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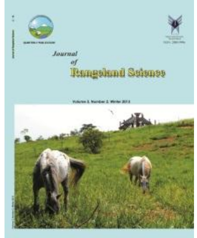

Full Length Article:

Studying the Effects of Grazing Capacity and Rangeland Conditions on Occurrence of Landslide in Subalpine Grassland (Case Study: Rangeland of Masoleh Watershed)

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Abstract. Subalpine rangeland as a rara avis ecosystem is very important because of ecological features. Consistency and resistance of this ecosystem is so frangible and its natural equilibrium is instable due to the effects of biotic and abiotic factors. The landslide as one of negative consequences in upland area is seen in Masoleh watershed (north of Iran). This study has investigated the roles of biotic factors playing in the occurrence of the landslides in Masoleh rangeland. Hence, two sites such as exclosure and grazing areas were analyzed and compared. The plot size was 1m² and totally, 128 plots were obtained by minimal area method and statistical formula approach, respectively. The rangeland conditions were measured by six-factor method. Clipping and weighing method was used to determine the grazing capacity. In order to do the landslide zonation, the landslide index was employed. Results showed that there were significant differences between species densities and soil conservation factors in both exclosure and grazing areas. There might be more than 1.2 overstocking in the grazing area. The rangeland conditions' classes and distance from fold, effective biotic factors, geologic formation, soil texture and effective abiotic factors were the most influential factors on the landslide occurrence in subalpine ecosystem of Masoleh. Regarding results of current research, the exclosure can protect the soil from the landslide through increasing the perennial and endemic species. Decreasing livestock and regulating the animal entrance and egress to reach the suitable circumstances of vegetation covers and pull up the landslide occurrence are recommended in this area.

Key words: Subalpine rangeland, Grazing capacity, Rangeland conditions, Landslide, masoleh

1. Introduction

Rangeland ecosystems are ecologically changing because of the effects of biotic and abiotic factors (Kulakowski and Veblen, 2007). Studying and recognizing the interactions between these factors in rangeland ecosystem may be the important tools to conduct the management programs to conserve the range health (Jouri *et al*., 2007). Subalpine ecosystems are dynamic ones while taking its special conditions into account, it is much brittle (Johnson, 2004). According to the definitions, subalpine rangelands are located upper the timberline with high sun radiations, frosty wind, chilly weathers and glacial and alternative snow. In accord with vegetation cover, it has perennial grasses, forbs and sedges along with cushion-acanaceous bushes and prostrated trees such as juniper (Rundel *et al*., 1977). Because of dominated species including grasses and forbs, this ecosystem shows a landscape where regarding the ecological aspect, it is entirely individual (Mclean *et al*., 1970). The aggregation of mentioned components to create the particular circumstances of subalpine rangelands states that the upland of Masoleh belongs to subalpine area. Different abiotic factors (e.g. landslide) along with biotic factors (e.g. livestock grazing) can endanger the ecosystem equilibrium of subalpine area. Existence of short landslides which are seen with the sequential breakages thoroughly alters the features of this ecosystem. It seems that these sorts of formation for the occurrence of landslides are specific in the rangeland ecosystems, especially upland rangelands (Roering *et al*., 2005). The evaluation of landslide hazards are considered as complicated issues because of variety of factors to happen this phenomenon (Choi *et al*., 2012). Understanding the effective factors in landslide incident is important to manage the natural resources and decrease its hazards. Totally, the most important and effective factors for the landslide occurrence refer to the geologic factors (lithology, geologic formation, weathering grade and distance from fault), geomorphologic elements (slope degree, slope aspect, relief and altitudinal classes), soil components (depth, structure, infiltration and porosity), land-use and hydrologic ingredients (Varnes, 1984).

