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Sustainable rangeland management in southwest Iran: application of the AHP-TOPSIS approach in ranking livelihood alternatives

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Abstract. This paper reports the continuation of a line of research exploring livelihood alternatives employing sustainable rangeland management (SRM). Determining appropriate alternatives was a multifaceted task, so multi-attribute decision-making (MADM) techniques were applied to a framework that incorporated livelihood alternatives and their relevant criteria. The livelihood alternatives promote balance between humans, livestock and the rangelands, and the livelihood criteria include livelihood capital and vulnerability contexts, as well as the policies, institutions and processes (PIPs) that affect each livelihood alternative and SRM as a whole. The livelihood alternatives were ranked according to SRM potential, and the most appropriate ones for the Bazoft region of south-west Iran were determined. Through a hierarchical process, nine livelihood alternatives were initially considered as being potentially suitable for SRM, based on the weights of predefined criteria. Using a collaborative process, various groups (local informants, local and regional practitioners and scientists) were asked to develop a list of livelihood criteria in order to identify appropriate livelihood alternatives. Initially, 20 experts were selected for undertaking criteria weighting, and subsequently 10 experts were selected to rank the alternatives for final decision-making. The weights of the criteria were determined by the Analytical Hierarchy Process (AHP) technique, and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was used to rank the alternatives. A non-resource-based livelihood was ranked as the most suitable alternative, followed by pastoralism with adaptation of various production systems. The application of the AHP-TOPSIS approach showed how criteria weightings influence the suitability of livelihood alternatives. Thus, the livelihood model enabled visualisation of the consequences of appropriate and/or inappropriate livelihoods for SRM. This study found that even the livelihood alternatives with the lowest values were worthy of consideration in planning for SRM, but they might need to be supported. Finally, the study suggested that the application of decision support models to the identification of users' livelihood alternatives and to structuring the criteria for adoption of the various alternatives enhances informed decision-making within the context of SRM.

Additional keywords: ecosystem-based adaptation, multiattributes decision-making, non-resource-based livelihoods, mobile pastoralism, mitigation strategies, multilevel stakeholder involvement.

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Introduction

There is a widespread sense that mobile pastoralism is under pressure more than at any time since the collapse of the customary rangeland management system (Desta and Coppock 2004; Tache 2008; Dong *et al*. 2011; Tahmasebi 2012; Hosseininia *et al*. 2013; Khedrigharibvand *et al*. 2015; Khedrigharibvand 2018). Looking back, mobile pastoralism had been demonstrated to be among the most viable and prevailing forms of production and land-use in the rangelands, especially in pastoral regions, and it had been resilient and sustainable for centuries (Dong *et al*. 2011). Now, however, the balance between humans, livestock and the rangelands has been upset by population growth, and the viability of pastoralism has been undermined by legal, economic, sociopolitical and climatic disincentives (Dong *et al*. 2011; Khedrigharibvand *et al*. 2015).

With these challenges facing pastoralists, some may maintain traditional mobile pastoralism (i.e. nomadic pastoralism and transhumance), but others may either shift to semi-mobile

pastoralism, or transform their way of living and transit to sedentary livestock production; some may opt for resource-based or non-resource-based livelihoods; the remainder may migrate to cities (Khedrigharibvand *et al*. 2015; Dong *et al*. 2016; Khedrigharibvand 2018). It appears that mobile pastoralism in its traditional form, previously considered sustainable, is no longer suitable for sustainable rangeland management (SRM) (Khedrigharibvand *et al*. 2015). However, approaching SRM remains the top priority in pastoral regions. Khedrigharibvand *et al*. (2015) argued that if a set of appropriate livelihood alternatives along with livelihood criteria were promoted, SRM could be approached. They describe a livelihood framework for SRM in which both livelihood alternatives and their relevant criteria are recognised. Livelihood alternatives are activities (options) that rangeland users can choose in order to create a balance between humans, livestock and rangelands. The criteria (including livelihood capital, vulnerability contexts, and policies, institutions and processes (PIPs)) affect livelihood alternatives and SRM as a whole.

According to Khedrigharibvand (2018), the livelihood framework is based on the following assumptions:

(1) SRM should not be sought as an optimal (single best) solution, but rather should have more or less feasible responses, since there is no perfect alternative for any given region (Boyd and Svejcar 2009; Brunson 2012).
(2) A range of livelihood alternatives, from grazing-based systems to outward migration, is necessary to create a sustainable balance between populations (both human and livestock) and natural resources (i.e. rangelands) (Khedrigharibvand *et al*. 2015; Khedrigharibvand 2018).
(3) Because of rangeland heterogeneity, the underlying criteria differ from place to place; policy, research and actions (measures taken) should consider such heterogeneity (Stafford Smith *et al*. 2000, 2009; Khedrigharibvand *et al*. 2015).
(4) Resilience thinking is required for the development of strategies for confronting the problems created by current conditions and climatic variability, and for addressing the social and ecological consequences of climate change. Possible responses to climate change include mitigation, adaptation and transformation strategies. (Dong *et al*. 2011, 2016; Joyce *et al*. 2013; Khedrigharibvand *et al*. 2015; Khedrigharibvand 2018).
(5) The provision of one or more supportive strategies is fundamental to assisting rangeland users to build more resilient livelihoods (Dong *et al*. 2011, 2016; Speranza *et al*. 2014; Khedrigharibvand *et al*. 2015; Shaw and Witt 2015).
(6) Due to the variety in the rangelands (i.e. topographic features, elevation, hillside aspects, soil characteristics, etc.), in the cultural and social contexts, and in the economic status of individuals and regions, one or more options (livelihood alternatives) may be suggested for a given area (Dong *et al*. 2011, 2016; Khedrigharibvand *et al*. 2015).
(7) No single entity can handle all aspects of the task; thus, there should be a collaboration of the various organisations, agencies, and local communities; i.e. multilevel stakeholder involvement (Dong *et al*. 2017; Khedrigharibvand *et al*. 2017).

Furthermore, Rabie (2016) argued that sustainability is not a lasting and perpetual (perdurable) status, but should rather be seen as a state of transition into a more desirable state of living, which supports the theory of 'appropriate livelihood alternatives'.

