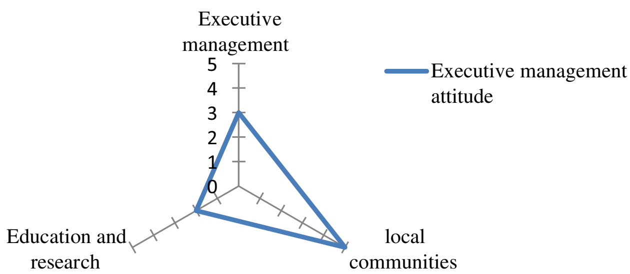

Fig. 4 The role of key players according to the scenario of managerial viewpoint. *Source*: Findings of the research

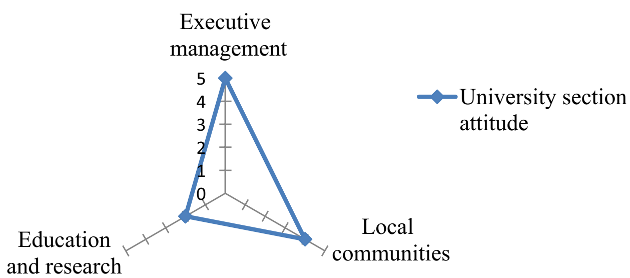

Fig. 5 The role of key players according to the scenario of academic viewpoint. *Source*: Findings of the research

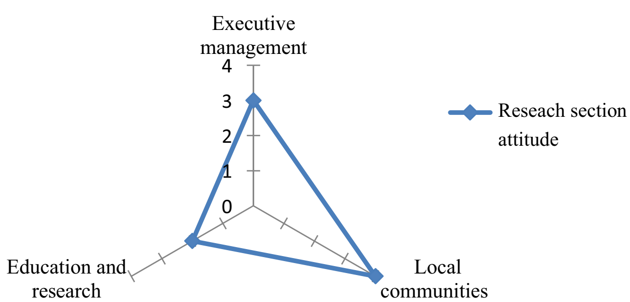

Fig. 6 The role of key players according to the scenario of the research section. *Source*: Findings of the research

in the second part, calculations related to Shapley value calculations were modeled based on the values of numbers 1 to 5. In the third part of the study, the value of coalitions was calculated for each scenario. Finally, for the ability to compare different numbers, normalization of these values was used to display values between zero and one for key players. Normalization is a technique most commonly used in decision-making computations such as AHP (Analytic Hierarchy Process) decision-making (Vafaei et al. 2016).

Since coalitions among different players could be useful in the management of Zagros forests, the issue was followed as a systematic analysis according to which each combination could add value to the coalition. Thus, this game was a super additive game (Alvarez et al. 2019). After presenting the preliminary results in order to present the final model for the optimal management of forestry in the study area, due to the close relationship between the two main players who have the highest Shapley values, a negotiation model for managing the relationship between these two stakeholders was used. The framework of this negotiation model between the main players is shown in Fig. 3. This model has the ability to interpret negotiation relationships between key players in this research.

In Fig. 3, two different states are assumed; P_1 and P_2 are two categories of players assumed for the game. α_1 and α_2 are various offers for P_2 in each stage of the game, and D is the direct transmisstion in which the game ends (Yan et al., 2011). In this paper, the model of Fig. 3 was used to show the relationship between the main key players in Zagros forest management.

Results and discussion

Figures 4, 5 and 6 show the quantitative measure of the role of each key stakeholder in the various perspectives of managerial, academic, and research scenarios based on the values presented in the Likert spectrum as preliminary measurements in these scenarios.

Figures 4, 5, and 6 are used to determine the importance of each of the key players in the management of Zagros forests. The results of this section show the importance of each of the key players individually and without a coalition. These individual values are modeled on different perspectives including the perspectives of management, academics, and research sections.