There are several studies about landslide phenomenon in the upland areas worldwide including those done by Yalcin *et al*. (2011) in the mountainous area of Turkey, Melchiorre *et al*. (2011) in Cuba, Pavel *et al*. (2011) in upland rangeland of USA, Choi *et al*. (2012) in South Korea, Bui *et al*. (2012) in Vietnam, Marjanovic *et al*. (2011) in Serbia and Zare *et al*. (2012) in the mountainous region of Vaz (Iran). Almost, the attitude of all areas investigated by the researchers emphasizes on physical (abiotic) factors. Researches which are based on the effective biotic factors on the landslide episode are rarely found in the related references. Especially, there are not any researches on the impacts of rangeland conditions and grazing capacity on the landslide incident while this research focuses on this case. There are some interactional effects on productivity, hydro and soil in the rangeland in different range conditions so that the losing of soil in poor conditions of rangeland at 1.07 equal of derelict land may be evidence to these relationships (Snyman, 1999). It can be stated that vegetation cover as a controller of soil erosion undulates under the effects of animal grazing and some abiotic elements (Zhou *et al*., 2006). In as much as animal acting is considered as an effective component on the ecologic equilibrium of the rangeland ecosystems, increasing the grazing intensity in the rangeland leads to omit the palatable species and replace them with invader species (Zhao *et al*., 2007). Studies of Rose and Plat (1992) on long term exclosure (34 years) in alpine rangeland in Europe show that the reduction of invader species is brought about to increase the frequency of palatable species. Presence of endemic species not only can infiltrate the water into subsoil but also held back the soil erosion and enhance the soil texture and structures through keeping enough litter in the surface of soil with permanent covering (Descheemaeker *et al*., 2006). Continuous grazing is to cause the baring of soil surface and compacting of subsurface soil so that it reduces the water infiltration and decreases the forage and consequently, increases the soil erosion (John and William, 2000). Desirable range capacity as a management method can enrich and conserve the endemic species, especially perennial species (Amiri and Arzani, 2009). With regard to the related references, increasing the grazing intensity can increase the soil erosion so that if the area is subjected to susceptible formation, it can be seen as a landslide event. In current research, it is tried to investigate the livestock effects on landslide occurrence in Masoleh rangeland in northern Iran.

2. Material and Methods

2.1. Study area

Masoleh watershed with the area of 4000 ha is located in the west of Fooman city (Fig. 1). Subalpine rangeland of this catchment limit is almost 977 ha; it means that about 200 ha of this may be unusable because of high destruction. 22 ha of the rangeland was closed about 13 years. The highest rate of precipitation which is hyper pressure air mass of Siberian and Mediterranean falls in the north and northeast or west and northwest of the study area (Alborz Sabz Institute, 2011). Mean annual precipitation of catchment is 601 mm which the most of it falls in autumn while the least of it falls in summer. Almost 90 days are regarded as a glacial period which the most of it is occurred in January and February. Soil texture of this area is loamy and has clay sorts. Mountainous rangeland of Masoleh is formed by several traditional grazing borders and each of them is surveyed as common exploiters. Goats and sheep as effective biotic factors to occur the landslide in this area graze the upland rangeland from mid of Jun to mid of Oct every year. 22506 AUM has been recorded in these area based upon Natural Resources Administration of Gillan province. The vegetation features of the study area regarding subalpine definition are close to subalpine rangeland. Some dominated perennial species in the exclosure are *Festuca arundinacea*, *Dactylis glomerata*, *Bromus tomentesus*, *Poa pratensis*, *Trifolium repense* and *Stachys inflate*. The grazing area, however, has *Taraxacum montanum*, *Malva neglecta*, *Allium aucheri*, *Galium verum*, *Eryngium caucasicum* and *Phlomis aucheri* as the dominated species. On the other hand, the most species in the exclosure are composed of perennial and palatable species while unpalatable and annual species embrace in the grazing area.