Some scholars have studied the effects of socioeconomic and natural factors on rangeland management (Dong *et al*. 2012; Hosseininia *et al*. 2013; Dong and Sherman 2015). However, the impact of these factors on livelihood has not been well addressed. In a recent study, Khedrigharibvand *et al*. (2016) assessed livelihood capital, vulnerability contexts and PIPs as livelihood cornerstones, but more in-depth consideration is needed. First, the various stakeholders' points of view about livelihood alternatives needs to be interpreted and clarified, and second, the factors that affect the choices need to be detailed. In line with this, in deriving a model for decision-making regarding an alternative livelihood, consultation with multiple stakeholders was essential for determining the most appropriate livelihood alternatives. Livelihood alternatives and SRM as a whole are multifaceted concepts, complicating informed decision-making. Hence, the need for a list of alternative livelihoods and for selection criteria, together with an inclusive approach, encouraging stakeholder participation in the decision-making process (Khedrigharibvand *et al*. 2017).

To integrate and incorporate all these components, and to design effective programs and policies to achieve SRM, the prioritisation of livelihood alternatives in terms of the criteria and from the viewpoints of the various stakeholders needs to be elucidated (Khedrigharibvand *et al*. 2017; Khedrigharibvand 2018). Although attempts have been made to study the factors (i.e. criteria) affecting SRM and livelihood alternatives separately, no study has determined the most fitting alternatives with reference to the criteria affecting the livelihood alternatives. In addressing this gap, since determining appropriate alternatives was a multifaceted and multi-attributes issue, multi-attributes decision-making (MADM) techniques were applied to the task of making informed decisions about livelihood alternatives for SRM (Khedrigharibvand *et al*. 2017). Decisions about livelihood alternatives and/or scenarios, observing the criteria, should take place within a hierarchical structure.

Among MADM techniques, Analytical Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) have been recognised as the most user-friendly techniques (Soltanmohammadi *et al*. 2010; Fox *et al*. 2016; Khedrigharibvand *et al*. 2017). They are more effective when applied together, especially in a situation in which several alternatives are related to a list of criteria. AHP is a research tool mostly applied to criteria weighting, and TOPSIS is used to determine the most appropriate of alternatives (Soltanmohammadi *et al*. 2010). In the context of natural resource management, Soltanmohammadi *et al*. (2010) proposed the use of these techniques (defined here as the AHP-TOPSIS approach) to support decisions on post-mining land-use determination. Regarding the livelihood issue, Khedrigharibvand *et al*. (2017) asserted that applying the AHP-TOPSIS approach could be suitable for the evaluation of livelihood policy framework. However, there has till now been

a lack of practical examples of tackling livelihood alternatives for SRM.

In order to achieve the main objective of this study, the following questions were posed:

(1) How should a decision-making process be modelled to determine appropriate livelihood alternatives for SRM?
(2) Which livelihood alternatives are appropriate for a move towards SRM?

Methodology

Study area

The study was conducted in the Bazoft region, towards the north-west of Chaharmahal Va Bakhtiari province, the largest high mountain area in Iran (Fig. 1). This region extends between 49°34′–50°30′N longitude and 31°37′–32°39′E latitude, and covers an area of 190 749 ha. It is vegetated with oak trees and various rangeland types, and the land is interspersed with streams and the Bazoft River. Approximately 56% of the watershed is covered by rangelands, the rest by forest and bare lands (Besalatpour *et al*. 2012; Almasi and Soltani 2017). Pastoralists have inhabited the area for many years. The Bazoft region is reported to be one of the strategic regions in Iran in terms of pastoralist population following the pastoralist livelihood strategy. Although traditional pastoralism has been acknowledged as the most important livelihood alternative in previous decades, because of declines in natural resources and increase in population growth, further livelihood alternatives should be explored as opportunities to utilise different resources in the region.

Theory of appropriate livelihood alternatives

According to the aforementioned assumptions, nine livelihood types were defined, representing the alternatives for SRM planning. An overview of the livelihood alternatives and their relevant criteria is available in Khedrigharibvand *et al*. (2015) and Khedrigharibvand (2018).

Sampling strategy

To respond to the study's objectives, a case study was conducted. First, in collaboration and consultation with experts, a process was applied to develop a list of criteria for livelihoods, while identifying appropriate livelihood alternatives. Then, the AHP technique and TOPSIS were applied to weigh the various livelihood criteria/attributes and rank the livelihood alternatives. Next, a sensitivity analysis was performed to test the robustness of the final rankings with respect to changes in the weights of criteria/attributes. Finally, based on the determined livelihood alternatives, suggestions for future studies were provided.

Purposive sampling was the preferred method for selecting respondents to cover a range of perspectives. The process was