Table 3 The Shapley value of the key players according to different viewpoints, Source: Findings of the research

The viewpoint Key players	Managerial	Academic	Research	Mean scenario
Management	6.17	10	5	5.94
Local communities	8.16	9	6	6.61
Research and universities	3.67	3	4	3.45

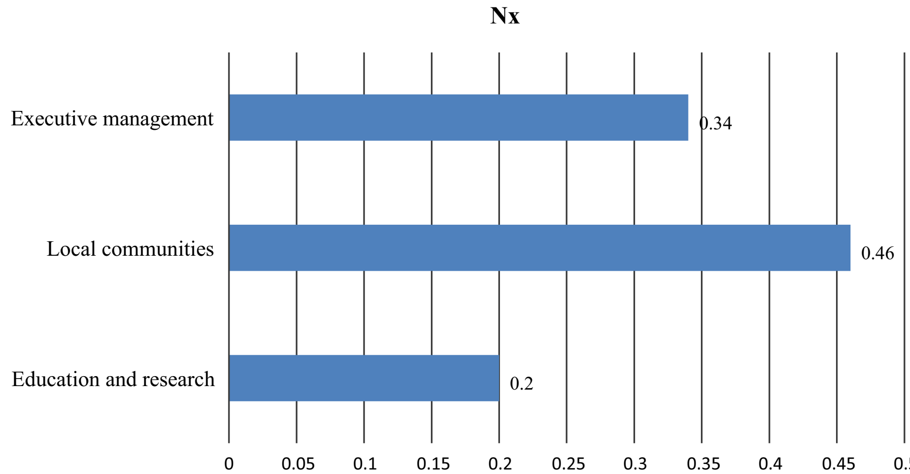

Fig. 7 The normalized Shapley value according to the scenario of managerial viewpoint. *Source*: Findings of the research

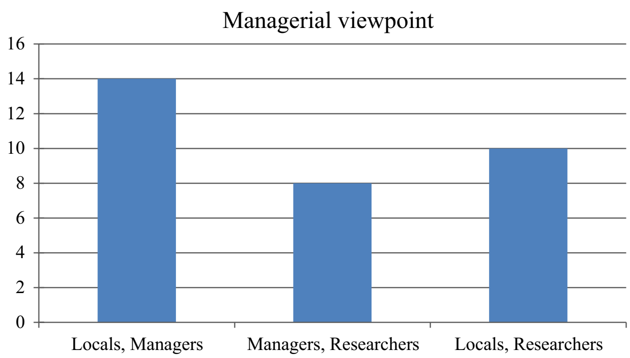

Fig. 8 The value of the coalitions according to the scenario of managerial viewpoint. *Source*: Findings of the research

Shapley values are calculated in Table 3, meaning that the numbers in this table not only indicate the power and role of a stakeholder alone but also his/her role in forming a coalition in forest management.

In general, the results of Table 3 are in line with other studies (Valipour et al. 2014; Zandebasiri et al. 2021) on the management of the Zagros forests of Iran, which have emphasized the key role and position of local people. Accordingly, there are no necessary conditions for this model of participatory management in the Zagros forests. Soltani et al. (2016) indicate a conflict in game theory modelling in the Zagros forests; Zagros forest management pursues different goals of local communities (Valipour et al. 2014; Zandebasiri et al. 2020a). Therefore, the main condition for creating synergy and forming a coalition between the key stakeholders of these forests is to define balanced goals between the local community and forest management in order to provide the conditions for participatory management for Zagros forestry.

The forest management viewpoint

Figure 7 shows the normalized Shapley value and Fig. 8 shows the value of coalitions based on this viewpoint. In Fig. 7, the value of N_X means normalized Shapley values. According to the results of this Fig., based on the managerial viewpoint scenario, the highest normalized Shapley value calculated in the management scenario belongs to the local community (NL = 0.46,). In other words, this value indicates that in order to develop a cooperative game, it is necessary

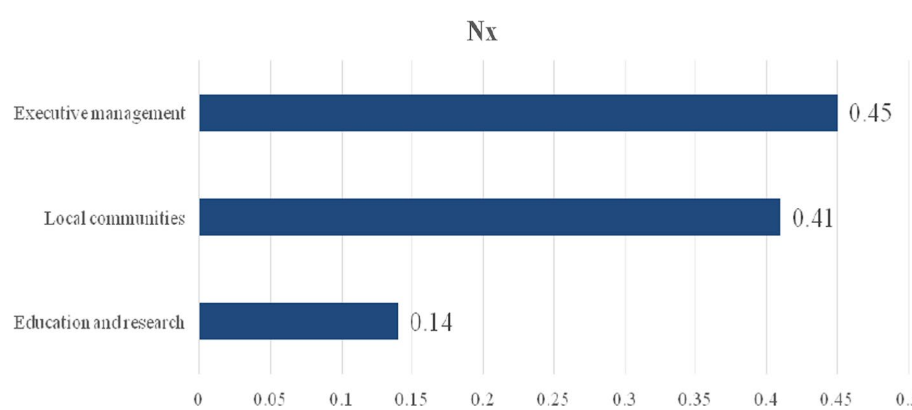

Fig. 9 The normalized Shapley value according to the scenario of academic viewpoint. *Source*: Findings of the research

