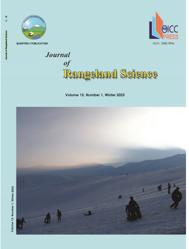

Volume 15, Issue 1, 152506 (1-12)

Journal of Rangeland Science (JRS)

https://dx.doi.org/10.57647/j.jrs.2025.1501.06

Determination of rangeland grazing suitability model (case study: Sarab Sefid Basin, Lorestan, Iran)

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Original Research

Received:
7 February 2023
Revised:
15 February 2024
Accepted:
21 February 2024
Published online:
20 January 2025

Abstract:

Livestock grazing in unsuitable land has increasingly grown in most parts of rangelands of Iran due to population growth. It causes many irreparable damages such as soil erosion, water loss, and wealth loss. Therefore, it is important to identify the best suitable land for livestock grazing. Land suitability for livestock grazing is affected by many ecosystem components, but due to time and funding restrictions, the most important and feasible elements have to be investigated. This paper adapted the schematic model based on the concepts presented by the Food and Agriculture Organization (FAO) suitability analysis for livestock grazing in Sarab Sefid Borujerd rangeland, Iran. Significant factors to livestock grazing, such as forage, soil and water which were in sub-models were determined and incorporated into the final model of rangeland grazing suitability. Some important maps include Digital Elevation Model (DEM), slope, aspect, range condition, range trend, forage, soil erosion, and water sources were used as input data. Three sub models including water accessibility, forage production and erosion sensitivity were considered. The most adaptation of Suitability occurs for class (Good) S_1, (Medium) S_2, (Poor) S_3 and (Non-suitable) N, respectively using Geographic Information Systems (GIS). First, the complete raster layers valued and ranked by FAO method for each factor, then integrated by overlays intersected command. Results showed that according to 16 types of vegetation cover, none of them were placed in S_1 class, and 3088.75 ha (52.68%) S_2, 1892.63 ha (32.27%) S_3 and 882.85 ha (15.06%) were in N class, respectively. Also, result determined that there was no limitation of water resources in total rangeland and the most and main important factor effects on suitability were soil erosion and slope due to mountainous area. According to the field data, and comparing with the study data, it was concluded that GIS technique is a fast and accurate method for monitoring and determining the suitability of rangelands.

Keywords: Livestock grazing; Rangeland suitability; Sheep grazing; Geographical information system

Introduction

Rangeland ecosystem good management needs to recognize situation of water, soil and plant resources which are vital sources to production. Sustainable utilization is needed for proper planning that not only decreases rangeland degradation, but also causes conservation and improvement of those. Thus, one of the most important and difficult factors in analysis and evaluation of rangelands is utilization based on those potential and abilities. Recognition of significant factors has special importance for desirable use and suitable management of rangeland. One of the main problems of developing countries such as Iran is utilization of natural resources without considering ecological situation and its potential, consequently, destruction of soil, water and plants as the most significant basis of suitable production. Most areas of Zagros Mountains include rangelands in spite of High-quality and adequate quantities of forage that are not suitable to grazing because of lack of access to water and more soil erosion. These factors are affected by rangeland utilization history (Moghadam, 1998). FAO guides a standard evaluation system to assessment of land. It was in 1972, its background was prepared and in the next year, the first format was written, then the final format of land evaluation was issued in 1976. Subsequent issued guides of land evaluation were for different land uses such as Dry land farming (FAO, 1991c), forestry, rain cultivation and expanded grazing (FAO, 1993). On one hand, suitable uses and land resources need balancing, more information and its utility to different systems relevant to the earth such as natural resources and on the second hand, nature of dynamics and those changeable ones cause human to use new methods and electronically instruments (Makhdum, 2001). Fikadu (2011) conducted a study on rangeland suitability analysis using GIS and remote sensing applying a multi-criteria evaluation method.

Locating suitable areas for livestock production using spatial models of the GIS would be vital to improving livestock productivity (Terfa and Suryabhagavan, 2015). Thus, as GIS is capable of handling and combining different types of data both non-spatial and spatial as well as multi-temporal and multi-scale in a time-efficient and cost-effective way, there has been a steady increase in interest for using GIS together with MCDA techniques (Myagmartseren et al., 2017).

Many advanced remote sensing methods have been utilized worldwide for estimating biophysical parameters of rangeland vegetation such as pasture quantity, pasture growth rate and primary production, among others (Fajji et al., 2018).

Analytical hierarchy process (AHP) technique is one of the most commonly used MCDM techniques in GIS-based suitability procedures because of its appropriateness for making decisions based on multiple factors ranked according to experts' preferences (Kahsay et al., 2018). GIS-based multi-criteria decision evaluation process is practiced by defining goals, determining and standardizing criteria/factors, determining a weight for each factor, aggregating the criteria and validating (Kefelegn et al., 2019).

Geographic information science (GIS Science) and remote sensing have long provided essential data and methodological support for natural resource challenges and environmental problems research (Pei et al., 2021).

Pandey and Sharma (2020) determined the land suitability analysis through Remote Sensing and Geographical Information Systems (GIS) technology (by assessing parameters like slope, geomorphology and land-use/land-cover) in which decision rules are applied on the multi-criterion basis.

Suitable utilization of rangeland need the recognition of its parameters; therefore, determination of rangeland suitability is one of the most significant factors and more difficult to rangeland analysis (Mohtashamnia, 2001). To determine livestock grazing suitability, some factors such as plant cover properties, topography, pedology, climate, geology, geomorphology, sediment and erosion, river network, and water resources must be investigated. Investigation of all effects on animal grazing is hard, but some most significant ones can be used by abilities of geographical information system to decrease time and increase accuracy for preparation of information layers and integrating them.