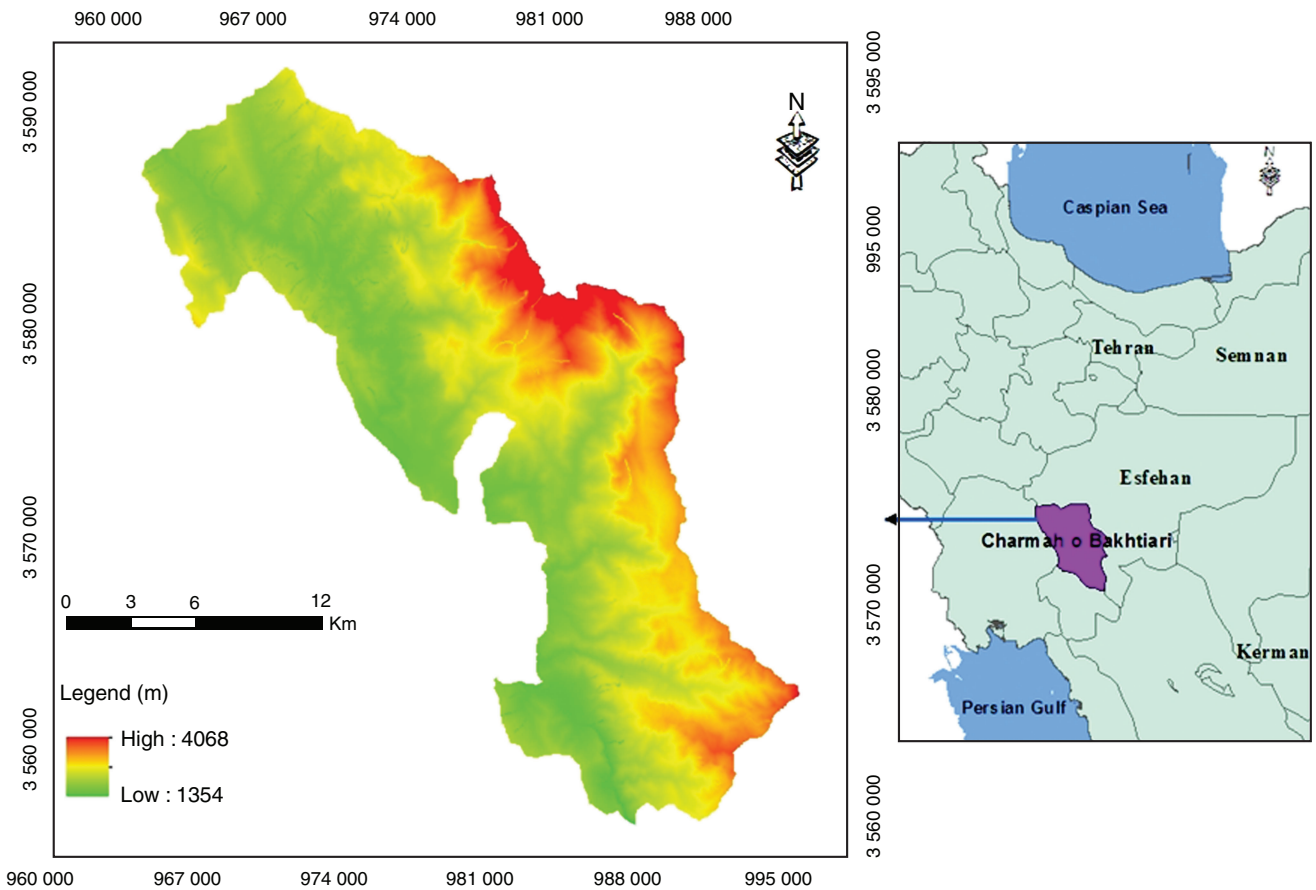

Fig. 1. Location of the study area (Bazoft region).

performed in a number of stages, with 20 and 10 respondents finally being selected to fill out the AHP and TOSIS questionnaires, respectively. Experts with a relatively high level of skill or knowledge were employed. A combined bottom-up and top-down approach was applied to reduce the bias in the participants' perspectives. Thus benefiting from the experts' point of view (i.e. their preferences) at both local and regional levels (Fraser *et al*. 2006; Reed *et al*. 2006). In this context, we benefitted from the knowledge of local key informants (e.g. pastoralists, migrants, recreationists), local and regional practitioners (e.g. professional rangelands experts, decision-makers, veterinarians, environmental experts, environmentalists and local practitioners), and scientists (e.g. academic and agency researchers), representing the main interest groups, all of whom were assumed to be knowledgeable about SRM. The local key informants we referred to were those who had a stake in the land and were either knowledgeable about the region or were representative of a particular group within the region (i.e. local leaders or experienced pastoralists). The local and regional practitioners, academic researchers and scientists were familiar with SRM programs and people's livelihoods. Questionnaires were administered to elicit the preference of values of the respondents. This information was used to develop a set of decision-making criteria, and we then applied decision-making techniques to weight the criteria and rank the livelihood alternatives.

Development of decision-making criteria

The basic steps employed in developing the criteria (i.e. livelihoods criteria) and ranking alternatives were based on procedures suggested in the literature (DFID 2001; Reed *et al*. 2006; Soltanmohammadi *et al*. 2010; Price *et al*. 2012; Khedrigharibvand *et al*. 2015). In order to identify the most important livelihoods criteria affecting livelihood alternatives in the Bazoft region, and as a first step, a questionnaire was distributed to the experts, who were asked to list criteria in order of their relative importance. The main question posed was: which aspects/factors of livelihoods are determinant in SRM? This was addressed to 60 experts ('key informants'), of whom 40 completed the questionnaires. To make a list of sub-attributes in the third level, the experts' responses were merged, all sub-attributes were included. Five most important sub-attributes suggested by the experts from each attribute (from second level) were extracted, resulting in 55 sub-attributes (Table 1).

Since the respondents were chosen by purposive sampling, probability statistics, which are based on the determination of sample size (i.e. representative of the population), do not necessarily matter. In fact, it is likely that an increase in sample size would have increased the complexity of the data, and not necessarily significantly improved the precision of the results. In addition, increasing the sample size would have thus unnecessarily prolonged the study, because the method is complicated and time-consuming. There is no specific rule regarding the number of the respondents in the application of MADM techniques. For example, with respect to the analysis of public values in relation to complex policy decisions, in their respective studies, Keeney *et al*. (1990), McDaniels and Roessler (1998) and Martin *et al*. (2000) elicited preferences from 23, 28 and 3 respondents. In the present study, 20 experts were asked to complete the AHP questionnaire to weigh the criteria, but due to some difficulties with the TOPSIS questionnaires (i.e. their complexity and time-consuming nature), only 10 experts ranked the alternatives for use in decision-making concerning alternative livelihoods. Finally, values were obtained indicating the most appropriate livelihood alternatives for approaching SRM.

Determination of the experts' preference values by application of the AHP-TOPSIS approach

Informative and accurate results have been provided by AHP and TOPSIS techniques used in a 'hybrid' approach (Chang and Chen 2011; Khedrigharibvand *et al*. 2017). Recently, interest in the AHP-TOPSIS approach has grown, and it has been applied in a wide-range of situations (e.g. Soltanmohammadi *et al*. 2010; Abdelhamid and Eldin 2012; Al Maliki *et al*. 2012; Fox *et al*. 2016; Khedrigharibvand *et al*. 2017). The AHP technique performs pairwise comparisons between the criteria (to weigh the value of the criteria) based on a hierarchical structure, and also ranks the alternatives. When the number of criteria and alternatives exceed what a typical AHP technique can deal with, the TOPSIS technique can be applied to rank the alternatives. The two techniques involve a number of steps previously explained in the literature (e.g. Soltanmohammadi *et al*. 2010; Fox *et al*. 2016). In summary, a set of criteria should be developed, which should then be evaluated by the AHP technique. Thereafter, the TOPSIS technique should be applied to select the most appropriate alternatives according to the criteria.

