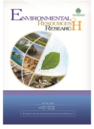

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Expert understandings on rangeland ecosystem services and their sustainable management (Atrak River Basin, NE Iran)

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Abstract
Over the last three centuries, worldwide improper utilization of rangelands has led to degradation of ecosystem services. Rangelands, like other natural resources used by humans, are embedded in complex socio-ecological systems. To determine how to better manage this important resource, we developed a rangeland ecosystem services model using the Driver-Pressure-State-Impacts–Response (DPSIR) conceptual model. The model was tested in a river basin in north-east of Iran. We asked 56 experts and 42 local land users on their perceptions of rangeland changes, causes of change, and possible actions to mitigate impacts using Delphi method, workshops, and questionnaires. A Multi-Criteria Decision Making method was used to evaluate the perceived interactions among the components of the DPSIR framework. Climate change and rangeland degradation were the most important pressures, leading to a decline in rangeland production, decreased vegetation cover, and land-use change. Experts and locals argued that forage and herbal species production, erosion control, and flood control were the most affected ecosystem services. They suggested the use of resistant plants, local training, and rangeland rest to manage these problems. The DPSIR framework was useful in developing a comprehensive insight for local people and managers on the social and ecological complexity of rangelands and the potential responses for coping with pressures.

Keywords: Rangeland management, MCDM, Pairwise comparison, Sustainable development.

Introduction
Rangelands are complex and dynamic ecosystems with specific characteristics such as low annual precipitation, variable temperatures (Hobbs et al., 2008), and native plant communities (McCollum et al., 2017). These ecosystems are the most extensive land cover type in the world providing 91% of grazing lands; and around 30% of people rely on rangelands for part of their livelihoods (Reynolds et al., 2007, Estell et al., 2012, and Reid et al., 2014).

Moreover, rangelands provide numerous ecosystem services, including the provision of material and energy needs, regulation and maintenance of the environment for humans and the non-material characteristics of ecosystems, affecting physical and mental states of people through cultural services (Haines-Young and Potschin, 2018). Overall, 20% of rangelands have been degraded, with another 12 million hectares being degraded worldwide each year (Brunson, 2014). Furthermore, the net primary production of rangelands might decline due to climate change (Boone et al., 2018). The mounting number of livestock and poor management often lead to overgrazing and degradation of rangelands and their ecosystem services (MA, 2005; Steinfeld et al., 2006, Khan and Hanjra, 2009). Rangeland management

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systems face various challenges, which may threaten rangelands' capacity to provide ecosystem services. For example, strict management prescriptions and rules that are not based on integrated management planning can be one of the causes of rangeland degradation (Briske, 2017).

Rangelands cover about 86.1 million hectares of Iran, of which 85% are located in arid and semi-arid regions (Azimi et al., 2013; Hajipour et al., 2016). Rangelands are often overused and degraded in Iran and would need better and more sustainable utilization and management (Mirdeilami et al., 2015).

The DPSIR framework offers a useful tool to understand these complex ecosystems and to develop sustainable management regimes by incorporating complex human-environment relationships (De Groot et al., 2010; Van Oudenhoven et al., 2012; Müller and Burkhard, 2012). The DPSIR framework was originally derived from the social sciences (Pressure-State-Response (PSR) model). Later, the Commission on Sustainable Development proposed the framework of Drivers-State–Response (DSR) in which pressures were altered by drivers to consider pressure roots, which typically emerge from people's needs and social conflicts. Eventually, the European Environment Agency (EEA) developed the Driver- Pressure-State-Impacts–Response framework, expanding both the PSR and DSR (EEA, 2001). The DPSIR framework is used to help analyze the relationships between the State (status and trends) of land resources; the direct Pressures on land resources; the Driving Forces (the indirect drivers that act on the Pressures); the Impacts (of changes in the State) on ecosystem services and people's livelihoods; and possible Responses from land users, policymakers, and other stakeholders (Borja et al., 2006; Atkins et al., 2011; Müller and Burkhard, 2012; Malekmohammadi and Jahanishakib, 2017).