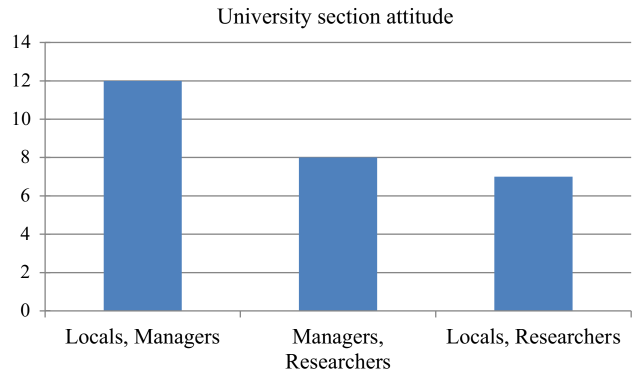

Fig. 10 The value of the coalitions according to the scenario of academic viewpoint. *Source*: Findings of the research

to pay the most attention to the local forest communities. In this scenario, the lowest role for the management of Zagros forests was also found in the players of the academic and research section (NR = 0.20). In this scenario and based on the results of Fig. 4, the most important coalition that can be important for the management of Zagros forests is the coalition between managers and local communities.

The university viewpoint

Figure 9 shows the normalized Shapley value and Fig. 10 shows the value of coalitions based on this view. In the academic viewpoint scenario, based on Fig. 9, forest managers (executive management) have the most roles in forest management. After that (and with a small difference), the local community has a prominent role, and finally, the least role belongs to the research section and the university. Based on the university viewpoint scenario, and based on the results of Fig. 10, in order to establish cooperative management, the Shapley value of managers and the local community has the highest value (0.45 and 0.41, respectively). In this regard, the lowest Shapley value belongs to education and research (NR = 0.14). Furthermore, according to the scenario of the university section and based on the results of Fig. 10, the most important effective coalition for cooperative forest management belongs to the coalition between managers and the local communities.

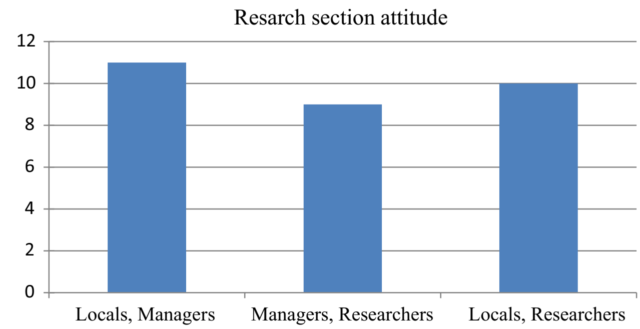

Fig. 12 The value of the coalitions according to the scenario of the research section. *Source*: Findings of the research

The research section viewpoint

Figure 11 shows the normalized Shapley value and Fig. 12 shows the value of coalitions based on this viewpoint. According to the scenario of the research section and based on the results of Fig. 11, in order to establish cooperative management, the Shapley value of the local community has the highest value (NL = 0.40), and then is the Shapley value of the forest management section (NM = 0.33), and finally, the lowest Shapley value belongs to the research section (NR = 0.27). According to the results of Fig. 12, the most important coalition belongs to the coalition between managers and local communities; however, the coalition between researchers and local communities has also noticeable importance.