An AHP questionnaire was designed to determine the weights of the 55 sub-attributes: the respondents were asked the following question for each pair of criteria: how important is criterion A compared with B in the Bazoft region? A nine-point scale was used, one representing equal importance, and nine representing complete dominance of one of the criteria (Saaty 1980). In a TOPSIS questionnaire, the respondents were asked to score the alternatives against the applied criteria, based on the five-point Likert scale. The criteria were weighted based on the experts' preference values. Then, the consistency ratio was calculated to indicate if the experts compared the criteria with great care (Saaty 1980). Finally, the TOPSIS was applied to the outcomes of the AHP to explore the most appropriate livelihood alternatives.

Sensitivity analysis

Sources of uncertainty in multicriteria decision systems are mostly derived from randomness, imprecision and preferences (Mendoza and Martins 2006). In this research, the experts were purposively selected. However, uncertainty was still associated with the experts' preferences regarding the criteria weighting. In such situations, sensitivity analysis, as a deterministic approach, is necessary (Mendoza and Martins 2006). There are numerous approaches to conducting sensitivity analysis, but there is no consensus on the best approach. Like Kangas *et al*. (2000), we applied an approach designed to analyse potential changes in the final rankings of alternatives. We built scenarios as a result of changing the weighting of three main criteria,

followed by the global weights. The expectation was that the final decision indicated by the sensitivity analysis would not be significantly different. Nevertheless, if the values of the final alternatives do change after the sensitivity analysis, the decision-makers must rethink their decision and adjust the structure of the model.

Results

Development of a set of novel decision-making criteria

The livelihood criteria were expanded and a list of suitable criteria developed (Table 1). Ultimately, 55 sub-attributes were developed (Table 1, third column).

Evaluating the weight of criteria by the AHP technique

The AHP technique was used to organise multiple-choice criteria into a hierarchy, assessing their relative importance, and to calculate the weight of each criterion and the overall weight of the criteria (Table 1). The consistency ratio was calculated as 0.1%, which showed that the experts compared the criteria precisely. Although all criteria with high weights were considered effective for approaching SRM, the three highest criteria in the context of the Bazoft region included: (1) income sources (0.158), (2) water (0.144), and (3) social security (0.135). Conflict (0.029), irregularity and uneven distribution of rainfall (0.026) and heavy snow (0.019) were ranked as the lowest sub-attributes respectively (Table 1). Fig. 2 illustrates the global weights of the evaluation alternatives.

Rankings of livelihood alternatives

After assigning weight to each criterion using the AHP, the livelihood alternatives considered potentially suitable for planning for SRM were ranked using the TOPSIS. In descending order of preference, the livelihood alternatives for approaching SRM are presented in Fig. 3. Non-resource-based livelihoods (0.554) were found to be the best alternative based on the affecting factors, followed by pastoralism through ecosystem-based adaptation (0.480) and transforming livestock production systems (0.468). Compared with other alternatives, the pastoralism through mitigation (0.307) and traditional pastoralism (0.279) were found to have the lowest values.

Sensitivity analysis

In this study, scenarios were developed based on changes in three main criteria, selected from among the livelihood criteria, vulnerability contexts, and PIPs. The relative weights of the criteria in the decision hierarchy for the first scenario were estimated at 0.404, 0.368 and 0.228 respectively, as they were attained by a decision-makers' task. Three further scenarios were considered. The three main criteria respectively were assumed to be 0.500, 0.300 and 0.200 for the second scenario; 0.060, 0.250 and 0.150 for the third scenario; and 0.450, 0.400 and 0.150 for the fourth one. The new weights were passed into TOPSIS, and changes in the outcomes were noted. However, the final decision (i.e. ranking alternatives) remained virtually unchanged (Table 2). The changes to the weighting of the criteria had little effect on the decision. Since the final decision was almost unchanged, it can be argued that the decision-makers made a well-reasoned decision and decided carefully. The scores of the livelihood alternatives were thus not found to be sensitive to the changes made to the criteria weights.

Discussion

Application of AHP-TOPSIS approach in ranking livelihood alternatives

Development of decision-making criteria

In selecting from among livelihood alternatives, specifying a set of criteria that measure progress towards SRM on a regional scale is important. Although increasing the number of criteria in the decision-making process may complicate the issue, the appropriateness of the decision should be enhanced. However, due to the increasing complexity in the decision-making process and ensuring the right decision is made, a specific number of criteria should be considered (Jalalifar *et al*. 2009). In the end, 55 sub-attributes were developed. The reasons for subdividing the criteria were:

(1) Since criteria in the first level and attributes in the second level were expressed as scientific concepts, they were broken down further into descriptions with which participants were familiar (the third level) for easier assessment.
(2) The more general concepts might influence the final weighting unduly. The more easily understood sub-attributes are more likely to generate precise weights.

Weighting of criteria by the AHP technique

Through application of the AHP technique, the criteria weights were obtained. The reasons for applying criteria weightings (1–9) based on Saaty's scale (1980) were: (1) some sub-attributes are difficult to assess through field methods, and precise data are scarce; and (2) collecting field data is sometimes time-consuming. Thus, the nature of the data guided users to assess sub-attributes values with experts' preferences. Under the conditions stated in this paper, it appeared that income sources were considered more important than other criteria; however, this may not apply to other regions. Regarding the criteria affecting livelihoods, Shang *et al*. (2014) noted that job opportunities (income source) such as dedicated livestock haulage and additional livestock-orientated businesses are essential for promoting an intensive livestock industry. Khedrigharibvand *et al*. (2015) provided a list of livelihood cornerstones, which fulfilled three main criteria identified in their study. Sharifiyan Bahraman *et al*. (2014) discussed the application of the AHP technique in rangeland management. They applied this technique to prioritising factors affecting rangeland exploitation. Their results indicated that income extension from livestock products, and drought and its consequences had the highest priorities in rangeland exploitation in terms of opportunities and threats respectively.