The main objectives of this paper are to study:

- the status of rangelands in an arid region of north-east of Iran and to understand how rangelands respond to natural events and management actions;
- how we can facilitate management and decision making by determining the main and influential driving forces, pressures, environmental status, and the possible impacts affecting the functions and the subsequent ecosystem services, and, finally,
- the possible responses in the form of management suggestions.

Our study is the first using the DPSIR framework for better management of the semi-arid rangelands in Iran. We also used the Multi-Criteria Decision Making method to prioritize our responses and provide new insights to decision-makers to combine the perception and understanding of locals and experts.

Materials and Methods

Study area

Atrak River basin (about 26,430 km^2) is located between 54° 18′ to 58° 05′ eastern longitudes and 37° 8′ to 39° northern latitudes, covering most of the north Khorasan and part of Golestan provinces in north-east Iran (Figure 1) with a population of more than 1 million. Atrak River, which is 669 km long, is the fifth-longest river in Iran. The elevation of the Atrak river basin is about 2903 m in upstream and -22 m in coastal areas near the Caspian Sea. Mountains and plains account for 5.76% and 95.23% of the area, respectively. Precipitation ranges from about 200 mm in the northwestern parts to 750 mm in mountain areas; however, a large part of the watershed has a precipitation of 250-400 mm.

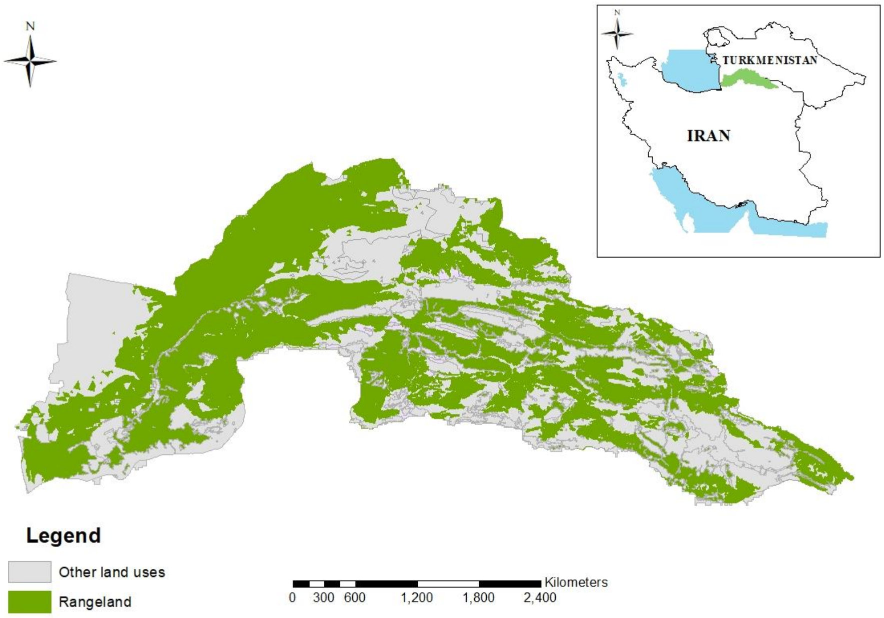

Figure 1. Study area: Atrak River Basin in north-east Iran

According to De Martonne classification (De Martonne, 1926), the climate of this area varies from arid to humid. The dominant soil types are Xerorthents in the eastern region; and towards the west, soils gradually change to Torriorthents, Haplosalids and finally to Aquisalids in the west, where the groundwater table is near the soil surface (Masoodi et al., 2017). Although 60% of the Atrak river basin is covered by rangelands, only about 20% has good quality (Figure 2) (Water and Wastewater Affairs, 2010).

(a) (b)

Figure 2. Rangelands of the Atrak River Basin: a) flat saline pastures dominated by *Halocnemum strobilaceum* and grasses near Gorgan used as winter pastures; b) pastures in the mountains with sparse *Juniperus communis* and *Carpinus orientalis* trees, used in summer

Figure 3 shows the status of the rangelands in study area. The area has 16 rangeland types. *Artemisia aucheri* and *Artemisia sieberi* are the dominant species in the rangeland. Other species, such as *Astragalus, Acantholimon, Salsola, Stipa, Salicornia, Poa, Hordeum* can also be dominants in some rangeland types.