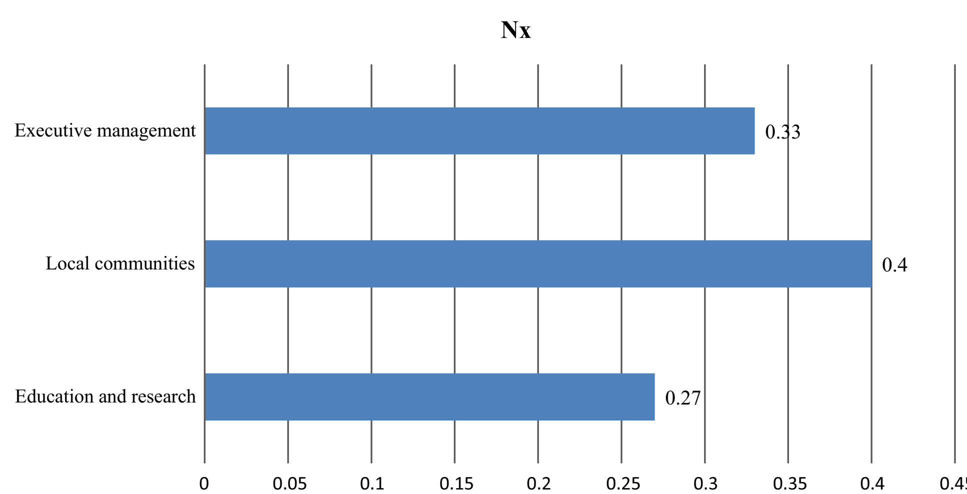

Fig. 11 The normalized Shapley value according to the scenario of the researchsection. *Source*: Findings of the research

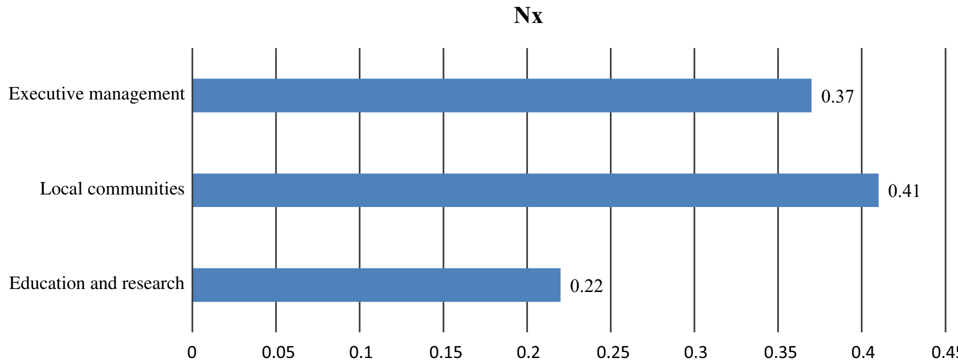

Fig. 13 The normalized Shapley value according to the scenario of the average of the viewpoints. *Source*: Findings of the research

The mean scenario for calculating Shapley value

Figure 13 shows the normalized Shapley value in the mean scenario for calculating the Shapley value. Based on the average of the views expressed in different scenarios in Fig. 13, the local community has the highest value (NL = 0.41), then there is the Shapley value of managers and the executive part of forestry projects with NM = 0.37, and finally, the lowest Shapley value belongs to education and research section (NR = 0.22).

Discussion

In this study, a negotiation model has been assumed for different local community harvestings of the forest resources. The role of forest managers and local community sections is far greater than that of the university and research sections (Fig. 7, 9, 11, and 13). In this way, the issue of communication between the two key actors/players (managers and local communities) becomes very important. Zagros forest management seeks more to conserve forests, but the local community targets livelihood needs such as grazing and harvesting of non-timber products. Since the nature of these goals can create a kind of conflict between the goals, a negotiation model can be used between these two players. In this model, based on a general model (Fig. 3), the most important cases of negotiation are assumed to be between two key players such as cattle grazing, non-timber forest products harvesting, branch lopping (in some areas), and fuel wood (in some areas). In the model of Fig. 3, different offers may be presented by forest managers, and local communities may accept or reject them. These offers can be presented in different technical issues in socio-economic problems such as (1) cattle grazing, (2) non-timber forest products harvesting, (3) branch lopping, and (4) fuel wood. Thus, determining the boundaries of α_j (like α_1 or α_2) for each subject is very important to reach an agreement between the key stakeholders of these forests. In the negotiation model for the Zagros forests of Iran, it is necessary to first examine the ecological needs of different regions separately. Then determining the needs of the local community for livestock grazing, non-timber forest products, and other needs could be helpful for the socio-economic capacity of each region. According to the social studies in each region, the required thresholds of forest resources should be defined for local community harvestings. In other words, a combined approach is needed here: the combination of ecology and socio-economics. The application of this model both in general and its local implementation depends on the ecological and socio-economic conditions of each region. At this stage, a balance is made between the technical demands of forest management and the local community needs. In areas where the ecological needs of the area are severe, it is necessary to inform the local communities and provide them with alternative solutions such as preparing forage from outside the forest.