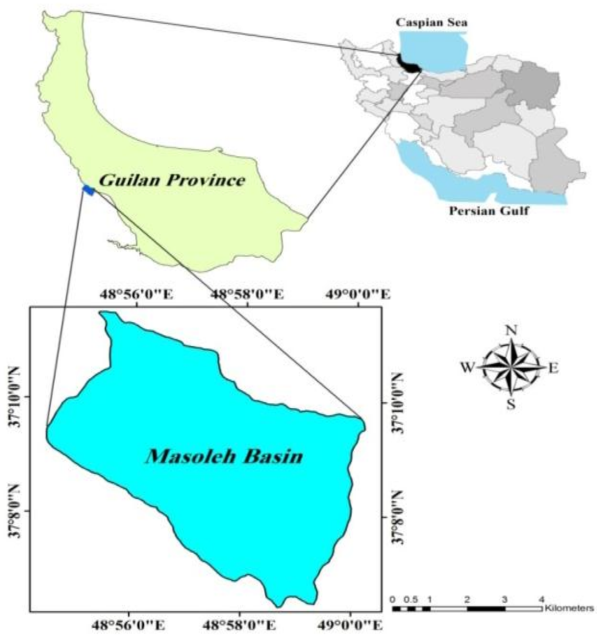

Fig. 1. Location map of the study area

2.2. Sampling method

In order to investigate the effects of rangeland conditions and grazing capacity on the landslide event, two sites such as exclosure (13 years) and grazing area were selected in the rangeland of Masoleh. Sampling in the rangeland was done as a field method to obtain the rangeland conditions' layers to enter GIS software. The sampling was coincidentally carried out in both sites. Regarding minimal area concept (Cain, 1932), plot area was calculated as 1m². Number of plots was obtained by a statistical approach (Mesdaghi, 2000) as here, it was 128 plots. The rangeland conditions were determined using six-factor method known as Daubenmire procedure (Daubenmire, 1968). Ranking approach for rangeland traits was used to settle the rangeland trends and the clipping and weighing method was accustomed to calculate the grazing capacity in both sites, too (Moghaddam, 2009):

$$\text{Animal Unit per Month (AUM)} = \frac{\text{Effect area of range} \times \text{Reachable forages}}{\text{Length of grazing period} \times \text{Daily requirement of livestock}} \quad (1)$$

Where

Reachable forages were calculated as 50% of first class (I), 30% of second class (II) and 15% of third class (III) of palatable species production. Daily requirement of livestock was also computed as 1.5-1.6 kg dry forage per day (Moghaddam, 2009).

2.3. GIS section

The landslide map was provided by ArcGIS 9.3 software using the recorded points by GPS. Topographic map in the scale of 1:25,000 from Geographic Organization of Armed Force and the geologic map in the scale of 1:100,000 from Geologic Organization of Iran were obtained and land-use map of the study area was extracted from ETM (2000) images. The other entered maps into ArcGIS software were the isohyet, soil texture, slope aspect, hypsometric, distance from fault, stream power index (SPI), Topographic Combination Index (TCI), distance from rivers, distance from road and lithological ones. The rangeland conditions' classes and distance from folds were also entered to ArcGIS software and fourteen layers were then assembled. In order to show the landslide susceptibility, Landslide Index (LI) methods were used on the basis of logarithm (ln) concentration of landslide in each class for the total landslide density maps (Van Westen, 1993). Following equation forms the basis of this approach:

$$W_i = Ln\frac{Densclass}{Densmap} Ln\frac{\frac{Npix(s_i)}{Npix(N_i)}}{\frac{SNpix(s_i)}{SNpix(N_i)}} \quad (2)$$

Where

Wi= weight given to a certain parameter class,
Densclass= Landslide density within a parameter class,
Densmap= Landslide density within an entire map,
Npix (Si)= number of pixels containing landslide in a certain parameter class,
Npix (Ni) = total number of pixels in a certain parameter class.

Each class has a specific weight according to Eq. 2. Classification and summation of weights have been done in ArcGIS. Total weights' liner graph and slope failure as hazard boundary might be divided into four risk categories of low, medium, high and very high and finally, landslide hazard map was drawn.

2.4. Statistical method

Multivariate standard regression as a stepwise method was employed to find out the correlation between rangeland conditions and species densities and between rangeland conditions with some protection traits of soil. This kind of regression helps to get information about each independent variable proportion in the variation of dependent variables. In order to compare two sites, mean comparison of them was tested by t-student in SPSS v.19 software.