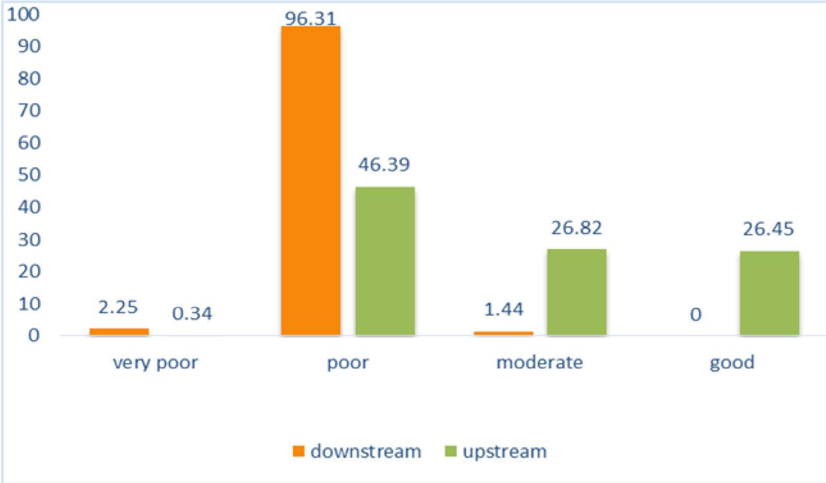

Figure 3. Status as present quality compared to potential of rangelands in Atrak River Basin based on Water and Wastewater Affairs (2010)

Physiographic and ecological conditions such as differences in topography, precipitation and phenology of vegetation divide the Atrak rangelands into two main groups. Winter rangelands are located in downstream areas and exploited for about 6 months a year; nevertheless, these rangelands do not meet the needs of livestock for forage, herders need to provide extra fodder in winter, so these rangelands are used mainly for breeding and protection of livestock from extreme weather conditions. Summer rangelands are located in mountainous regions and are exploited for a maximum of 110 days, approximately from April 20 to August 10 (Water and Wastewater Affairs, 2010). About 63% of people in this region are living in rural areas and most are farmers and pastoralists. Kormanj nomads are one of the most important pastoralists. Each year they visit parts of east watershed (North Khorasan Province) as a summer rangeland. Kormanj nomads arrive at winter rangelands in Golestan Province in early November and stay there until early May. The nomadic community (Kurds and Turkmens) benefit from about 370,000 ha rangelands in the middle and west of Atrak river basin. Sheep and goat are the most common livestock with a population of about 1.0 -1.5 times more than the capacity of forage production (Salmanmahiny et al., 2013; GNWM, 2015). Therefore, heavy and untimely grazing, and lack of proper management principles are the important issues to be investigated in this basin.

Data collection and analysis

Randomly selected pastoralists and nomads were subjected to questionnaires using the Delphi method. Afterwards, the expert and local perceptions were solicited from 98 respondents using the questionnaire. The list of pressure types was elicited from the questionnaires (Table 1). The importance of the impacts (ecosystem services) was estimated based on their effect on states using the MCDM technique (Table 2). Then, management suggestions were developed by a selected group of experts, indicating which ecosystem services could be managed by these responses.

Table 1. List of DPSIR elements for rangelands of Atrak Basin; based on expert, local knowledge and literature

D	P	S	I	R
Environmental factors	• Climate change (decrease in precipitation, precipitation in inappropriate season, increase of temperature) • Dust increase	• Decline in rangeland productivity • Drought • Decreased vegetation cover	• Increase of erosion • Lack of fresh water for livestock and herders • Increase of flood • Lack of forage and herbal species	• Rangeland rehabilitation and restoration by plants that are resistant to salinity and drought • Changing the time of entry and exit of livestock according to the phenological stages of the plants • Closing some dams or dam removal
Management or Policy Factors	• Deep and shallow well drilling and over-exploitation of groundwater • Weakness of natural resources management • Lack of clear and well-defined rules • Organizational budget shortage • Lack of training and educational programs • Inattention to local knowledge	• Drying springs • Severe aquifer loss • Inappropriate time of entry and exit of livestock in rangelands • Weakness to implement integrated and costly projects • Poor implementation of range management projects	• Changes in water nutrients • Reduction of biodiversity • Economic problems and poverty of local communities	• Integration of local knowledge in using rangeland • Temporal fencing and resting of rangelands • Rewriting the rules and increasing the organization budget • Capacity building for nature tourism and ecotourism considering the potential of the region • Providing more training classes and informing stakeholders about the use of natural resources
Social and cultural factors	• Lack of sense of ownership • Low level of literacy and awareness • Inappropriate methods for utilizing rangelands • Rangeland degradation for ownership	• Overgrazing • Reduced cover of palatable species and increased cover of invasive species • Disagreement of herders • Land-use change	• Increased erosion • Reduction of Natural heritage • Reduction of tourism • Reduction of aesthetic views	• Expansion of exploitation of sub-products and medicinal plants • Beekeeping • Controlling and preventing rangeland degradation by government and NGOs