Application of the TOPSIS

From application of the TOPSIS, non-resource-based livelihoods were found to be the best alternative, followed by pastoralism through ecosystem-based adaptation, and transforming livestock production systems. Thus, the alternative non-resource-based livelihood had the highest weight in terms of criteria such as job opportunities and water; these are the

Table 1. A list of main criteria, attributes and sub-attributes and their weights

	Criteria/Weights	Attributes/Weights	Sub-Attributes	Weights	Global Weights
1	Livelihood criteria (0.404)	Natural capital (0.166)	Water	0.357	0.144
2			Plant density	0.198	0.080
3			Plant products	0.129	0.052
4			Assess to land	0.228	0.092
5			Minerals and soil nutrients	0.088	0.036
6		Human capital (0.310)	Indigenous knowledge	0.328	0.133
7			Education and training rational practices	0.214	0.086
8			Health	0.184	0.074
9			Skilled labour force	0.147	0.059
10			Women's empowerment	0.127	0.051
11		Social capital (0.184)	Social security	0.333	0.135
12			Societal norms	0.160	0.065
13			Social relations and trust	0.177	0.072
14			Social cohesion	0.148	0.060
15			usufruct (Personal and social usage rights)	0.173	0.070
16		Economic capital (0.080)	Job opportunities (income source)	0.390	0.158
17			Savings	0.141	0.057
18			Credit insurance	0.135	0.055
19			Livestock and its products	0.220	0.089
20			Fund for support	0.115	0.046
21		Physical capital (0.260)	Roads and public transport services	0.138	0.056
22			Schools	0.118	0.048
23			Water point supply	0.314	0.127
24			Affordable energy	0.267	0.108
25			Sanitation	0.162	0.065
26	Policy, Institution and Processes (0.368)	Policy (0.519)	Land reform	0.118	0.043
27			Nationalisation of rangelands and forests	0.182	0.067
28			Sedentarisation	0.113	0.042
29			Social and economic programs	0.329	0.121
30			Devolution of land and resources right	0.257	0.095
31		Institution (0.274)	Law and right regimes	0.294	0.108
32			Traditional customs and practices	0.191	0.070
33			Development of Markets	0.166	0.061
34			Local councils and NGOs	0.169	0.062
35			Cooperatives	0.180	0.066
36		Processes (0.207)	Modernisation and social changes	0.148	0.054
37			Participation processes	0.246	0.091
38			Land tenure process	0.272	0.100
39			Land allocation process	0.217	0.080
40			Administrative process	0.117	0.043
41	Vulnerability contexts (0.228)	Seasonality (0.201)	Rising temperatures and melting snow	0.304	0.069
42			Drought	0.280	0.064
43			Heat stroke and chilling injury	0.215	0.049
44			Irregularity and misdistribution of rainfall	0.116	0.026
45			Heavy snow	0.084	0.019
46		Shocks (0.493)	Economic shocks	0.378	0.086
47			Diseases	0.148	0.034
48			Conflict	0.127	0.029
49			Loss to property	0.209	0.048
50			Unexpected events	0.139	0.032
51		Trends (0.306)	Population growth	0.152	0.035
52			Land-use change	0.162	0.037
53			Land degradation	0.279	0.064
54			Biodiversity loss	0.153	0.035
55			Extra-exploitation	0.254	0.058

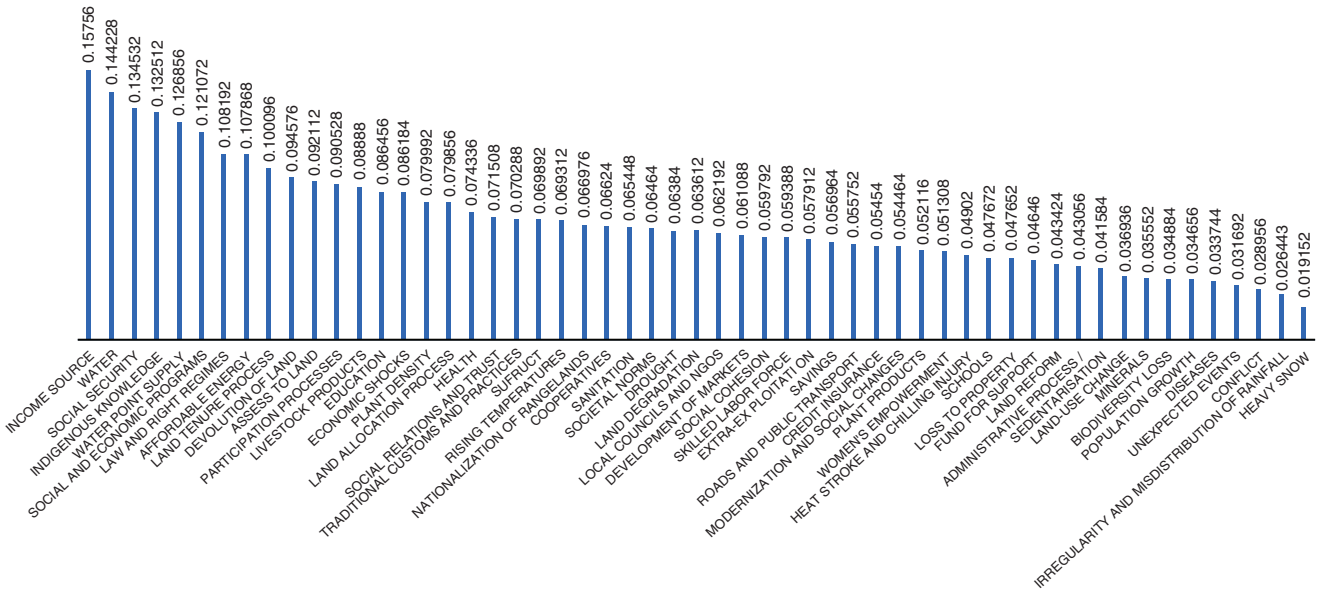

Fig. 2. Global weights of the evaluation attributes calculated using the AHP technique.