3. Results

3.1. Rangeland conditions

Outcomes of conditions' determination for both sites in the study areas show that the score of range conditions in the exclosure was 73.8 regarding as good conditions with a progressive trend while in the grazing area, the score was 56.5 as fair conditions with a regressive trend. The stepwise regression in the exclosure showed that the species density of classes I and II had been significantly correlated with the rangeland conditions ($P<0.01$). Regarding standard equations (Table 1), first class of species density had the utmost effects on the range conditions' variation in both areas. On the basis of the equations, second class of species density performs a moderate role in the grazing area. The analysis of stepwise regression for soil conservation factors with the range conditions in both areas showed that there was a strong correlation ($P<0.01$) between them.

The standard equations show that basal area in both sites positively had the most justification of the rangeland conditions' variation (Table 2).

The results of t-test showed that there was a significant difference ($P<0.01$) between species densities of I, II and III classes in both sites. Also, same statistical results had been found for rock and stone, litter and basal area in both areas (Table 3).

Table 1. Regression equations for range condition as a dependent variable and species density as an independent variable

Sites	Regression Equations	Coefficient of Determination (R^2)	F	Sig.
Exclosure area	Y=0.739 I +0.45 III	0.489	59.877	.000
Grazing area	Y=0.568 I + 0.325 II + 0.293 III	0.826	196.362	.000

Y= Range condition, X_1=50% palatable species first class (I), X_2=30% second class (II), X_3=15% third class (III)

Table 2. Regression equations for range condition as a dependent variable and soil protections elements as an independent variable

Sites	Regression Equations	Coefficient of Determination (R^2)	F	Sig.
Exclosure area	$Y= 0.633 X_1 + 0.305 X_2$	0.663	123.161	.000
Grazing area	$Y=0.713 X_1 + 0.288 X_3$	0.943	1.039	.000

Y: The rangeland condition's score, X_1: Basal area, X_2: Rock and stone, X_3: Litter

Table 3. T-test comparisons between two sites of exclosure and grazing area for range conditions' species density and soil conservation elements

Variables	Exclosure	Grazing Area	T-test	Sig.
Range conditions	73.8	56.5	6.05	0.00 **
Density I	89.4	49.2	8.75	0.00 **
Density II	15.4	49.9	-11.26	0.00 **
Density III	32	95.4	-10.86	0.00 **
Basal area	19.8	19.8	-0.00	0.977ns
litter	40.4	1.5	27.58	0.00 **
Rock and stone	50.4	24.1	7.36	0.00 **

ns: non-significant,**Correlation is significant at 0.01 level

3.2. Grazing capacity

Reachable forages are obtained for the exclosure and grazing areas as 384.5 kg/ha and 120 kg/ha respectively using consuming coefficients of classes I, II and III. There is a production of 3.2 in the exclosure to grazing area. Hence, AUM of the exclosure and grazing areas was obtained as 1705 and 18266, respectively. Therefore, it showed that there was AUM of 4240 as extra capacity in the grazing area. The overstocking has deformed the landscape of subalpine rangelands of Masoleh (Fig. 2).

A. landslide phenomenon in the study area

B. Livestock presence and its role to heighten the landslide

C. Landslide and reduction of grazing area

D. Destruction intensity because of short landslide

Fig. 2. Different positions of landslides in sub-alpine rangelands of Masoleh

3.3. Landslide evaluation

Considering the investigation of the landslide occurrence factors in Masoleh catchment, the allocated weight of each element was obtained by LI method. The results showed that the maximum landslide in the study area had occurred in the rangeland (Fig. 3). Also, rangeland conditions' levels and distance from corrals (less than 500 m) had the highest weight as compared to the other factors (Table 4). The geologic formation and soil texture were the most weighted factors than the others on the basis of LI model (Table 4). This model shows that there was a high risk in landslide computed as 27.04% of whole catchment (rangeland area) in which 82% of the landslides might happen in this area limit (Fig. 4). As it has been observed in (Fig 4), the most dangerous area was in very poor conditions (Table 4) and had less palatable-perennial species.