Grazing livestock species including cattle, sheep, and goats would be different according to physical factors such as slope, dimension of range, natural barriers, water resource spreading, soil properties, soil sustainable, soil sensitive to erosion, percent of plant cover, soil cover and forage production (Moghadam, 1998). Seventy percent of Iranian livestock are dependent on rangelands, so determination of suitability is important. Borujerd Sarab Sefid rangeland was selected according to the higher number of livestock (sheep) and plays a role in the rural economic.

Despite the presence of sufficient water resources in some pastures, it is not possible to use fodder due to the lack of uniform distribution. In fact, it is important to provide enough water for livestock and wildlife.

Sheehy and Vavra (1996) concluded that potential forage of communities can be used by GIS in the *Festuca-Agropyron* and *Agropyron-Poa* for grazing. Results showed that Mule deer preferred buckwheat-bluegrass scabland plant communities at medium distance from the forest edge at higher elevation.

Amiri (2009b) reported that range suitability and its grazing capability are the most important criteria in rangeland analysis and monitoring in semi-arid regions. Determination and monitoring of factors affecting range suitability and diagnosis of them are important. He showed that 15.73% (1,126 ha) were moderately suitable, 68.67% (4,916 ha) were marginally suitable and 15.6% (1116 ha) were classified as unsuitable for grazing. The most important limiting factors in the area were the abundance of invader plant species, especially around the watering points and villages, low range productivity, erosion, slope classes (relatively flat to steep gradients), access to quality water resources and low temperatures during winter and autumn.

Results of study in semi-arid rangelands of Iran on integrated components of available forage by GIS showed that from 18346 ha in the range area, only 8.36% of the rangeland was in good conditions and the rest were in fair (13.8%), poor and very poor (77.82%), about 16812.85 ha (91.64%). The range conditions, situation and its trend in consideration of soil and slope properties indicate that the rangeland in Vahregan central of Iran has a fragile production system, sensitive to soil erosion and rangeland degradation. So, for a long time, sustainable exploitation should be going to minimize land degradation in the future (Amiri and Shariff, 2012).

Many rugged ranges can be better used by wild animals than by livestock. Goats can graze or browse on steep slope that are unsuitable for cattle and other large animals (Fikadu, 2011).

Water resources suitability model using GIS in rangeland's Borujerd was determined by Ariapour et al. (2013). He showed that all of 16 plant vegetation types were dropped in I and II classes of water resources suitability which did not have any limitations according to quantity and quality and distance of animal husbandry and livestock.

Karami et al. (2013) had developed a model of limiting factors of forage production suitability using GIS in Aliabad Rangelands of Lorestan province, Iran.

Ariapour and Shariff (2014) showed that fire risk zonation using remote sensing and geographical information system technologies in Borujerd rangeland and argued that GIS had high performance and precision.

Arzani et al. (2014) determined the influential factors affecting extensive grazing and converted it into a model in a study entitled "rangeland sustainability model for livestock grazing" in Taleghan area, Iran. Suitable areas in four levels of suitability were determined. They suggested that managers could be benefited from the model to devise the measures more wisely to cope with the limitations and enhance the rangelands health and condition.

Nowadays, using RS and GIS is essential in order to plan for sustainable use in areas exposed to high exploitation (heavy grazing, human activities) and tough environmental conditions (FAO et al., 2007).
Amiri et al. (2014) determined suitable areas at four levels of suitability using geographic information systems. The most important reducing factors in model suitability were: a) landuse and vegetation cover (in relation to soil erosion sensitivity), b) the amount of the available forage in comparison with the total production, and c) the existence of less palatable plants among the pasture plant species (forage production suitability). They suggested GIS and Remote Sensing techniques to offer a convenient and powerful platform to integrate spatially complex and different land attributes for performing land suitability analysis. They used Landsat TM 2011 remote sensing satellite image for land-use/land-cover analysis, and multi criteria evaluation in a GIS environment to come up with the final suitability map. Factors such as rainfall, land-use/land- cover, soil, slope, access to water, veterinary service and livestock market center were considered. The result of the suitability analysis in Isfahan province revealed that 5.6, 4.9, 5.4, and 10.1% of the study area were highly suitable for cattle, sheep, goat and camel, respectively; 44.75%, 44.15%, 45.5% and 58.6% of the land were classified as moderately suitable for cattle, sheep, goat and camel, respectively (Amiri et al., 2014).
Moghaddam et al. (2017) showed that AHP-Fuzzy model based on the weighted linear combination rangelands were classified as moderate suitability (S_2), 9.55% of the lands were in suitability class of low suitability (S_3) and 6.21% of the lands were in non-suitability (N) class. So, the limiting factors in this model for sheep grazing in the study area are water resources, high slope and vegetation.
Kifle et al. (2020) studied rangeland suitability analysis for livestock production using GIS and multi-criteria evaluation in Delo Mena Woreda, Bale zone, southeast Ethiopia and found that 2, 5 and 7% of the land were highly suitable for cattle, goat and camel, respectively whereas 55, 52 and 66% of land were moderately suitable for cattle, goat and camel, respectively. Moreover, 26% of land was marginally suitable for goats and cattle while 11% of the land was for camel production. But the insignificant percent of the land of the woreda was not suitable for cattle, goat and camel production.

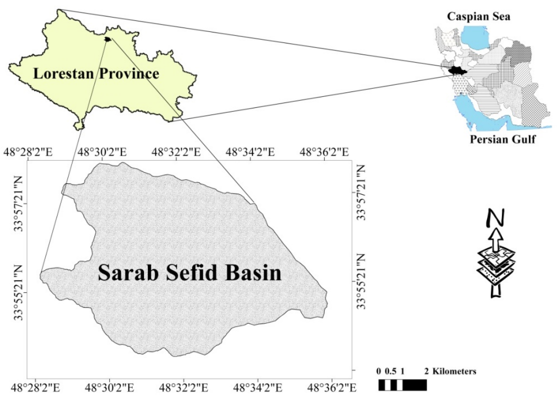

Figure 1. Map of location of the study area, Sarab Sefid basin, Borujerd, Iran.