This model is valid as long as the indicators of sustainable development are provided and the local community has less dependence on forest ecosystems. At the same time, land use planning programs can be fully prepared and areas can be identified with more dependence. Next, technical requirements should replace local requirements after achieving rural sustainable development. Until then, negotiation should be done between forest managers and the local community. This negotiation can be dependent on time and it can be agreed that in the short term, one of the essential demands for the local community will be more met, and in the medium term, the opposite will happen. In the optimal conservation policy and the time parameter, a timing game is formed in which the intergenerational allocation of benefits and costs should be considered on the subject of deforestation. In this game, the concepts of conversion and conservation are noticeable in terms of social welfare criteria and critical threshold for the local community harvesting (Corato 2012). In addition, in this form of examining the game between the key players, it is necessary to consider the relationships between stakeholders and the laws and policies governing environmental conditions (Klautau et al. 2021).

Some case studies in forest management have been presented for investigating equilibrium in game theory such as

Soltani et al., (2016) in the study of the North Zagros forests of Iran, Zandebasiri et al. (2017a, 2020a, b a) in the study of the Middle Zagros forests of Iran, as well as Klautau et al. (2021 in the assessment of Amazon forests in Brazilian forest management. Contrary to these studies, the issue of modelling coalitions was assumed to examine the conditions of formation of the cooperative game.

Cooperation can take the form of various coalitions between key stakeholders. In the results related to the formation of different coalitions in all scenarios (Fig. 8, 10, and 12), the most important effective coalition for forming a cooperative game is the coalition between the managers and the local communities. It seems that the history of preparing previous Forest Management Plans (FMPs) is the most important issue that has played a major role in the results. Since 1963, when FMPs began in the Zagros forests of Iran, one of the issues that prevented FMPs from achieving the organizational goals was the issue of social non-acceptance of the plans (Jazirei & Ebrahimi Rostaghi 2013). Therefore, the coalition between forest management and the local community in these forests is very important.

If the coalition between forest managers and the local community is not designed as the main coalition, the possibility of achieving cooperative forest management will be lost. Thus, the conditions for achieving this coalition and cooperative management are very important. It seems that in this situation, social learning is the basis of cooperative forest management. Social learning is a process for establishing proper communication and interaction between stakeholders and proper planning and control of goals and activities according to a full understanding of the desires and goals of stakeholders. Organizational learning in the forest groups, mutual monitoring in the forest groups, and investigating beyond the internal stakeholders for forests are three main forms of social learning processes. In other words, learning is not limited to internal stakeholders and needs to be combined with external stakeholders (Dedeurwaerdere 2009). Accordingly, several issues are more important in Zagros forestry. Social learning based on the relationship between the local community and forest management is one of these topics. Another issue about the role of local communities and their high Shapley value is to examine the traditional knowledge of local communities in the forest ecosystem. Understanding the role of local communities depends on understanding their indigenous knowledge. This may require additional efforts to enhance the knowledge related to non-timber forest products and to strengthen the marketing facilities.

Based on all the designed scenarios, local communities and executive managers (forest managers) have the most important role and effect in the management of Zagros forests. Similarly, local communities have the highest Shapley value in providing cooperative forest management (based on Fig. 7, 9, 11, and 13); however, there are some differences in the results of different scenarios. In the scenarios of the managerial viewpoint, as well as the research section, the most important key player is the local community, but in the scenario of the academic viewpoint, the most important key player is forest management. Finally, the results of the mean scenario show that the local community has the most important roles and the highest Shapley value. The reason for this could be the impact of local communities on all FMPs.

Local communities are very important in forest management, both because of their dependence on forests for their livelihood and because of their influence on FMPs. The findings of this study are consistent with those by Valipour et al. (2014), Soltani et al. (2016), and Zandebasiri et al. (2021), considering the role of local communities in the management of Zagros forests. CBFM can be of great help to the management of Zagros forests. Community-based natural resource management, especially forest management, has seen significant scientific growth over the past few decades (Don Gilmour 2016; Ayana et al. 2017). CBFM refers to a style of forest management in which management programs are targeted based on forest social issues. In other words, the output of socio-economic issues of forests is the input of goal-setting in the forest ecosystem.