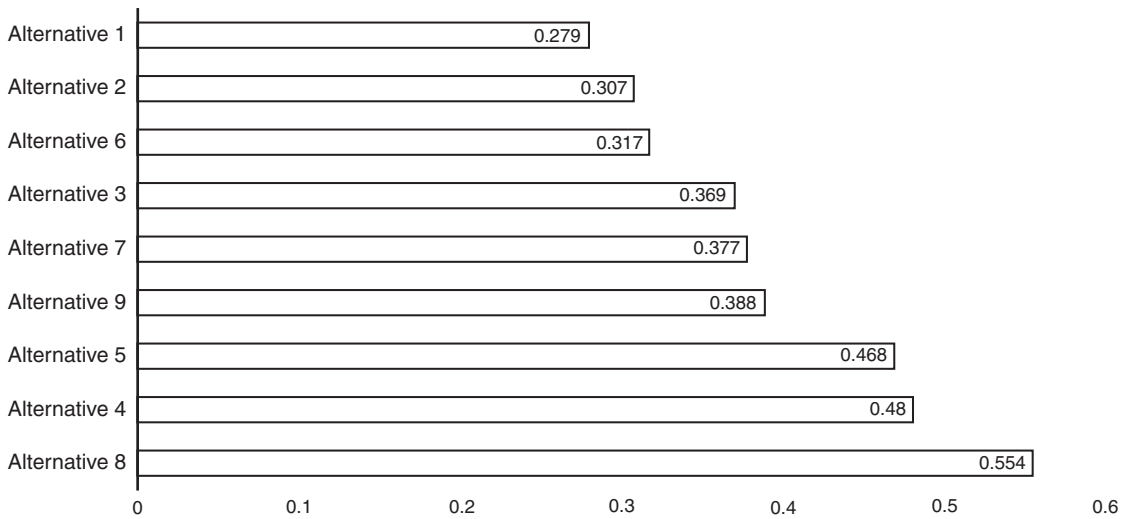

Fig. 3. Descending preference order of livelihood alternatives towards SRM Alternatives 1–9 are different options for achieving SRM that have been explained in details in Khedrigharibvand *et al*. (2015) and Khedrigharibvand (2018). They include (1) Traditional sustainable pastoralism; (2) Sustainable pastoralism through mitigation strategies; (3) Sustainable pastoralism through adaptation based strategies in rangelands; (4) Sustainable pastoralism through adaptation of different production systems; (5) Sustainable intensification through transforming livestock production systems; (6) Transformation to resource-based livelihoods through rangeland user's self-reliance; (7) Transformation to resource-based livelihoods through participatory processes; (8) Transformation to non-resource-based livelihoods; and (9) Migration.

factors primarily responsible for this ranking. In comparison with other alternatives, traditional pastoralism, and pastoralism with some mitigation had the lowest values, resulting them being deemed the least appropriate livelihood alternatives for SRM. However, all alternatives should be considered in regional planning for SRM and sustainable development in general. Since the alternatives are related to people's livelihoods, no priority should be ignored.

The implication of appropriate livelihood alternatives for SRM

Several studies have reported that the first three livelihood alternatives might become appropriate livelihood alternatives for rangeland users. The experts ranked the non-resource-based livelihood alternative (i.e. alternative eight) as the most appropriate one. It has been claimed that this alternative can be selected in locations where viable livelihood strategies

Table 2. Sensitivity analysis scenarios (changes in the main criteria)

Sensitivity analysis scenarios (changes in the main criteria)												
Scenarios	1			2			3			4		
Main criteria	0.404	0.368	0.228	0.500	0.300	0.200	0.060	0.250	0.150	0.450	0.400	0.150
Alternatives	Score		Ranking	Score		Ranking	Score		Ranking	Score		Ranking
Alternative 1	0.2791		9	0.2913		9	0.2997		9	0.2828		9
Alternative 2	0.3070		8	0.3186		8	0.3202		8	0.3175		8
Alternative 3	0.3685		6	0.3808		6	0.3814		6	0.3804		6
Alternative 4	0.4803		2	0.4991		2	0.4993		2	0.4989		2
Alternative 5	0.4683		3	0.4901		3	0.4884		3	0.4911		3
Alternative 6	0.3171		7	0.3563		7	0.3576		7	0.3556		7
Alternative 7	0.3766		5	0.4086		5	0.4090		4	0.4083		5
Alternative 8	0.5543		1	0.5802		1	0.5798		1	0.5804		1
Alternative 9	0.3876		4	0.4088		4	0.4087		5	0.4089		4

within a variety of resource-based livelihoods (i.e. rangelands, forests, farm, fisheries, tourism, and mining) cannot be realised. This alternative includes services aimed at supporting the resident population, such as providing goods and services, food, pastoral advice and governance at all scales, and tourism-based activities (Stafford Smith *et al*. 2008; Stafford Smith and Cribb 2009; Khedrigharibvand *et al*. 2015). In order to develop alternative eight in the Bazoft region, and make it more appropriate, a variety of actions can be undertaken by the government and by the people themselves. Although people should have an interest and a significant role to play in some of these actions, the government has a key role. In line with this, Todaro and Smith (2014) emphasised the role of governments in investing in physical and social infrastructure, health-care facilities, and educational institutions, as well as in providing a suitable climate for private enterprise. Consequently, for developing such alternatives, recognition of the role of governments is vital; that role is manifested in investment coordination, environmental outcomes, and strengthening of infrastructure.

Regarding pastoralism through adapting different production systems, McCabe *et al*. (2010) found that the integration of agriculture with pastoralism has profound implications for sustainable pastoralism. Although agroforestry and planting trees along with pastoralism have been recognised as important elements for sustainable livelihoods, Foundjem-Tita *et al*. (2013) reported that these activities are constrained by factors internal and external to the household, and related to the policy and legislative environment. They suggested that legislation designed to express the policies must be in line with the objectives of poverty reduction. Therefore, it can be argued that the development of alternative four in the Bazoft region requires some policy-making support. For instance, people whose livelihood depends on resources need to be supported by good legislation and regulations. Furthermore, support in the form of promotion of diversification can help achieve the sustainability goals for this alternative.

Following sustainable intensification for a move towards commercial systems, Tarawali *et al*. (2011) addressed the role of mixed crop–livestock systems in sustainable development. They argued that if these livelihoods were to be sustainable, technology-based production and efficiency-enhancing dimensions, together with innovative and practical approaches encompassing institutional, policy and market solutions should be considered. Furthermore, Shang *et al*. (2014) asserted that to improve the commercial value of livestock, market centres should continue to be concentrated in the traditional areas between pastoral and arable regions. Consequently, if arable regions exist close to pastoral regions, developing commercial livestock production systems would be feasible. They also emphasised that integrating these systems with farming should be facilitated. This livelihood alternative has been criticised for increased vulnerability to change by replacing a diverse multi-resource economy with a single-product ranching system (Grice and Hodgkinson 2002; Khedrigharibvand *et al*. 2015). However, this alternative could be well suited to the Bazoft region, if the following measures are considered, as emphasised by Shang *et al*. (2014): (1) support for extensive rural economies; (2) developing husbandry methods; (3) providing feed technology and equipment; (4) continued exploration and expansion of marketing outlets; (5) placement of good transport networks around the existing towns; and (6) proximity of townships to provide a flexible labour source.