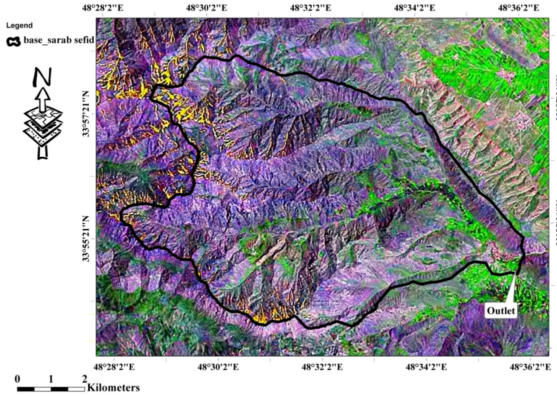

Figure 2. Satellite imagery of Sarab Sefid basin.

Sarab Sefid rangeland in Borujerd was selected according to the higher number of livestock (sheep) and plays a role in the rural economy so the aim of this study was to use geographical information system in preparing rangeland grazing sustainable model to livestock grazing based on the FAO method (1991), and to determine the most important factors effect on sustainable area in Sarab Sefid rangeland of Borujerd for sheep.

Materials and methods

Study area

The Sarab Sefid rangeland under study is located in west of Borujerd county in Lorestan province (48°27′46″ to 48°36′30″ E and 31°53′33″ to 33°58′24″ N). The region is 5864 -ha (58.6 Km^2) (figure 1). The average annual mean (20 years) precipitation of the area is 450.9 mm, falling mainly in the autumn and winter. The average minimum and maximum temperatures are 11.5 °C and 39.2 °C, respectively. The area is located in Iran-Toran area (High Mountain Region). The mean altitude at the sea level is 2744 m with the minimum and maximum altitudes of 1947 and 3451 masl, respectively (figure 2).
According to mountainous area, most of the land use is rangeland. So, 5246.6 ha (89.47%) rangeland, 593.3 ha (10.13%), and 23.1 ha (.039%) are agriculture and urban areas, respectively (figure 3).
This study was based on FAO (1991a) model for evaluat-

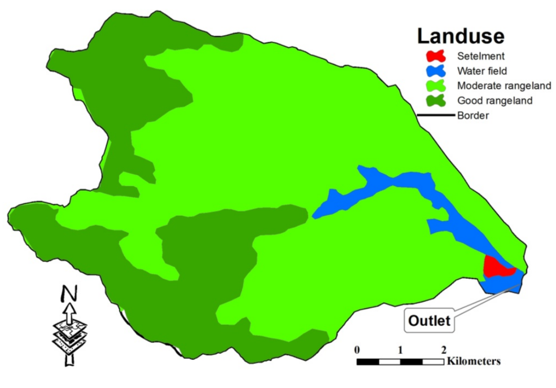

Figure 3. Land uses of Sarab Sefid basin.

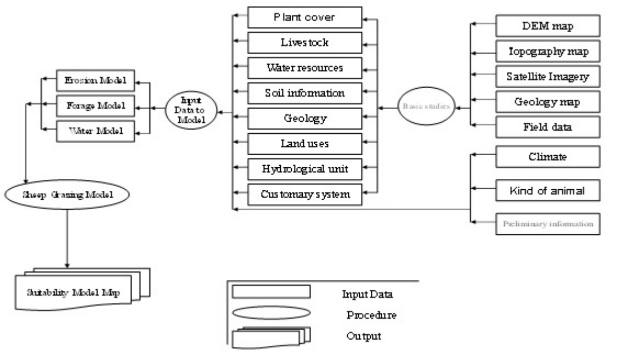

Figure 4. Rangeland suitability model (Amiri et al., 2014).

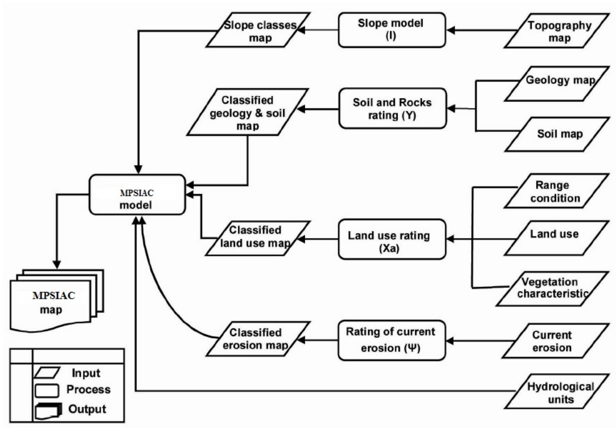

Figure 5. Criteria in the MPSIAC erosion model (Amiri, 2009b).

ing extensive grazing. Maps were analyzed based on raster structure. The land conditions necessary for successful implementation of land utilization types are known as land use requirements, and are expressed in terms of land quality or in a negative manner as land use limitations. Final suitable rangeland model for sheep grazing in the area was obtained by soil erosion, water resource and forage production models integration (figure 4).

Classifing factors

Each factor was classified in terms of four classes with critical values (Table 1). Based on the suitability classes of each factors for each objective, the final land suitability map was given from N (unsuitable) to S_1 (most suitable). The main steps involved in this suitability assessment model are presented in Table 1.

