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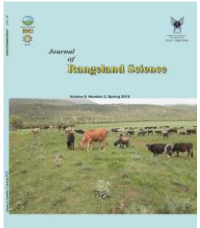

Research and Full Length Article:

Assessing Impact of Anthropogenic Disturbances on Forage Production in Arid and Semiarid Rangelands

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Abstract. Forage is one of the main products of rangeland ecosystems, which is threatened by different anthropogenic disturbances. This study was conducted to assess the impact of urbanization, rural development, agriculture extension, road construction and industry on forage production in an arid and semiarid rangeland using InVEST habitat quality model in spring 2018. In 14 rangeland types, thirty 2×1m quadrats were randomly located to measure forage production using double sampling method. Habitat quality was mapped based on the relative impact of each threat, the relative sensitivity of each rangeland type to each threat and the distance between the habitats and threats. The results showed that there is a significant relationship between rangeland condition and habitat quality ($p<0.01$). Habitat quality varied between 0 and 0.77 across the study region. Habitats with low quality comprised half of the total area (51%) where anthropogenic factors were concentrated. Habitat quality was significantly correlated with forage production ($p<0.01$). The dominant species *Artemisia sieberi* was replaced by invasive species *Salsola brachiata* and forage production was decreased to the minimum 21 kg ha^{-1} in habitats with low quality. Rangelands with medium habitat quality produced two and a half times more forage than the ones with low habitat quality and half of the ones with high habitat quality. *Astragalus gossypinus* and *Artemisia aucheri* in high habitat quality areas supplied the highest forage production (216 kg ha^{-1}). Since the large areas of agricultural lands are in the low quality habitats, agriculture can be considered as the main threat of forage production. Hence, the extension of agricultural lands with short-term benefits should be controlled in order to improve ecosystem services which have long-term benefits in sustainable development.

Key words: Ecosystem services, Habitat quality, InVEST

Introduction

Rangelands cover more than half of globe's area and provide many ecosystem goods and services (ESs) such as forage production, water yield, cleansing the atmosphere, biodiversity and genetic reserves, production of medicinal plants and industrial plants with use in food production, nature tourism, recreational activities and so on (Eskandari *et al.,* 2008). ESs are the benefits that human can obtain from the natural ecosystems (Daily, 1997). Many of these services are essential for survival of the poor rural communities (Dougill *et al.,* 2010). Assessment of ESs can be considered as a tool that provides land managers with information to understand sustainable use of natural resources and to maintain the benefits of ESs for future generations (MA, 2005; Egoh *et al.*, 2012). In rangelands, the main provisioning service is forage supply for livestock production that accounts for 20% of total value of rangeland (Winkler, 2006). Forage is defined as annual growth of grazed plants or ecosystem energy during a season or a year (Odum, 1971). The potential food for livestock and wildlife is defined as forage including herbaceous and woody sources (Coulloudon *et al.*, 1999). Forage represents primary production of the ecosystem and can greatly affect local population's economic and social situation (Yeganeh Badrabadi *et al.*, 2015). Rangelands are widely used for grazing and provide income for nearly 3 million people through forage and livestock production (Badripour *et al.,* 2006). Forage production is reduced not only by overgrazing and mismanagement but also by other human actives threatening rangelands habitat quality.

Anthropogenic factors such as urbanization, construction and agriculture are increasingly threatening the ecosystems services (MA, 2005). There are many studies that show the impact of different human activities on ecosystem goods and services. Eigenbrod *et al.* (2011) studied the relationship between urbanization and ecosystem services and concluded that urbanization declined the supply and use of ecosystem service function. Human activities increase erosion through overgrazing, cutting down trees and converting natural land into agriculture (Shayan *et al.,* 2013). Based on the citizens' opinions, wildfires and land use change for expansion of urban areas are the most important threat to rangeland ecosystems (Kyriazopoulos *et al.,* 2013). Shoyam and Yamagata (2014) revealed changes in land-use affected the provision of ESs. Mosavi *et al.* (2015) examined the density and diversity of plant species at different distances from the cement factory. Their results showed the impact of the distance from the plan on vegetation. Wan *et al.* (2015) stated that urbanization has either positive or negative effects on the ecosystem over time but negative effects are more due to shrinking arable land, growing developmental constructions, and increasing industrial pollution. Tardieu *et al.* (2013) also indicated that developmental projects cause ESs loss and ecosystem types differently respond to human activities.