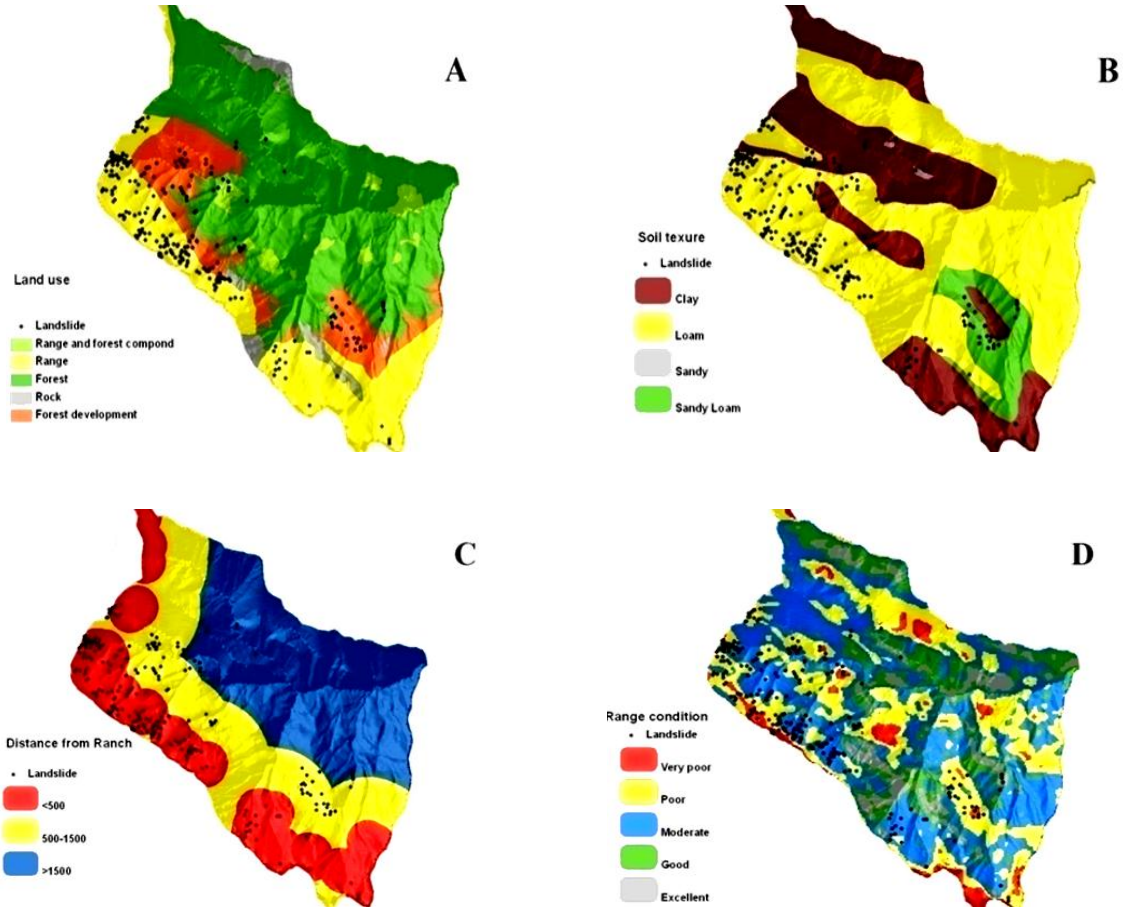

Fig. 3. A. Land-use map; B. Soil texture map; C. Distance from folds map; D. Rangeland conditions' map

As it has been stated on the basis of LI model, four factors were the most effective elements to come to pass the landslide such as distance from folds (0.961), geologic factor (0.337), rangeland conditions (0.72) and soil texture (0.234) and the minus symbols of the landslide index show the least impact and if the number and its symbol go to high and positive, there is a preponderant impact on the landslide occurrence (Table 4).