Table 2. Importance of pressures based on expert ranking and number of state categories affected in the Atrak semi-arid Iranian rangelands

Pressure	Expert ranks	No. of states affected by one pressure	Final score (Log)
Climate change	12	7	1.92
Rangeland degradation for ownership	11	6	1.81
Inappropriate methods for utilizing rangelands	10	6	1.77
Weakness of natural resources management	9	6	1.73
Lack of clear and defined rules	8	4	1.50
Lack of training and educational programs	7	4	1.44
Deep and shallow well drilling and over-exploitation of groundwater	6	4	1.38
Dust increase	4	4	1.20
Lack of sense of ownership	3	4	1.07
Low level of literacy and awareness	5	1	0.69
Lack of organizational budget	2	2	0.60
Inattention to local knowledge	1	2	0.30

Figure 4 illustrates the overall framework of the research process. The framework of Müller and Burkhar (2012), which linked DPSIR and ES, was used in this study. First, the authors and four selected rangeland experts selected a list of potential ecosystem services specific to the study area based on the Common International Classification of Ecosystem Services (CICES) (Haines-Young and Potschin, 2018).

Figure 4. Overall framework of the research process

The same group of experts selected the drivers, states and impacts that were relevant to the rangelands during three meetings based on literature (Ahmadpour et al., 2016; Mirdeilami et al., 2015 and Khoshfar et al., 2017) and their own experiences. We used Delphi method to determine the categories; a brainstorming exercise was held to determine the first set of elements; then the most important ones were selected by scoring, resulting in a list of 22 elements comprising 12 state variables and 10 impact types. According to drivers, the elements were divided into three groups including environmental factors, management or policy factors, and social and cultural factors. These elements (states and impacts) were used in the questionnaire (Tables in Appendices 1and 2).

In the second phase, the questionnaires were distributed among academic experts (15), government experts (30), academics with rural background/livelihood experiences (11), present and former livestock owners and herders (19), nomads (16), and farmers (19). Altogether, 98 questionnaires were completed. The average age of respondents was 41.5 years; more than half had a university degree, and some just had a high school degree; 24 were females and the rest were male. The respondents were asked to highlight the importance of each element by using a Likert scale, a reliable point scale for valuation and measuring stakeholders' ideas and perceptions in environmental studies (Schmidt et al., 2017). The reliability of the questionnaires was determined based on Cronbach's alpha coefficient (a= 0.7), showing a high degree of internal coherence and consistency.

In the next step, four experts and six academics with a background of living in Atrak Basin were asked to estimate the effect of pressure types on state variables, and the effect of state variables on impact types. They provided their understanding and how many categories were affected by a certain type (an example is provided in Table A.3). To quantify the indicators and estimate their importance in the local human-environment system, a Multi-Criteria Decision Making (MCDM) technique was used (Tables 2 to 4).

This technique aims to evaluate, assess, and select alternatives from the best to the worst under conflicting criteria concerning decision-makers' preferences (Abdel-Malak et al., 2017). The frequency and score were multiplied to get the final evaluation score.

In the final step, the authors and 10 selected rangeland experts as well as academics with a background of living in Atrak Basin, offered suggestions and responses for the local community and government based on their knowledge and experiences, to improve rangeland ecosystem services status and indicated how many impacts (ecosystem services) could be managed by certain responses.