Loss and degradation of natural habitats are the primary causes of declining habitat quality (Fuller *et al.,* 2007) and habitat quality is a proper proxy to assess anthropogenic factors impact on ecosystems (Tallis *et al.,* 2011). Habitat quality in The Integrated Valuation of Ecosystem Service and Tradeoff (InVEST) model has currently been used to assess how human activities can alter ecosystems (Egoh *et al.*, 2012). In most studies, the effect of one or more anthropogenic disturbances on ecosystem properties has been assessed. Terrado *et al.* (2016) assessed the impact of anthropogenic factors (agricultural, urban, mining and road) on the quality of the habitat of the Mediterranean ecosystems in Spain using the InVEST model. Sallustio *et al.* (2017) used the

InVEST model to investigate the human impact on biodiversity in order to identify areas with higher priority for conservation. The InVEST model has the capability to assess the integrated effects of several anthropogenic disturbances on ecosystems. In this model, sensitivity of habitat types to various threats is considered as the input data. Habitat quality refers to the ability of the ecosystem in providing conditions appropriate for individual and population persistence (Johnson, 2007). InVEST model can provide information related to the ecosystem health which can be used for ecosystem management. In this model, habitat quality is considered a continuous variable ranging from low to medium and high quality which depends on a habitat proximity to human land uses and their intensity. Habitats with high quality as biodiversity hotspots are relatively intact and have the highest value for conservation plans (Tallis *et al.*, 2011).

Identifying the loss of ESs associated with anthropogenic disturbances is currently a major challenge to the improvement of environmental planning (Geneletti, 2013; Tardieu *et al.*, 2013). Humans should balance conservation with development needs. It is difficult to strike such a balance with inadequate information about the consequences of our decisions on land use and management. Forage production is very sensitive to degradation caused by improper management (Kohestani and Yeganeh, 2016).

This study is aimed to use InVEST habitat quality as a suitable model for considering the integrated effects of anthropogenic disturbances on habitat quality of rangeland ecosystem and assessing forage change under anthropogenic disturbances.

Materials and Methods

Study areas

The study area is a part of Negar rangelands with 2392 km^2 area (56° 10′ to 56° 58′ E and 29° 33′ to 30° 5′ N) located in the Kerman province, southeastern Iran (Fig. 1). The study area is characterized by hot summers and cold winters. The area receives about 206 mm annual precipitation which is highly variable. Spring precipitations occur in April and May but most of precipitation comes during autumn and winter. The area elevation ranges from 1885 to 3738 m. Agricultural areas currently cover 17% of the basin and consist of mostly irrigated farms in the plains and rain-fed agriculture in higher elevation areas. However, the basin is currently experiencing both economic growth and urbanization. Urban and industrial areas comprise about 2 % of the basin. Overall, rangeland is the main land use in the region.

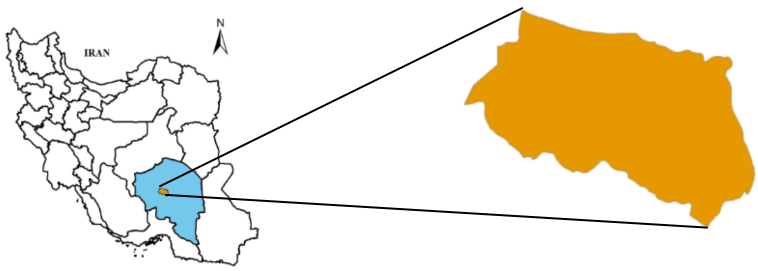

Fig. 1. The map of study area.

Field sampling

Forage production

Thirty 2×1 m quadrats were used to estimate forage production through double sampling method in each rangeland type (14 rangeland types, Table 3) in spring 2018. The sampling and quadrat sizes were based on sampling size equation (Mesdaghi, 1995) and minimal area method (Mueller and Ellenberg, 1974). In this method, plant production is visually estimated in each quadrat. Furthermore, plants production is measured by clipping and weighing in every five quadrats. Then, a regression analysis was used to compare the estimated and harvested values of plant production in the calibration quadrats.

In order to calculate the allowed forage, it is needed to determine plants palatability and proper use factor. Classification of plants palatability was recorded by direct observation of the grazing behavior of livestock in the field during sampling, knowledge gathered from nomadic peoples and literature review. Then, 50% of plants in Class I, 30% of plants in Class II and 10-15% of Class III plants were included in the calculation of allowed forage (Moghaddam, 1998).