Erosion model

Most soil erosion studies use empirical models owing to insufficient data available. MPSIAC (Modified Pacific Southwest Inter Agency Committee) model has been widely used in the country (FAO, 1991b; Mohtashamnia, 2001; Amiri et al., 2007; Amiri, 2010; Daneshvar and Bagherzadeh, 2012). In this model, nine factors were evaluated in a map format including land use, topography, soil characteristics, geology, weather, hydrologic, plant cover, existing erosion and vegetation types in each catchment (figure 5). Final erosion model in the area was obtained by integration of these factors and classes based on Table 2.

Forage model

Forage production suitability was measured before the start of the grazing season in the pastures of the region in May and June using the criterion including range condition (four factor method, range trend (comparing method), range types (cover percent and physiognomy) and forage production (clipping and weighting method) (figure 6).

Water model

There is one permanent river in the basin under the title of Sarab Sefid from a spring with this name which is divided to many main waterways and secondary ones. Its direction is from south-west to north (figure 7). Also, there are many

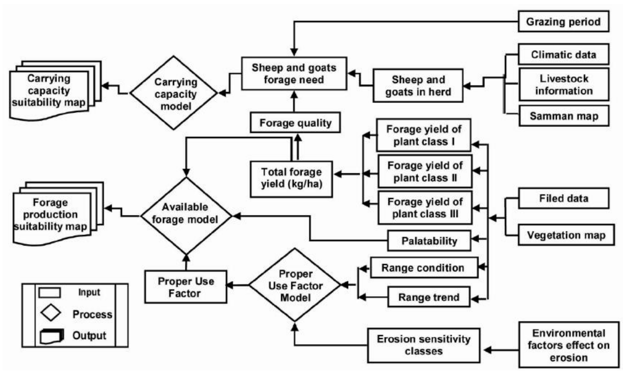

Figure 6. Components of carrying capacity and suitability of forage production in livestock use model (Amiri, 2009b).

Table 1. land characteristics classification and description (FAO, 1991c, 1993).

Order	Class	Description
	S_1 (Highly suitable)	Land having no, or insignificant limitations to the given type of use
Suitable (S)	S_2 (Moderately suitable)	Land having minor limitations to the given type of use
	S_3 (Marginally suitable)	Land having moderate limitations to the given type of use
Not Suitable(N)	N (Unsuitable)	Land that have so severe limitations that are very difficult to be overcome

Table 2. sensitivity to erosion classification based on MPSIAC model, (Amiri, 2009b).

Erosion	Minor	Low to Moderate	High	Very High
Class	S_1	S_2	S_3	N

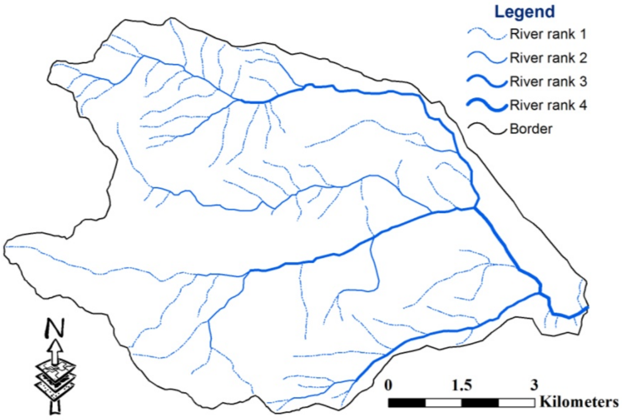

Figure 7. The map of basin hydrological networks.

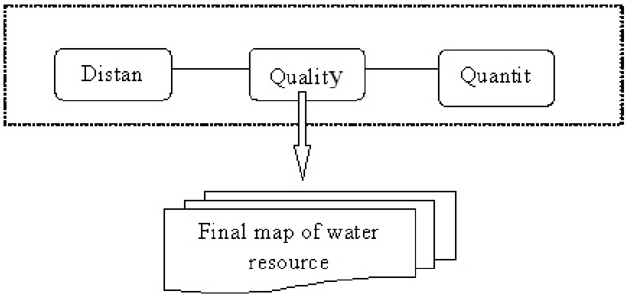

Figure 9. The final model of water resource suitability for sheep grazing.

permanent and seasonal springs in the area. The determination of distance map from water resources perpetrated the map of water resource locations as a point map (figure 8).

Criteria of water resources suitability

The model is made by makes up of three sub models that are water resource distance, quality and quantity. According to these sub models in each types of rangeland and through combining them, water resource suitability was determined in the area for sheep grazing (figure 9).

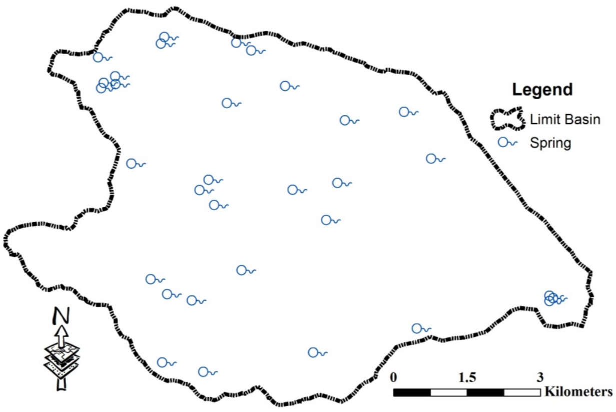

Figure 8. The map of basin springs.

Water resources model

The water resources suitability consists of three sub-models which include: water remoteness, quality and quantity. In this study, the location, quantity, quality and remoteness of water resources in each traditional boundary were determined.

Water accessibility sub-model

First, the slope maps of the study areas were classified and water remoteness in each slope class was calculated and the related map was extracted using ArcGIS®9.3. Overlaying both maps led to the final water accessibility model. The distance from water sources to suitability classes in livestock use is illustrated in Table 3.