Table 4. Weights of four effective factors on the landslide occurrence based upon LI model in Masoleh watershed

Type	Range	Landslide not Occurred		Landslide Occurred		Landslide
		Count	Ratio	Count	Ratio	Index
Lithology	Jcs*	2867	7.90	1	0.58	-0.44
	Js	12521	34.50	122	70.93	0.72
	Kln	11374	31.34	27	15.70	-0.691
	P	1922	5.30	5	2.91	-0.599
	Pzs	4925	13.57	0	0.00	-10.76
	Qal	34	0.09	0	0.00	-10.76
	T	2655	7.31	5	2.91	-0.922
Range conditions	Excellent	2714	7.48	3	1.74	-1.450
	Good	5158	14.21	3	1.74	-2.090
	Moderate	16309	44.93	91	52.91	0.163
	Poor	10383	28.60	63	36.63	0.247
	Very poor	1737	4.79	12	6.98	0.377
Soil texture	Clay	11306	31.14	26	16.35	-0.722
	Loam	22023	60.67	132	83.01	0.234
	Sandy	102	2	0	0	-0.999
	Sand-loam	2867	7.89	1	0.06	-0.044
Distance from folds	<500	10082	27.77	125	78.16	0.961
	500-1500	11165	30.75	39	24.52	-0.304
	>1500	15051	41.46	8	5.03	-2.180

* Jurassic-conglomerates, Jurassic-shale, Cretaceous-limestone, Permian, Paleozoic-silt, Quaternary-alluvial, Triassic

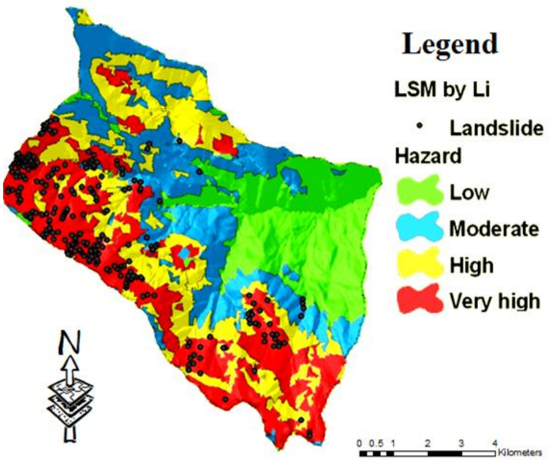

Fig. 4. Landslide susceptibility map using landslide index

4. Discussion and Conclusion

As it has been stated, abiotic components (e.g. geologic formation, climate, soil texture and so on) and biotic factors (e.g. animal and human) play important roles in varying the ecologic equilibrium in the rangelands (Kulakowski and Veblen, 2007); as it may be seen in the study area (Figs. 2 and 3). Considering abiotic factors, the geologic formation and soil texture were the most effective factors to occur the landslide in the subalpine rangeland of Masoleh. Most part of the area had been formed by Shemshak formation which is composed of siltstone, shale, clay stone and sandstone. Hence, these formations are the causes of landslide occurrence because of water reservation of them which are dilated and cause the slide of up-layers as Mohammadi *et al.* (2010) and Porghasemi (2006) reported it as well. Regarding the fact that most of landslide occurrences are found in the loamy and sandy-loamy textures, soil texture element also absorbs more water while loam texture is of bigger colloid granules as compared to clay texture and it can receive more water in its vacuity. The present result is matched with the other researches' finding presented by Yalcin *et al.* (2011), Pavel *et al.* (2011), Melchiorre *et al.* (2011), Marjanovic *et al.* (2011), Choi *et al.* (2012), Bui *et al.* (2012) and Zare *et al.* (2012).

Classes of range conditions and distance from folds had the most important effects on landslide incident as compared to the other biotic factors. Whatsoever the conditions are moving from an excellent mood toward poor conditions, increasing slide zones has furthered. The livestock trampling is more around the corrals far from the folds. Hence, it leads to deform the surface soil and consequently, decline the rooting zone of perennial species. Overgrazing and continuous grazing of endemic and palatable-perennial species are at the highest level around the corrals. Ensemble of these circumstances brings about less frequency of perennial species seen around the folds and the outcomes of direct effects of overgrazing can be observed in downturn of first class's (I) species density and increase of species density of class III (Table 3). It is obvious that the decrease of class I species can result in soil surface's Shemshak formation as they are endemic and perennial where the existence of enough precipitation and steep slope lead to take place the landslides in the rangeland. Same results are reported by Zhou *et al*. (2006) and Zhao *et al*. (2007).