Rangeland condition and trend and soil sensitivity to erosion are required to determine the proper use factor (Azhdari, 2009).

The rangeland condition was determined based on quantitative climax method, developed by the Soil Conservation Service (now Natural Resources Conservation Service) and rangeland trend (apparent trend) was determined by ranking soil and water criteria method (National Research Council, 1994).

Erosion Potential Method (EPM) was applied to determine soil sensitivity to erosion (Ahmadi, 2007). EPM use the following equation to calculate erosion severity (z):

$$Z = X_a Y (Ø + I^{1/2}) \qquad \text{eq.1}$$

Where X_a is land use coefficient, Y is soil sensitivity coefficient to erosion, Ø is erosion coefficient and I is the mean slope (Ahmadi, 2007).

Then, the proper use factor was estimated for each rangeland type.

InVEST model

Urban, industrial and rural regions, agricultural lands, roads and dirt roads were considered as anthropogenic disturbances by visiting the study area and Google Earth. Raster threat map was produced based on 0 (absence of threat) and 1 (presence of threat). Land units were determined using DEM, aspect-slope, aspect and geology maps in the area. In each unit, rangeland types were considered as habitat types.

In InVEST model, the sum of the total threat's level in a grid cell x of habitat type j provided a degradation score Dxj for the cell (Eq. 2) that was then used along with habitat suitability to compute a score for habitat quality Qxj (Eq. 3).

$$D_{xj} = \sum_{r}^{R} \sum_{y=1}^{y} \left(w_r / \sum_{r=1}^{R} w_r \right) r_y i_{rxy} s_{jr} \qquad (2)$$

Where y refers to all grid cells on raster map and Y_r indicates the set of grid cells on r's raster map and thus, W_r is the degradation source's weight (Tallis *et al.*, 2011). S_{jr} indicates the sensitivity of habitat type j to threat r that was estimated based on relative change in the Simpson Index between habitat type with threat and without threat.

$$Q_{xj} = H_j \left(1 - \left(D_{xj}^z / D_{xj}^z + k^z\right)\right) \qquad (3)$$

Where H_j is the relative habitat suitability score. We used the Simpson Index for each habitat to determine H_j, z and k are scaling parameters.

Statistical Analyses

In order to achieve forage production and habitat quality values between different rangelands types (habitat types), data were analyzed using Analysis of variance (ANOVA) followed by post hoc LSD (Least Significant Difference) test. Spearman and Pearson correlation was used to assess relation of habitat qualities with rangeland condition and forage production, respectively. All statistical analyses were done using IBM SPSS Statistics for Windows, Version 24.0.

Results

Habitat quality was mapped using InVEST model. Habitat quality values varied between 0-0.77 and were classified to three classes: low, medium and high quality (Fig. 2). In order to introduce the main threats in the region, the relative areas of all threats in each habitat quality class are presented in Table 2. In areas with low habitat quality, 23.2, 5.7, 2.7, 1.7 and 0.86% of total area were respectively occupied by agricultural lands, urban and rural zones, road and dirt road. In areas with medium habitat quality, agricultural lands, industrial and rural zones, road and dirt road covered 7.8, 1.76, 3.2, 1.1 and 0.58% of total area, respectively. In areas with high habitat quality, 3, 5.4, 0.89 and 0.61 % of total area were occupied by agricultural lands, rural zones, road and dirt road, respectively (Table 2).

Results indicated that there were 14 rangeland types in study area (Fig. 3). Allowed forage was estimated based on plants palatability (Table 1) and proper use factor. There were significant differences among rangeland types in forage production and habitat quality values (Table 3). Rangeland type *Salsola brachiata- Artemisia sieberi* had the lowest forage production (21±5.9 kg ha^{-1}) and habitat quality value (0.17±0.04) in downstream basin. Rangeland type *Astragalus gossypinus-Artemisia aucheri* provided the greatest amount of forage production (216±45. 6 kgha^{-1}) and habitat quality (0.72±0.04) in upstream basin (Table 3). Spearman's correlation analysis revealed a significant relation between habitat quality and rangeland condition at 99% confidence level (Fig. 4). There was a significant relationship between habitat quality and forage production (Fig. 5).

Table 1. The plant species list in the study area with their palatability class.