Water quantity sub-model

In this step, the location and discharge of water resources were determined and summed up within each type of plant boundary to calculate water availability. Comparing animal water demand and available water results in the water quantity suitability sub-model. According to climatic conditions, vegetation characteristics, grazing season and animal type, animal water demand (liter per day) was estimated using the equation: $a \times w\ (\text{kg}) \times 0.82 = ?$
Where: (a) is the coefficient calculated based on local investigations. The '?' is the amount of water needed by the livestock, and (a) the livestock live weight is based on kg. The suitability categories were then determined by comparison of the available water with the water needed by the livestock (Table 4).

Table 3. Water resource distance (m) and its suitability classes (Ebrahimi, 2004).

Suitability class	Slope class (%)			
	0 – 10	10 – 30	30 – 60	>60
S_1	0 – 3400	0 – 3000	0 – 1000	N
S_2	3400 – 5000	3000 – 4800	1000 – 3600	N
S_3	5000 – 6400	4800 – 6000	3600 – 4100	N
N	>6400	>6000	>4100	N

Table 4. Water resource suitability classes.

Available water in pasture ration to livestock need (%)	>76	51 – 75	26 – 50	<25
Suitability classes	S_1	S_2	S_3	N

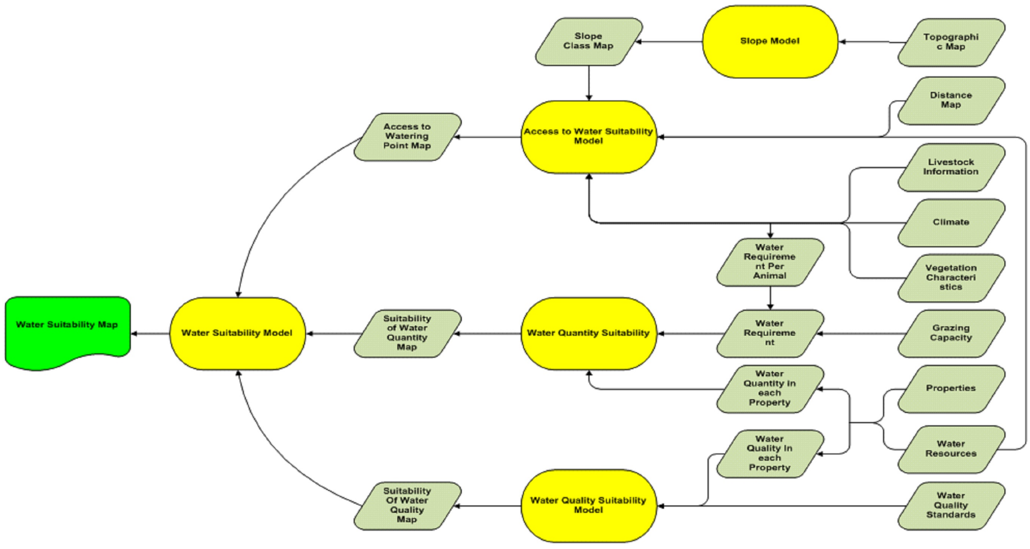

Figure 10. Model for classification of water resources suitability.

Water quality sub-model

In this study, water quality data of water resources [pH, EC, Total Dissolved Salts (TDS), Na, Cl, Co_3, Mg, SO_4, Ca, Total Hardness (TH), S.A.R, K^+, Mg^{2+} and NO_3] were acquired from local offices, Lorestan water management and other research and compared with standards to determine water quality suitability. Finally, these three sub-models were integrated to make the final water resources suitability model for extensive grazing (figure 10).

Results

Determination of rangeland suitability for sheep grazing

The evaluation of potential and actually production to sustainable utilization of rangelands is a high priority in Iran. As pointed before, the aim of this study was sheep grazing modeling to sustainable utilization in Sarab Sefid basin. To achieve this aim, three sub models were integrated based on FAO (1991c) limitation model to final model. The sub models include soil sensitivity to erosion, forage production and water resources.

Suitability model of soil erosion

The soil sensitivity model to investigate erosion situations has been prepared using the MPSIAC model. This model incorporates nine environmental factors that contribute to the watershed's sediment yield. These factors are surface geology, soil, climate, runoff, topography, ground cover, land use, channel and upland erosion. Soil sensitive suitable categories results showed that the whole area, which is 5846 ha, falls into four sections, 2063.89 (35.20%), 1146.91 (1956%), 1917.13 (32.69%) and 736.28 ha (12.56%) in low (S_1), moderate (S_2), high (S_3) and very high (N) suitable classes, respectively (Table 5 and figure 11).

Suitability model of forage production

This section illustrates the results of some plant cover properties including; percent of crown cover plant, plant diver-

Table 5. Soil suitability categories to erosion in whole basin and plant types.