Furthermore, the results of this study are in line with the results of the study by Kumar & Kant (2016). In situations where local communities use forest ecosystem resources, a game is usually formed between forest management and local communities regarding decision-making processes for ecosystem planning. Kumar & Kant (2016) in studying 5 villages in central India examined the game of public goods for investigating the success of JFM as well as the role of the revealed social preferences in various JFM outputs. The results of their study showed that the allocation of public goods in the game has a strong correlation with the success of JFM. Therefore, in our study, due to the large size of the Shapley value for local communities, especially in the average Shapley value scenario (Fig. 13), we suggest suitable allocation, public goods, and budget share for local communities to increase the probability of success of Zagros FMPs.

It should not be assumed that this allocation (in terms of harvesting) for local communities may mean more destruction and reduction of forest resources. Therefore, it is necessary to act with long-term planning and supervision to prevent deforestation. Programs such as participatory monitoring and control by the local communities themselves can be effective in preventing deforestation. This discussion is consistent with the results of Lee et al. (2018) by showing profit sharing for local communities. Lee et al. (2018) have shown if local communities have more profit sharing, they can be engaged in activities related to monitoring forest management such as playing a more effective role in suppressing illegal logging. This may be related to the motivation of local communities to participate in reducing deforestation. Long-term planning can also be used to organize local communities for short and medium-term planning to reduce the harvesting of the resources in the long run.

The results of other studies on game theory in the Zagros forests of Iran also confirm these issues. In the Zagros forests of Iran, forest managers try to limit the supply of livestock fodder from forest trees and livestock grazing as well as logging for refueling (Soltani et al. 2016). Hence, the issue of benefit sharing for local communities is very important. In this way, the need for CBFM approaches and greater benefit sharing is noticeable. Of course, this does not mean giving full authority to local communities in forest management, but by assigning rights and duties to local communities, the ground for CBFM can be provided. Shapley value is a useful tool for allocating resources and creating justice in ecosystems, especially in situations where the goals of stakeholders are different and even contradictory. If inequality sharing is created by managers for communities, iniquity develops, which can lead to conflict between managers and local communities (Kumar & Kant 2016).

In this study, Shapley value is very high for local communities in all scenarios (Table 3) and this issue should be considered in sharing benefits. The number 0.41 in the normalized Shapley value for local communities (Fig. 13) can be guidance for allocating funds in the management of Zagros forests. In this concept, Frisk et al. (2010) examined the cost allocation of cooperative forest transport in eight companies in southern Sweden. Using the Shapley value and nucleolus methods, they found that collaboration could increase economic savings for each company from 9% to a total of 14%. Accordingly, in line with their study, the Shapley values of this study can be considered in setting up a budget guide to save the proposed budgets in forest management in the Zagros forests, Iran.

One of the applicable results of the model in this study is the use of a negotiation model for the optimal management of stakeholders/players. According to Zandebasiri et al. (2017a), the results of different scenarios focus on two key players, local community and forest management. The nature of local community goals and forest management is different. Therefore, it is expected that there will be a disparity in the demands between the two key players. In previous studies, researchers found that in a situation where there is local forest management for the use of forest resources, a disparity could be created between participatory forest management, institutional principles, and local forest management practices (Ayana et al. 2017). In this regard, the negotiation solution between key players can lead to the formation of a coalition or transformation of a non-cooperative game into a cooperative game. The issue of negotiation can be an approach in the game through a change in preferences or administrative initiative (Carlson & Wilson 2004).