Regarding the calculated grazing capacity, there are a 1.2 equal of overstock in the grazing area showing high grazing intensity in rangeland. The overstock of capacity for instable and brittle of subalpine ecosystems shows the ecologic capability of this ecosystem so that its effects can be seen around the folds (stripping of soil surface) with lower scores of range conditions. Consequences of these effects can be noted when statistical comparisons of the exclosure and grazing areas regardless of topographic conditions' matching (e.g. slope, aspect, altitude and so on) and climatic position (e.g. temperature and rain) in both area are done and it is shown that the grazing area has more landslide spots and demolition intensity than the exclosure. John and William (2000) and Descheemaeker *et al*. (2006) had also revealed the overgrazing impacts on the stripping of soil surface and increasing of surface erosion. Thus, exclosures can play specific roles as a dissuasive factor to the landslide occurrence via increasing the perennial and endemic species (Tables 1 and 3). Hence, it is recommended that short term exclosures should be considered in different areas of the subalpine rangelands in Masoleh as periodical practices in the range development programs. Regulating the desired capacity of rangeland as a management tool to enforce of perennial species (Amiri and Arzani, 2009); it is suggested that decreasing of current the capacity of rangeland in short-term and mid-term periods should be carried out to increase the percentage and density of perennial species in the area. It is obvious that the revival of endemic species can act as a biological program to tick off the landslide in the study area.

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نقش ظرفیت چرایی و وضعیت مرتع در ایجاد پدیده زمین لغزش در مراتع شبه آلپی (مطالعه موردی: مراتع حوزه آبخیز ماسوله)

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چکیده

مراتع شبه آلپی به عنوان یک اکوسیستم نادر، به لحاظ اکولوژیک و بوم شناختی از اهمیت ویژه‌ای برخوردار است. ثبات و پایداری این اکوسیستم ضمن پیچیدگی، بسیار شکننده بوده و تعادل طبیعی که تضمین کننده بقای آن است، تحت تاثیر عوامل زنده و غیرزنده به شدت متزلزل و ناپایدار است. زمین لغزش یکی از تبعات منفی در این اکوسیستم به شمار می‌آید. از مناطق مستعد در بروز این عامل طبیعی، مراتع شبه آلپی حوزه آبخیز ماسوله در شمال کشور است. هدف این تحقیق بررسی نقش عوامل زنده در ایجاد و تشدید پدیده زمین لغزش در این مراتع است. بدین منظور دو سایت مطالعاتی قرق (شاهد) و منطقه چرایی مورد ارزیابی و مقایسه قرار گرفت. با استفاده از روش حداقل سطح و فرمول آماری، اندازه سطح پلات یک مترمربع و تعداد آن ۱۲۸، بدست آمد. وضعیت مرتع با روش شش فاکتوره تعیین شد. برای تعیین ظرفیت چرایی مرتع از روش قطع و توزین علوفه استفاده شد. به منظور پهنه بندی خطر زمین لغزش از روش شاخص لغزش استفاده شد. نتایج نشان داد که در دو سایت قرق و چرایی بین تراکم و فاکتورهای حفاظت خاک با وضعیت مرتع تفاوت معنی‌دار بالایی وجود دارد. نتایج ظرفیت چرایی حضور ۱/۲ دام مازاد بر ظرفیت را در مراتع این حوزه نشان داد. از بین فاکتورهای زنده تاثیرگذار در بروز زمین لغزش، طبقات وضعیت مرتع و نیز فاصله از آغل و از میان عوامل فیزیکی نقش زمین ساخت و بافت خاک، بیشتر از دیگر عوامل در اکوسیستم شبه آلپی ماسوله موثر بوده است. با توجه به نتایج تحقیق حاضر نقش قرق به عنوان یک عامل بازدارنده از طریق افزایش گونه‌های چند ساله و بومی در بروز زمین لغزش نمایان شده است. برنامه کاهش دام و نیز تنظیم زمان ورود و خروج دام تا رسیدن به شرایط مناسب پوشش گیاهی در جلوگیری از بروز و تشدید لغزش‌های کوتاه در این مراتع توصیه می‌شود.

کلمات کلیدی: مراتع شبه آلپی، ظرفیت مرتع، وضعیت مرتع، زمین لغزش، ماسوله