Code	Abbreviation	Area (ha)	Area (%)	Condition	Trend	Suitable to erosion
1	*Ga-Fa*	416.48	7.10	Moderate	Fix	S_3
2	*As.ad-Er.no*	1094.09	18.66	Moderate	Upward	S_1
3	*As.ad-Er.no*	969.80	16.54	Moderate	Upward	S_1
4	*As.mi-An.gr*	261.27	4.46	Poor	Down ward	N
5	*As.mi-An.gr*	205.67	3.51	Poor	Down ward	N
6	*As.mi-Co.ja*	206.19	3.52	Poor	Down ward	S_3
7	*As.mi-Co.ja*	491.37	8.38	Moderate	Fix	S_2
8	*As.mi-Co.ja*	533.49	9.10	Moderate	Fix	S_2
9	*As.mi-Me.pe*	122.06	2.08	Moderate	Down ward	S_2
10	*As.mi-Me.pe*	146.56	2.50	Poor	Down ward	S_3
11	*As.mi-Me.pe*	140.91	2.40	Moderate	Fix	S_3
12	*As.mi-Rh.co*	269.35	4.59	Poor	Down ward	N
13	*Ho.bu-As.mi*	361.35	6.16	Poor	Down ward	S_3
14	*Ho.bu-As.mi*	327.60	5.59	Moderate	Down ward	S_3
15	*Ho.bu-As.mi*	116.75	1.99	Moderate	Up ward	S_3
16	*Ho.bu-As.mi*	201.29	3.43	Moderate	Down ward	S_3

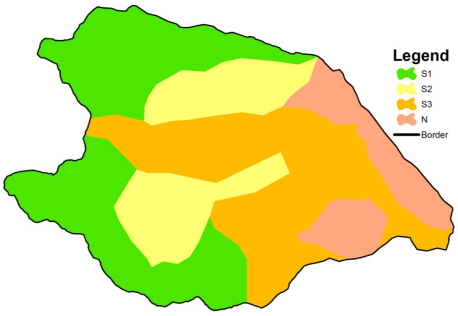

Figure 11. Soil suitability categories map to erosion.

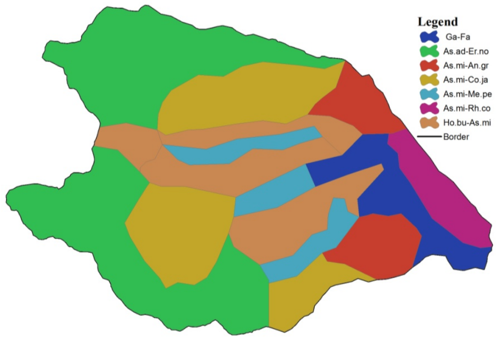

Figure 12. Plant cover types map.

sity according to palatability classes (I, II and III), litter, stone, sand, bare soil, range condition and trend and area of each plant type in the area.

Results showed that plant type *Astragalus adscendens-Eryngium noeanum* was the biggest forage production in the area with 213347 Kg/ha (18% of the whole area), respectively. In some parts of area, plant type caused rangeland degradation since some invader plant had propagated such as *Cousinia jacobsii*. This species is favorite for sheep and goats (based on local interview). Also, *Hordeum bulbosum-Astragalus microcephalus* was the smallest in the area with 24635 kg/ha (2% of the whole area). These plant types were grown in 60% slope with calcareous soils, lithosoil and mountainous climate (figure 12). Primary plant type cover showed 16 dominant plant types in area (Table 6 and figure 12).

Results showed that except 4, 12 and 13 plant types, in other types there was negative trend or downward trend. According to the range conditions all plant types were in medium and poor condition (Figs. 13 and 14).

Table 7 shows results of forage production model to determine forage production suitability class for each plant type in the area according to proper use factor or allowable use factor. As Table show *As.ad-Er.no* fall in S_1 (suitability class one) and *As.mi-An.gr*, *As.mi-Me.pe* and *As.mi-Rh.co* are in N (none suitable) for grazing (Figs. 15 and 16).

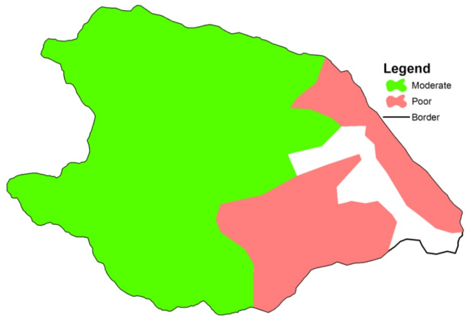

Figure 13. Range condition types map.

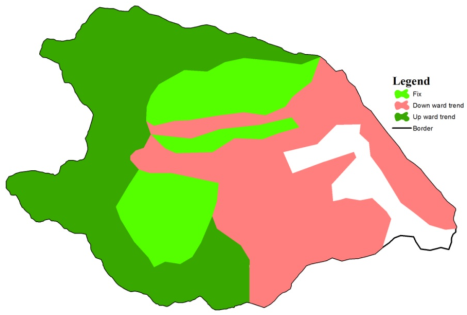

Figure 14. Range condition trend types map.

Table 6. Types of plants in the basin and amount of area's types.

Code	Type Name	Abbreviation	Area (ha)	Area (%)
1	*Garden-Farm land*	*Ga-Fa*	416.48	7.10
2	*Astragalus adscendens-Eryngium noeanum*	*As.ad-Er.no*	1094.09	18.66
3	*Astragalus adscendens-Eryngium noeanum*	*As.ad-Er.no*	969.80	16.54
4	*Astragalus microcephalus–Annual grass*	*As.mi-An.gr*	261.27	4.46
5	*Astragalus microcephalus–Annual grass*	*As.mi-An.gr*	205.67	3.51
6	*Astragalus microcephalus-Cousinia jacobsii*	*As.mi-Co.ja*	206.19	3.52
7	*Astragalus microcephalus-Cousinia jacobsii*	*As.mi-Co.ja*	491.37	8.38
8	*Astragalus microcephalus-Cousinia jacobsii*	*As.mi-Co.ja*	533.49	9.10
9	*Astragalus microcephalus-Melica persica*	*As.mi-Me.pe*	122.06	2.08
10	*Astragalus microcephalus-Melica persica*	*As.mi-Me.pe*	146.56	2.50
11	*Astragalus microcephalus-Melica persica*	*As.mi-Me.pe*	140.91	2.40
12	*Astragalus microcephalus-Rhus coriaria*	*As.mi-Rh.co*	269.35	4.59
13	*Hordeum bulbosum-Astragalus microcephalus*	*Ho.bu-As.mi*	361.35	6.16
14	*Hordeum bulbosum-Astragalus microcephalus*	*Ho.bu-As.mi*	327.60	5.59
15	*Hordeum bulbosum-Astragalus microcephalus*	*Ho.bu-As.mi*	116.75	1.99
16	*Hordeum bulbosum-Astragalus microcephalus*	*Ho.bu-As.mi*	201.29	3.43
		Total	5864	100

Table 7. Types of plants with production, available forage and forage production suitable classes in allowable use factor situation.