Results

We found three main driving forces including environmental factors, management or policy factors, and social and cultural factors (Table 1). Reduced vegetation cover, drought, and land-use change with scores 3.5, 3.34, and 3.15, respectively, were the most important state variables. Forage and herbal species production (3.3), freshwater for livestock and herders (3.16), and erosion control (2.97) were the most significant perceived impacts.

Climate change, rangeland degradation for ownership, and inappropriate methods for utilizing rangelands were identified as the most significant pressures in the rangelands of the region (Table 2). Local respondents expressed concern about utilizing rangelands, stating, "*The most important problem is depletion of nature*". The most affected rangeland ecosystem services were forage and herbal species production, erosion control, and flood control according to the experts and academics (Table 3). In terms of flood and erosion control, one herder noted: "*Our life is dependent on water and water flow depends on us*" and another one stated that "*in the past, we were just worried about water, but now we should also be concerned about soil, I hope it rains soon*".

Table 3. Importance of impact types based on expert ranking and their impacts on state variables

Impact (ecosystem services)	Expert ranks	No. of states that affect an impact type	Importance Final score (Log)
Forage and herbal species production	10	8	1.90
Erosion control	9	8	1.85
Flood control	8	8	1.80
Biodiversity	6	6	1.55
Freshwater for livestock and herders	7	5	1.54
Nutrient retention and Water quality	5	3	1.17
Natural heritage	3	5	1.17
Tourism	4	3	1.07
Economic problems and poverty of local communities	2	5	1.00
Aesthetic views	1	4	0.60

Rangeland rehabilitation and restoration by plants resistant to the current situation, more training classes and information on the use of natural resources, and temporal fencing and resting of rangelands were the most important suggested responses that could potentially help to improve the current rangeland situation (Table 4).

In Table 4, score of ecosystem services were determined from Table 3. Then, we asked academics and experts about the impacts of responses on ecosystem services. For instance, rangeland rehabilitation and restoration can affect forage and herbal species production, erosion control and etc. As such, the total score of this response will be the combination of score of the affected ecosystem services. These scores and the quantity of affected ecosystem services by one response were multiplied and the log of that was considered as the final score.

Table 4. Importance of various major responses to managing pressures for better provision of ecosystem services in the Atrak Basin, NE Iran

Response \ Ecosystem services	Freshwater yield	Forage and herbal species production	Erosion control	Flood control	Nutrient retention and water quality	Biodiversity	Economic problems and poverty	Natural heritage	Aesthetic views	Tourism	Total score of responses	No. of ES affected by one response	Final score
Ecosystem services score (from Table 3)	1.54	1.90	1.85	1.80	1.17	1.55	1.0	1.17	0.60	1.07			
Rangeland rehabilitation and restoration by plants that are resistant to current situation		1.90	1.85	1.80	1.17		1.0		0.60	1.07	9.39	7	1.81
Providing more training classes and informing stakeholders on the use of natural resources			1.85	1.80	1.17		1.0	1.17		1.07	8.06	6	1.68
Temporal fencing and resting of rangelands		1.90	1.85	1.80		1.55	1.0				8.1	5	1.60
Controlling and preventing rangeland degradation by government and NGOs			1.85	1.80			1.0	1.17		1.07	6.89	5	1.53
Changing the time of entry and exit of livestock according to the phenological stages of the plants		1.90	1.85			1.55	1.0				6.3	4	1.40
Rewriting the rules and increasing the organizational budget			1.85	1.80	1.17					1.07	5.89	4	1.37
Reducing operation of some dams or their removal	1.54		1.85	1.80					0.60		5.79	4	1.36
Expansion of utilizing by-products of rangelands		1.90					1.0	1.17		1.07	5.14	4	1.31
Integration of local and formal knowledge in using rangeland	1.54						1.0	1.17		1.07	4.78	4	1.28
Capacity building for nature tourism and ecotourism considering the potential of the region								1.17	0.60	1.07	2.84	3	0.93
Beekeeping						1.55					1.55	1	0.19

Discussion

According to the results, climatic and management factors were the key pressures. "Climate change" led to droughts and low precipitation in the last decade and made difficulties for nomads and their water resources, so they had to use Atrak river water directly (Mianabadi et al., 2015). This period, followed by a year with torrential rains and floods (2019), created other problems such as destruction of rangelands and villages. Additionally, lots of rangelands are transformed into farmlands due to the unemployment of people (Salmanmahiny, 2013), referred to as rangeland degradation for ownership.