Name	Family	Palatability class
Acantholimon scorpius	Plumbaginaceae	III
Acanthophyllum glandulosum	Caryophyllaceae	III
Achillea aurophora	Asteraceae	III
Aelleni subaohylla	Chenopodiaceae	III
Agropyron desertorum	Poaceae	II
Alhagi pseudalhagi	Papilionaceae	III
Anabasis aphylla	Chenopodiaceae	III
Annual Forbs	Different families	II
Annual Grasses	Poaceae	III
Artemisia aucheri.	Asteraceae	II
Artemisia sieberi	Asteraceae	II
Astragalus gossypinus	Fabaceae	III
Cousinia esfandiarii	Asteraceae	III
Echinops ritrodes	Asteraceae	III
Ferula assa-foetida	Apiaceae	II
Hertia angustifolia	Asteraceae	III
Hordeum violaceum	Poaceae	II
Noaea mucronata	Chenopodiaceae	II
Peganum harmala	Zygophyllaceae	III
Phlomis olivieri	Lamiaceae	III
Plantago lanceolata	Plantaginaceae	II
Poa bulbosa	Poaceae	II
Rheum ribes	Polygonaceae	III
Salsola brachiata	Chenopodiaceae	III
Scariola orientalis	Asteraceae	II
Stachys inflata Benth.	Lamiaceae	II
Stipa barbata	Poacea	III
Thymus fedtschenkoi	Lamiaceae	II
Trifolium pratense	Fabaceae	I
Ziziphora clinopodioides	Lamiaceae	III
Zygophyllum eurypterum	Zygophyllaceae	II

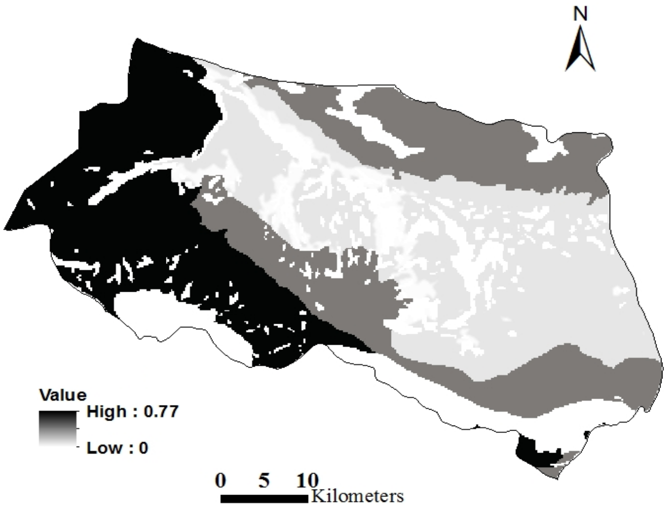

Fig. 2. Habitat quality map in study area.

Table 2. The relative areas of three habitat quality classes and relative areas of threats (agriculture lands, urban, industrial and rural regions, road and dirt road) in each class

Habitat Quality	Area%	Relative area of threat (%)					
		Agricultural Lands	Roads	Industrial zones	Urban areas	Dirt Roads	Rural areas
Low (0-0.22)	51	23.2	1.7	0	5.7	0.86	2.7
Medium (0.22-0.51)	24	7.8	1.1	1.76	0	0.58	3.2
High (0.51-0.77)	25	3	0.89	0	0	0.61	5.4