Code	Abbreviation	Sign	Area (ha)	Area (%)	Forage (Kg/ha)	Forage (Kg/Area)	Allowable forage	Suitable production
1	*Ga-Fa*	G	416.48	7.10	315	131190	39357.09	S_3
2	*As.ad-Er.no*	E1	1094.09	18.66	195	213347	85338.88	S_1
3	*As.ad-Er.no*	E2	969.80	16.54	214	207537	83014.91	S_1
4	*As.mi-An.gr*	F2	261.27	4.46	166	43370	N	N
5	*As.mi-An.gr*	F1	205.67	3.51	174	35786	N	N
6	*As.mi-Co.ja*	B1	206.19	3.52	186	38351	7670.10	S_3
7	*As.mi-Co.ja*	B2	491.37	8.38	215	105644	36975.46	S_2
8	*As.mi-Co.ja*	B3	533.49	9.10	230	122702	42945.63	S_2
9	*As.mi-Me.pe*	D2	122.06	2.08	175	21360	6407.98	S_3
10	*As.mi-Me.pe*	D3	146.56	2.50	190	27846	N	N
11	*As.mi-Me.pe*	D1	140.91	2.40	120	16909	5072.59	S_3
12	*As.mi-Rh.co*	C	269.35	4.59	60	16161	N	N
13	*Ho.bu-As.mi*	A1	361.35	6.16	192	69380	13875.95	S_3
14	*Ho.bu-As.mi*	A2	327.60	5.59	210	68797	17199.20	S_3
15	*Ho.bu-As.mi*	A4	116.75	1.99	211	24635	7390.53	S_3
16	*Ho.bu-As.mi*	A3	201.29	3.43	225	45290	11322.55	S_3

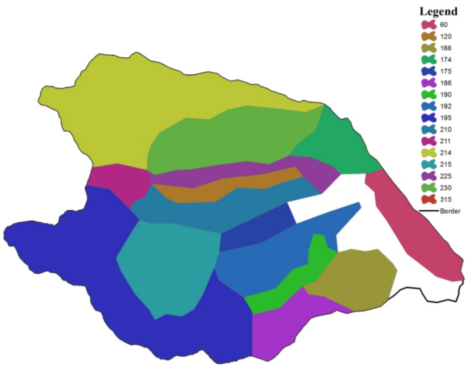

Figure 15. Forage production map in each types of plants (Kg/ha).

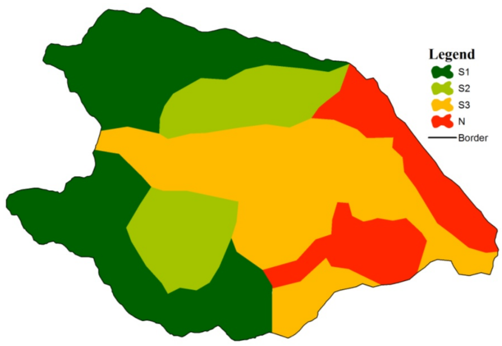

Figure 16. Forage production suitability category map according to allowable use factor in each types of plants.

Suitability model of water resources

In this study, a model for water suitability assessment for grazing of Sarab Sefid rangeland in Iran was elicited. Based on previous studies and field experience, three limiting conditions such as quality, quantity and distance for grazing (FAO, 1991c) were taken into account. A model was proposed for each given criterion.

Suitability model of water quality

The suitability categories of this model were determined using the combination of three criteria such as quality, quantity and distance from water sources. Based on the water resources quality and considering the water quality, there were no limitations in the range area in question, and the whole range area fell within the S_1 suitability category. Results show that Total Hardness (TH) based on standard is good for sheep. Also, this result is similar with Cl, pH (7/8), NO_3 (4/4), EC (235mimhos per cm), TDS (140/8 mg/lit) and other factors except SO_4. For the last factor (SO_4), there is a little limitation for drinking by sheep.

Suitability model of water resources quantity

The results revealed that there were no limitations on the amount of water in the region, so all of them fell into the S_1 suitability category, because of high precipitation of the region, which is between 500 and 700 mm per year (annually) and it have good intensity during the year. In mountains and high elevations, precipitations is mostly as snow and cause save it and its result much spring in the basin which wills suitable water quantity for sheep as Loree local breed. In this basin there is enough water during grazing season for livestock and wildlife and moreover water is needed based on determined grazing capacity.

Distance from water resources suitability

The results of the sub-modal on the distance from water resources suitability revealed that 4960.02 ha of the rangeland area (84.58%) fell into the S_1 suitability category and 904.20 ha (15.42%) of the rangeland of the region in question fell into the S_2 suitability category, in addition, no rangeland area fell into the S_3 and N suitability category (Table 8).

Final water resources suitability

In this basin, 16 types of plant were determined based on field data. The final outcome of the model on water resources is illustrated in Table 9. The region in question had no problems regarding the quantity and quality of the

Table 8. Area and percent of categorize of distance form water resources suitability.

Categorize of suitability	Area (ha)	Area (%)
S_1	4960.02	84.58
S_2	904.20	15.42

Table 9. Categorization of land area into suitability classes based on water resources model in each type of plants in the study area.