Mobile (traditional) pastoralism was deemed to be the lowest option. However, in responding to concerns for ecology and long-term sustainability, it can still be remained; merely as a livelihood alternative or together with the other alternatives (Shang *et al*. 2014). In this context, Grice and Hodgkinson (2002) asserted that science should recognise the culturally and environmentally appropriate production systems that meet the market needs for higher quality products, i.e. the demand for 'naturalness' and for benefits such as freedom from pesticide and herbicide residues. Thus, mobile/traditional pastoralism has been recognised as an ecologically sustainable alternative since it maintains traditional culture, and through its mobility, contributes to biodiversity conservation (Grice and Hodgkinson 2002; Khedrigharibvand *et al*. 2015). Regarding the benefits from this alternative, much lower levels of rangeland degradation than those alternatives that have promoted sedentary livestock production systems have been reported (Shang *et al*. 2014). As a result, alternative one, mobile pastoralism, has received little support in the Bazoft region. However, given its enhancement of long-term sustainability and biodiversity, it can be promoted as one of the culturally and environmentally favourable alternatives, and should be considered in planning for SRM.

Pastoralism based on mitigation strategies was placed at the lowest level. This alternative has been considered to be the best option when carbon sequestration functions well, and it can reinforce livestock–rangeland systems. An example of this livelihood alternative is semi-pastoralism, in which pastoralists depend only upon the rangelands. This system has been criticised due to its reduced flexibility in response to environmental changes (Khedrigharibvand *et al*. 2015). Alternative two (i.e. pastoralism based on mitigation strategies) can be supported by several mitigation strategies, including carbon sequestration and the potential to reduce greenhouse gases through better soil management, as well as reduction in methane and carbon dioxide emissions by livestock and rangeland management. Furthermore, the mitigation strategies can be embedded through changing livestock management practices, including reducing livestock numbers and changing livestock mix. If this livelihood alternative is going to be considered as the appropriate option in the Bazoft region, and to make it more sustainable, both local users and the government should deliver a variety of mitigation strategies. Dependency on one or a limited number of strategies may be insufficient to cope with the overwhelming effects of the ongoing changes. All of the above-mentioned strategies should provide a sustainable livelihood if the appropriate number of livestock for a sustainable livelihood is observed.

In this study, all possible livelihood alternatives concerning SRM were ranked in the context of the Bazoft region. A set of alternatives exist, which are appropriate for SRM. Specifically, and with respect to the Bazoft region, while considering all alternatives, further investment should occur in the most appropriate ones. Thus, ranking the appropriate livelihood alternatives can make it easier to create a balance between humans, livestock and the rangelands, which in turn affected by stakeholders' preferences and the regional potential. When all alternatives are considered for SRM planning, policy-makers are able to make informed policies/decisions. This could prevent the occurrence of undesirable changes (i.e. rangeland degradation and livelihood vulnerability) and create desirable changes (i.e. balance between humans, livestock and rangelands), which are steps towards SRM. Furthermore, decision-makers and policy-makers should not only focus on multiple alternatives, but also pursue a set of supportive strategies essential for enhancing livelihood resilience. If the goal is SRM, a balance between humans, livestock and rangelands is considered essential, followed by a set of livelihood alternatives and some supportive strategies should be considered.

All of the livelihood alternatives are affected by the livelihood capital. Furthermore, they need to be enhanced by suitable PIPs, and the vulnerability contexts influencing them must be well understood (DFID 2001; Khedrigharibvand *et al*. 2015). While livelihoods are embedded at the heart of SRM on a regional scale (e.g. in the Bazoft region), households should be considered as the smallest economic unit; by enhancing livelihoods, approaching SRM would be accelerated. To achieve sustainable livelihoods, while the focus should be directed at the household level, livelihood alternatives should be enhanced by the livelihood criteria. Eventually, the livelihood alternatives should be maintained at the desirable status quo or transferred into desirable status in the future. Since there are various rangeland users' livelihoods in the Bazoft region, all the livelihood alternatives considered might be possible, and lead to positive outcomes. Thus, policy needs to address sustainability through such diversified livelihoods activities.

The implication of decision-making techniques for SRM

Although the application of the AHP-TOPSIS approach has been recognised in the literature, little understanding has been given to its applicability in the rangeland management domain and livelihood issues. Soltanmohammadi *et al*. (2010) applied the AHP-TOPSIS approach to determine post-mining land-use, which resulted in the suggestion that industrial land-use was the most suitable. Moreover, Ahmadi Mirghaed *et al*. (2013) applied the AHP-TOPSIS approach to evaluation of the environmental capability of the land, and developed a range of management plans. Comparing the results of this study with those of the previous studies revealed that, while the same processes were considered in all case studies, the AHP-TOPSIS approach was a valid approach to identifying and selecting appropriate alternatives. Indeed, through the combination of the AHP and the TOPSIS, nine alternatives were evaluated based on their performance against the 55 decision criteria. Other techniques of MADM can be applied and the outputs can be compared with the current results.

In our case, each individual decision-maker assigned a weight to each criterion/alternative. However, to make an integrated and informed decision, it was considered beneficial to form a group of decision-makers so that, for any applications of the MADM techniques, the criteria and alternatives for decision-making were provided in advance by a team. Thus, in order to simplify decision-making activities, to make effective decisions, and to solve real-world problems, it was essential to apply an integrated group decision-making procedure (Shih *et al*. 2007). In line with this, the applications of group decision support systems have been developed and expanded in various study areas (Shih *et al*. 2007; Yue 2011). Regarding the application of the AHP-TOSIS approach here, not only were livelihood alternatives accompanied by a hybrid multicriteria group decision-making approach, but this was the first study to explore its use in the context of SRM. Concerning its applicability in dealing with the livelihood alternatives, this approach (i.e. the hybrid multicriteria group decision-making approach) could be introduced as a way forward for approaching SRM.