These pressures are the reasons for current states such as the decline in rangeland production, vegetation reduction and land-use change. These states were the ones that had the most impact on the lives of the locals and also changed significantly. In the rangelands of the developing countries, vulnerability is higher and the impact of these states is likely to be substantial (de Leeuw et al., 2016). As illustrated above, there were 13 types of impacts and the most important ones were related to forage production, water yield, and soil erosion. Due to the vegetation reduction in the area and land-use change, the amount of runoff in the area increased and led to increased soil erosion. However, erosion is lower in good quality rangeland which is covered by shrubs and lush green hills. The dominant bedrock of these rangelands is loess. Although these soils are one of the most fertile soils in the world, they can be prone to erosion (Catt, 2001; Hossienalizadeh et al., 2018). Furthermore, overgrazing in some parts led to increased bare land and reduced forage in the study area (Hosseini et al., 2014; Azimi et al., 2013).

The average annual rate of erosion in Iran is around 1.3 times more than that of Atrak Basin, but it is still higher than the annual average soil erosion of the world (GNWM, 2015). Consequently, some responses and solutions have been suggested to address the problems and improve the current status of rangelands and their ecosystem services in the Atrak Basin. The most effective response suggested is the rangeland rehabilitation and restoration by the plants resistant to the current situation. Considering the physiological and edaphic conditions of the area, some species such as *Festuca ovina*, *Ferula gommusa*, and *Agropyron trichophorum* in the uplands and other species such as *Atriplex canescens* and *Nitraria schoberi*, which are suitable for saline habitats, are suitable to be planted in the downstream to rehabilitate degraded rangelands (FRWO, 2018). Another important response is "offering more training classes and informing local people about the use of natural resources". Some participatory management plannings, such as those suggested by Robinson and Nganga (2018), could be used to build constructive relationships among stakeholders and managers at higher levels.

Temporal fencing and resting of rangelands is a convenient and feasible way to manage these rangelands. Nevertheless, these methods are not so effective in the short-term (GNWM, 2015). One of the advantages of our method (combining ecosystem services with the DPSIR framework) is that we can understand the role and impact of stakeholders on ecosystem services. In addition to the supply of ecosystem services, the demand for these services would be evaluated indirectly as well (Harris et al., 2010; Rounsevell et al., 2010). The conceptual framework used in this paper, could provide a comprehensive and appropriate insight for local people and managers about social and ecological concepts of rangeland ecosystems. However, this method is complex and has various phases, making it a little difficult to follow. Also, each DPSIR component can have many elements, and the more elements we consider the more complex the results will be. Local people's opinions will change due to changes in environmental and political situations, and decision-making needs to be re-evaluated through time (as the system is dynamic). Thus, the results and conclusions of this research may need to be adjusted in the future.

We could take more comments and distribute more questionnaires, if we had more time. Nearly a quarter of the questionnaires were filled in by women and if this number were higher, presumably we would have more information about the importance of medicinal plants and other areas about which women are more familiar.

Summary and Conclusion

Assessment of rangeland ecosystem services including the provisioning, regulating and cultural services under different climatic conditions, were performed for Atrak river basin. Nowadays, these ecosystems face various challenges such as climate change, and purely ecological research approaches are not enough to tackle these challenges. Socio-ecological models are needed, which not only involve cultural and biological dimensions in the decision-making process but also could provide diverse and resilient suggestions and solutions to help adapt to changing situations. In this paper we modeled rangeland ecosystem services using DPSIR and MCDM. Overall, forage and herbal species production, erosion control, and flood control were the most affected ecosystem services in Atrak river basin. This study will be extended to map and visualize ecosystem services in combination with InVEST model which provides a spatial pattern to decision makers and help them to understand and prioritize importance of ecosystem services. The conceptual framework in this study can be used for sustainable management in arid and semi-arid ecosystems.

Acknowledgments

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