Andrés-Domenech et al. (2015) investigated the role of the world's forests as a carbon sink and the effect of forest depletion on carbon dioxide (CO_2) accumulation by using the bargaining game theory model. The result of the Nash bargaining solution shows that the cooperation between forest owners and non-forest owners in forest management has an effective role in abating the emission and reduction of network deforestation. In this study, a general bargaining model as a game tree of the two-stage bargaining (according to the model proposed by Yan et al. 2011) was proposed in game theory for two key players in Zagros forestry (local community and forest management). In this model, it is necessary to first identify the resources that are very important for the local communities (to harvest). Previous studies such as those by Kumar and Kant (2016) and Zandebasiri et al. (2020a) have shown that the behaviour of the local community is conditional and these conditions are determined by the general commodity allocation of the forest ecosystem. Furthermore, local communities that cooperate more with FMPs lead to more success in the FMPs. The most important forest resources for local communities in the Zagros forests are non-timber forest products harvesting, branch lopping (in some areas), fuelwood (in some areas), and cattle grazing (Valipour et al. 2014; Soltani et al. 2016; Zandebasiri et al. 2020a). These uses need to be shared in this negotiation model. Quantifying the size of each of these ecosystem resources is the first step in this benefit sharing. According to the approaches of forest managers in the Zagros forests of Iran, for forest protection and conservation (Jazirei & Ebrahimi Rostaghi 2013), the issue of the intensity of conservation also needs to be quantified. This issue should be considered in relation to renewability and quality of resources. This factor can influence the strategic interventions of key players (Fesselmeyer and Santugini 2013).

Conclusion

The results of this study show that the most important coalition for creating cooperative forest management is the coalition between local communities and forest managers. Negotiation solutions in this field could be very effective in providing solutions for forest protection and meeting the needs of local communities of the Zagros forest. Game theory provides solutions for the next decisions of the stakeholders/players and could model other decisions of them. In this study, different scenarios had almost similar results. This issue can be derived from the important and very significant position of the local community. According to the results of this study, our policy recommendation is to develop the position of local communities in FMPs and to pay more attention to their role in decision-making processes. Due to the Shapley values, stakeholders in academia and the research section of the Zagros forests need more research on specialized issues related to these forests. In particular, research on social groups and their effect on the Zagros forests could be helpful in forest management planning. The combination of forest conservation concepts and local community knowledge can also play an important role in this way.

In this study, the role of each stakeholder was quantitatively modeled in forming a coalition. In this context, game theory concepts were used for this modelling. Game theory could be used in economic and political issues in previous studies. In recent decades, game theory has been modelled on various fields of forestry. In this study, a model of game theory was presented for forestry with a focus on forest policy-making. The model was designed in the field of cooperative forest management which tries to determine a Shapley value for each of the key stakeholders/players. Shapley value is a reflection of the role of these key stakeholders in cooperation and forming coalitions with them for cooperative forest management.

One of the main limitations of this study was the number of forest management stakeholders as key players in the forests. In game theory modelling in forestry, the studies on the Shapley value were very limited, so increasing the number of stakeholders has complicated the complexity of the study. Accordingly, the number of key stakeholders was limited in this study (as one of the first articles in the Shapley value in forest management).

For future research, we propose to expand the number of stakeholders to provide a quantitative study of the role of all stakeholders in forest management. Subsequent studies can also use economic concepts to examine the Shapley value in forestry and natural resource management.

In the field of policy recommendation, two issues (i.e. policy framing and policy implementation) should be mentioned; first policy framing and second implementation. In the case of policy framing, initial decisions must be made with the participation and support of local communities. Accordingly, local communities should be considered in the main goal-setting for forest management plans. In the field of policy implementation, new methods of planning and policy-making, such as Shapley value, can be the basis for various allocations, such as the allocation of finance, power, and responsibilities in forest management. In this section, two issues were raised. First, game theory as a new approach in the management of forest ecosystems has many capabilities, such as considering the interaction effect of stakeholder strategies, and can model the most important positions of social issues related to ecosystems in different ways. The second issue is that the importance of the local communities must be practically determined in ecosystem management. The Shapley value method introduces a quantitative approach to this issue, especially for allocating financial funding to them. The results of this study show the position of society in forest policy and management more than before. This study calculated Shapley values for three different forest management stakeholders and this can start the way for further studies with a wider range of stakeholders illustrating different stakeholders' viewpoints on forest policy issues. Hence, it would be suggested that future researches on game theory should be applied in forest management.

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Author contribution All the authors have contributed to develop the current study. MZ designed the study and developed the original manuscript. HA, AHV and FW enriched and edited the manuscript in all sections. HJ dealt with the literature review and data analysis, YI helped with data collection and analysis, and MI dealt with the literature review and helped in preparing the map. All authors read and approved the final manuscript.

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Data availability For further information please contact with the corresponding author: mehdi.zandebasiri@yahoo.com.

Declarations

Conflict of interest The authors declare no conflict of interest.

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