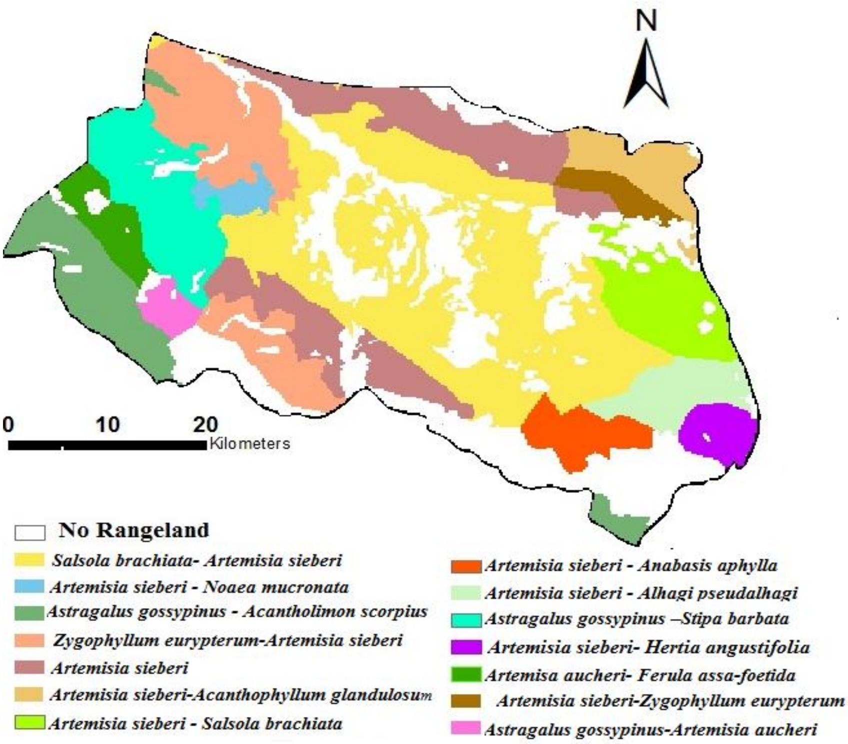

Fig. 3. Rangeland type map in the study area

Table 3. Different rangeland types in the region and their means compartion of forage production and habitat quality.

	Rangeland types	Area (ha)	Sensitivity to Erosion	Range condition	Range trend	Forage (kg.ha^{-1})	Habitat quality
1	*Salsola brachiata- Artemisia sieberi*	59131	S3	poor	negative	$21^{a}\pm5.9$	$0.17^{a}\pm0.04$
2	*Artemisia sieberi - Noaea mucronata*	2501	S2	fair	positive	$31.06^{ab}\pm4.4$	$0.22^{b}\pm0.09$
3	*Astragalus gossypinus - Acantholimon scorpius*	13783	S2	good	positive	$187^{ef}\pm40.8$	$0.65^{g}\pm0.05$
4	*Zygophyllum eurypterum-Artemisia sieberi*	21805	S1	good	positive	$199^{fg}\pm45.7$	$0.62^{fg}\pm0.07$
5	*Artemisia sieberi*	25174	S2	fair	positive	$88.6^{d}\pm6.8$	$0.43^{e}\pm0.05$
6	*Artemisia sieberi-Acanthophyllum glandulosum*	6840	S2	fair	positive	$92.4^{d}\pm12.13$	$0.39^{de}\pm0.06$
7	*Artemisia sieberi - Salsola brachiata*	11191	S3	poor	Negative	$37.1^{b}11.6$	$0.22^{b}\pm0.07$
8	*Artemisia sieberi - Anabasis aphylla*	5893	S2	fair	Positive	$85.3^{d}\pm8.2$	$0.39^{de}\pm0.09$
9	*Artemisia sieberi - Alhagi pseudalhagi*	7710	S2	poor	Negative	$58.6^{c}\pm29.1$	$0.26^{c}\pm0.08$
10	*Astragalus gossypinus –Stipa barbata*	15191	S2	good	positive	$211.4^{ghi}\pm31$	$0.65^{g}\pm0.05$
11	*Artemisia sieberi- Hertia angustifolia*	4053	S1	fair	positive	$98.4^{d}\pm5.8$	$0.39^{de}\pm0.08$
12	*Artemisia aucheri- Ferula assa-foetida*	5081	S2	good	positive	$178.3^{e}\pm40.7$	$0.59^{f}\pm0.12$
13	*Artemisia sieberi-Zygophyllum eurypterum*	3132	S1	fair	positive	$95.7^{d}\pm4.8$	$0.40^{e}\pm0.09$
14	*Astragalus gossypinus-Artemisia aucheri*	2390	S2	good	positive	$216^{h}\pm45.6$	$0.72^{h}\pm0.04$

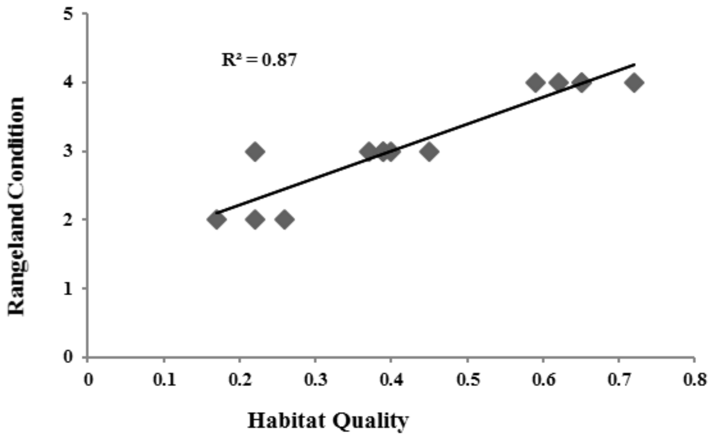

Fig. 4. Spearman correlation between rangeland condition and habitat quality values