In considering the uncertainty related to the respondents' preferences, Mendoza and Martins (2006) recognised sensitivity analysis as a deterministic approach that reduced uncertainty in the judgments concerning the weights of the criteria. MADM techniques such as ELECTRE and PROMETHEE, as well as the AHP-Entropy-TOPSIS approach, have been proposed for dealing with uncertain judgements (Mendoza and Martins 2006; Jalalifar *et al*. 2009; Khedrigharibvand *et al*. 2017). This study applied the sensitivity analysis to reducing uncertainty in judgements. Although criteria weightings were considered very important, if respondents' preferences varied, the weightings could become diverse. Because of the experts' selection process, it was expected that sensitivity analysis would not indicate that the final decision would change significantly. As the results indicated from four scenarios, only

one had minor changes in ranking, and these were within only two alternatives. It was concluded that the values of the final alternatives (especially, the most and least) did not change significantly after the sensitivity analysis. Thus, decision-makers were not asked to rethink their decision or to adjust the structure of the model.

Conclusion

To come up with a livelihood model for SRM, the experts ranked the criteria and livelihood alternatives. The criteria weightings were assigned using the AHP technique. The livelihood alternatives that were considered potentially suitable for a study of planning for SRM were ranked using the TOPSIS. At the end, a livelihood model was extracted. The model visualised the consequences of appropriate and/or inappropriate livelihoods for SRM. This study concluded that all the livelihood alternatives, including the highest and lowest rankings, are important for approaching SRM at the Bazoft region. The study suggested that the livelihood alternatives with the lowest values (i.e. traditional/mobile pastoralism and pastoralism through mitigation) should still be considered in planning for SRM, and that governments, institutions and people themselves should be responsible for supporting the livelihood alternatives (through supportive strategies) (Khedrigharibvand *et al*. 2015). However, the potential of each region for the alternatives with the highest values should be explored as a priority. This implies that more supports and investments should be allocated for the most appropriate alternatives.

There was a clear and close relationship between livelihood alternatives and income source, water, and security. While conflict, misdistribution of rainfall, and heavy snow were considered to be the lowest value factors, it appeared that there were still many criteria which should be addressed. In response to changes and transformations, people will inevitably tend to settle in pastoral regions, but the criteria significantly affecting their livelihood should still be considered. Criteria such as job opportunities and water were deemed important, and awareness of them was high. Regarding the most appropriate alternatives, developing non-resource-based livelihoods can greatly reduce pressure on natural resources, and can create new job opportunities and prevent unemployment. Addressing these criteria can stabilise the population of each area, while creating a balance between humans, livestock and natural resources. In considering these criteria, this research demonstrated that selecting from livelihood alternatives was a complex and complicated decision. Thus, designing effective programs and policies for achieving SRM within a livelihood policy framework required the prioritisation of appropriate livelihood alternatives, while considering influential criteria and involving different stakeholders.

The fundamental assumption behind the livelihood policy framework was that to achieve SRM, a set of appropriate livelihood alternatives should be promoted. In other words, SRM can be realised if appropriate livelihood alternatives are available. In this study, livelihood alternatives were introduced to the respondents, and they were asked to rank their appropriateness according to both the region's potential, and their preferences. This approach, where several alternatives instead of just one option for regional sustainable development are considered, has policy implications, both in general and for SRM in particular. It should be mentioned that according to the case study under consideration, all alternatives should be promoted. However, for other case studies (i.e. other regions), due to the different conditions, ranking of the livelihood alternatives would have different outputs.

Research must focus on the suitability and profitability of livelihood alternatives in order to make an informed decision, thus identifying alternatives feasible for people and beneficial to the environment. Concerning mobile pastoralism, if it is still profitable and suitable (although not dominant in the region), it may be pursued by people who could depend solely on livestock for their livelihood. Therefore, it should be maintained as an appropriate livelihood alternative, and be considered in planning for SRM. However, it should be reinforced by supportive strategies to make it more resilient. Accordingly, the livelihood alternative with the lowest score (i.e. traditional/mobile pastoralism) might be appropriate in terms of some beneficial issues (e.g. rangeland productivity and biodiversity). Thus, a lower rating did not necessarily imply that the alternative was not important. Rather, fewer people may be interested in it, or the potential of the case study may be too low to develop and be promoted. Consequently, in development planning, such alternatives should be considered, and those who were willing to continue such a way of life should be provided with the required relevant services. According to the regional conditions and public interest, alternatives with a higher score were, currently, those whose development potentials were the main alternatives being explored in the region. However, in other case studies elsewhere, sometimes the results obtained might be different. It was concluded that multicriteria decision support systems and livelihood systems are both dynamic, varying according to the circumstances. Livelihood alternatives with the lowest scores in some case studies may be appropriate and workable elsewhere. Thus, it is essential to consider all livelihood alternatives in order to make an informed decision regarding integrated planning for SRM.

The approach presented here (AHP-TOSIS) is suitable for policy-makers and rangeland managers when evaluating livelihood alternatives during rangeland management planning. Moreover, the applications of the AHP-TOSIS approach can be assessed under future scenarios for SRM planning regarding the supportive strategies considered likely to enhance the livelihood alternatives. In this study, the deterministic approach of sensitivity analysis was applied to minimise the uncertainty in the judgements concerning the weights of the criteria. Some scenarios were developed in which three main criteria followed by the global weights were changed to see the effect of the changes on the final rankings of the livelihood alternatives. Future studies could consider other scenarios, including changing the criteria at the second and third levels, or skipping one or more experts randomly.

For assessing uncertainty in judgements, further research can examine other techniques such as ELECTRE and PROMETHEE. These two techniques are classified in outranking methods. Furthermore, in addition to sensitivity analysis, entropy-AHP-

TOSIS can be applied, given that it includes a combination of both objective (entropy) and subjective (AHP) methods, which lessen uncertainty.

Recognising the applicability of group decision support systems in dealing with decision problems, the group AHP-TOPSIS approach can be introduced as a way forward for solving decision problems in future studies. Furthermore, although multicriteria decision-making systems aim to make an informed and rational decision by considering input from a wide range of experts from different domains, future studies can assess the attitudes of different groups separately, not all together. The combination of the AHP-TOPSIS approach and a GIS tool can create an additional information source for examining the suitability of each alternative. Future studies can further apply a fuzzy AHP-TOPSIS approach in cases where uncertainty is due to imprecision and imperfect information, meaning that the outcome of the decision is ambiguous. In addition, it will be helplful to assess other MADM techniques that consist of hybrid approaches, including AHP-VIKOR, AHP-ELECTR and AHP-PROMETHEE.

Conflicts of interest

The authors declare no conflicts of interest.

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