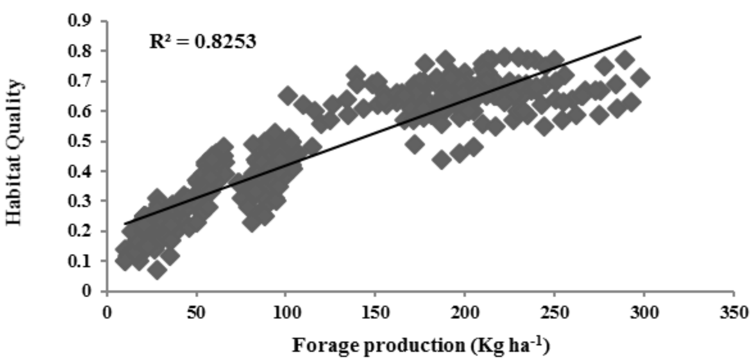

Fig. 5. Pearson correlation between forage production and habitat quality values

Discussion

Land degradation caused by anthropogenic disturbances results in reduction of habitat quality so that most ecosystems show at least some levels of habitat destruction (Fischer and Lindenmayer, 2007). Results indicated that low habitat quality was observed in downstream areas where anthropogenic disturbances were concentrated. A significant relationship was found between rangeland condition and habitat quality which affirms the results of model running. Habitat degradation has been considered to be the most important factor affecting the current decline of plant species and communities (Tikkanen *et al.,* 2007) with decreasing environmental fitness for a species growth and increased mortality and lower productiveness (Mortelliti *et al.,* 2010). Species may be lost as species in most cases are threatened by habitat degradation rather than completing habitat loss and fragmentation (Metzger *et al.,* 2009). The results showed that the dominant species *Artemisia sieberi* was replaced with invasive species *Salsola brachiata* in rangelands with low habitat quality. Invasive species are the significant threat to ecosystems and native plant diversity (Hassan *et al*., 2005). On average, abundance and diversity of native plant species decrease in invaded sites (Vilà *et al*., 2011). Ecosystems respond differently to land conversion due to threshold behavior (Swift and Hannon, 2010). Any damage or loss of ecological structure would affect the provision of ESs (Wan *et al.,* 2015). Results show that the rangeland types *Salsola brachiata- Artemisia sieberi*, *Artemisia sieberi - Noaea mucronata*, *Artemisia sieberi - Salsola brachiata* and *Artemisia sieberi - Alhagi pseudalhagi* provided the least forage among different rangeland types.

There was a significant correlation between forage production and habitat quality as forage production was increased on rangelands with medium and high habitat quality. *Artemisia aucheri- Ferula assa-foetida, Artemisia sieberi, Artemisia sieberi-Zygophyllum eurypterum, Artemisia sieberi-Acanthophyllum glandulosum*, *Artemisia sieberi- Hertia angustifolia* and *Artemisia sieberi - Anabasis aphylla* were rangeland types with medium habitat quality. These rangeland types had supplied forage two and half times more than the ones with low habitat quality. The rangeland types with high habitat quality including *Astragalus gossypinus-Artemisia aucheri*, *Zygophyllum eurypterum-Artemisia sieberi*, *Astragalus gossypinus –Stipa barbata and Astragalus gossypinus - Acantholimon scorpius* produced forage two times more than the ones with medium habitat quality. These rangeland types are located on high lands and have the capability to produce more forage due to better environmental conditions such as higher precipitation (Bayat *et al.,* 2016) and lower anthropogenic disturbances. Being far from anthropogenic disturbances helped these rangelands to maintain their capability to produce forage.

On rangelands with high habitat quality, dirt road and rural areas were the dominant anthropogenic threats. Pastoralism is the main occupation of rural people in these areas. Overgrazing is known as the main factor of land degradation in arid and semiarid rangelands (Mesdaghi, 1995) and livestock grazing is broadly associated with changes in ecosystem structure (Asner *et al.,* 2004). Our results showed that other anthropogenic disturbances especially agriculture caused more rangeland degradation than grazing in the study area. Cropland covered large areas in the regions with low habitat quality because agriculture is the only way for rural people to raise their income. Rangelands are converted into agricultural lands to meet food security needs (Butt et al., 2005). Concerns about future food security have risen with increasing population and consumption in developing countries (Bruinsma, 2011). However agriculture plays an important role in national economics of the country with supplying about 90% of the domestic food demands (Mesgaran *et al.*, 2017), but it has led to the reduction of rangelands habitat quality through rangeland ecosystem fragmentation and reduction of vegetation. Rangeland fragments are still threatened by pesticide and fertilizer from adjacent agricultural lands (Zulka *et al*., 2014).

In sustainable development, Wan *et al.* (2015) revealed that we cannot blindly pursue short-term economic interests with development urbanization, and ignore long-term benefits that ecosystems bring to us. We should continue to improve the protection of environment with controlling the scale of construction and agriculture extension. Rangeland health monitoring plans can be the best way to provide necessary information for land managers to potentially avoid irreversible degradation (Herrick *et al.*, 2005). Iran is currently experiencing unusual water shortage problems, it is essential to use certain modern agricultural practices (e.g. greenhouse farming and advanced irrigation systems) for supplying demands (Mesgaran, 2017). Scherr and McNeely (2008) recommended enhancing eco-agriculture policies to conserve and restore biodiversity and ESs as well as to improve local livelihood.

Acknowledgements

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ارزیابی تاثیرات آشفتگی‌های آنتروپوژنیکی بر تولید علوفه در مراتع خشک و نیمه‌خشک

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چکیده. علوفه مهمترین تولید اکوسیستم‌های مرتعی است که توسط عوامل آشفتگی‌های انسانی تهدید می‌شود. هدف این مطالعه بررسی تأثیر آشفتگی‌های آنتروپوژنیک(شهرسازی، توسعه روستاها، گسترش کشاورزی، جاده‌سازی و صنایع) بر تولید علوفه با استفاده از مدل کیفیت رویشگاه InVEST در مراتع خشک و نیمه‌خشک در بهار ۱۳۹۷ بود. در هر یک از ۱۴ تیپ مرتعی، سی قاب ۱×۲ متری برای اندازه‌گیری تولید علوفه با استفاده از روش نمونه‌گیری مضاعف به صورت تصادفی قرار داده شد. نقشه کیفیت رویشگاه بر اساس تأثیر نسبی هر تهدید، حساسیت نسبی رویشگاه به هر یک از تهدیدات و فاصله رویشگاه به تهدیدات تهیه شد. نتایج نشان داد که رابطه معنی‌داری بین وضعیت مرتع و کیفیت رویشگاه وجود دارد(p<۰/۰۱). کیفیت رویشگاه در منطقه مورد مطالعه بین ۰ و ۰/۷۷ متغییر بود. مناطق با کیفیت رویشگاه پایین نیمی از مساحت کل را شامل می‌شد(۵۱٪) و در جایی که آشفتگی‌های آنتزوپوژنیک متمرکز هستند قرار داشت. کیفیت رویشگاه با تولید علوفه همبستگی معنی‌داری داشت(p<۰/۰۱). مراتع با کیفیت رویشگاه کم، گونه غالب درمنه دشتی(*Artemisia sieberi*) با گونه مهاجم سالسولا(*Salsola brachiata*) جایگزین شده بود و کمترین میزان علوفه ۲۱ کیلوگرم در هکتار را داشت. تولید علوفه در مراتع با کیفیت رویشگاه متوسط حدود ۲/۵ برابر بیش از مراتع با کیفیت رویشگاه پایین و نصف تولید مراتع با کیفیت رویشگاه بالا بود. گون و درمنه کوهی(*Astragalus gossypinus-Artemisia aucheri*) در مناطق با کیفیت رویشگاه بالا، بیشترین میزان تولید علوفه را داشتند(۲۱۶ کیلوگرم در هکتار). با توجه به مساحت زیاد اراضی کشاورزی در مناطقی با کیفیت رویشگاه پایین می‌توان اراضی کشاورزی را مهمترین تهدید اراضی مرتعی دانست، بنابراین در توسعه پایدار برای بهبود حفاظت از خدمات اکوسیستم با مزایای بلند مدت، گسترش اراضی کشاورزی با مزایای کوتاه مدت باید تحت کنترل قرار گیرد.

کلمات کلیدی: خدمات اکوسیستم، کیفیت رویشگاه، InVEST