Code	Abbreviation	Type sign	Area (ha)	Percent	Water resource suitability
1	*Ga-Fa*	G	416.48	7.10	S_2
2	*As.ad-Er.no*	E1	1094.09	18.66	S_2
3	*As.ad-Er.no*	E2	969.80	16.54	S_2
4	*As.mi-An.gr*	F2	261.27	4.46	S_2
5	*As.mi-An.gr*	F1	205.67	3.51	S_1
6	*As.mi-Co.ja*	B1	206.19	3.52	S_2
7	*As.mi-Co.ja*	B2	491.37	8.38	S_1
8	*As.mi-Co.ja*	B3	533.49	9.10	S_2
9	*As.mi-Me.pe*	D2	122.06	2.08	S_1
10	*As.mi-Me.pe*	D3	146.56	2.50	S_2
11	*As.mi-Me.pe*	D1	140.91	2.40	S_1
12	*As.mi-Rh.co*	C	269.35	4.59	S_2
13	*Ho.bu-As.mi*	A1	361.35	6.16	S_2
14	*Ho.bu-As.mi*	A2	327.60	5.59	S_1
15	*Ho.bu-As.mi*	A4	116.75	1.99	S_1
16	*Ho.bu-As.mi*	A3	201.29	3.43	S_1

water resources; it was only the distance from the resources that mainly determined the suitability of the rangeland with respect to water resources (figure 17).

Rangeland suitability final model for sheep grazing

The final model has been created by integration of three sub models according to FAO (1993) method involving soil sustainable to erosion, forage production and water resources to Loree (Loree is one of the local sheep in Lorestan province) ethic sheep grazing.

Final model according to allowable use factor in each type

Results show that rangelands fall in four categories according to suitability; non suitable 736.28 ha amount 12.56% in N, good suitable 2063.89 ha amount 35.20% in S_1, moderate suitable 1024.85 amount 17.48% in S_2 and low suitable 1892.63 about 32.28% in S_3 (Table 10). This calculation for each type was determined separately (Table 11 and Fig. 18).

As results show, there are not any types in S_1 category and 52.67% about 3088.74 ha, 32.28% about 1892.63 ha and 15.06 about 882.84 ha fall in S_2 (moderate suitable), S_3 (weak suitable) and N (non-suitable) for sheep grazing, respectively.

Discussion

studies to determine livestock grazing suitability, this method has been used. Three sub-models include, soil erosion, water resource and forage production for animal grazing model based on FAO (1991a) method were used based on previous studies (Borzolabadi, 1996; Mohtashamnia, 2001; Parviz, 2001; Ebrahimi, 2004; Arzani et al., 2006;

Figure 17. The final model of water resource suitability.

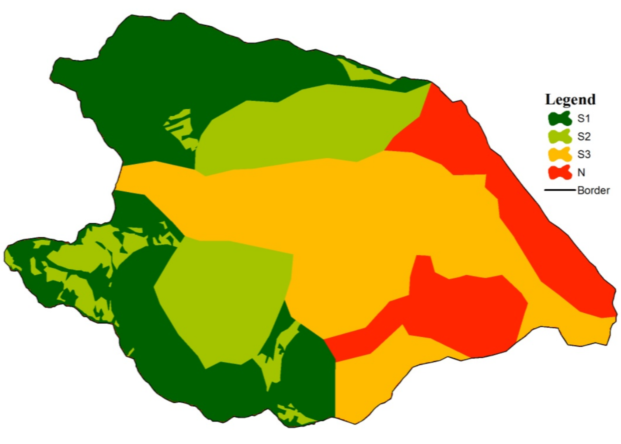

Figure 18. Final model of sheep grazing according to suitability in allowable use factor situation for each type.

Table 10. Categories of final model of sheep grazing model in allowable use factor.

Area (ha)	Area (%)	Suitable categories
2063.89	35.20	S_1
1024.85	17.48	S_2
1892.63	32.28	S_3
736.28	12.56	N

Table 11. Final model of rangeland suitability for sheep grazing according to soil sensitive to erosion, water resources and forage production in allowable use factor situation in each type based on limitation factors.

Code	Abbreviation	Area (ha)	Area (%)	Erosion model	Water model	Forage model	Final model based on limiting factors
1	*Ga-Fa*	416.48	7.10	S_3	S_2	S_3	S_3
2	*As.ad-Er.no*	1094.09	18.66	S_1	S_2	S_1	S_2
3	*As.ad-Er.no*	969.80	16.54	S_1	S_2	S_1	S_2
4	*As.mi-An.gr*	261.27	4.46	N	S_2	N	N
5	*As.mi-An.gr*	205.67	3.51	N	S_1	N	N
6	*As.mi-Co.ja*	206.19	3.52	S_3	S_2	S_3	S_3
7	*As.mi-Co.ja*	491.37	8.38	S_2	S_1	S_2	S_2
8	*As.mi-Co.ja*	533.49	9.10	S_2	S_2	S_2	S_2
9	*As.mi-Me.pe*	122.06	2.08	S_2	S_1	S_3	S_3
10	*As.mi-Me.pe*	146.56	2.50	S_3	S_2	N	N
11	*As.mi-Me.pe*	140.91	2.40	S_3	S_1	S_3	S_3
12	*As.mi-Rh.co*	269.35	4.59	N	S_2	N	N
13	*Ho.bu-As.mi*	361.35	6.16	S_3	S_2	S_3	S_3
14	*Ho.bu-As.mi*	327.60	5.59	S_3	S_1	S_3	S_3
15	*Ho.bu-As.mi*	116.75	1.99	S_3	S_1	S_3	S_3
16	*Ho.bu-As.mi*	201.29	3.43	S_3	S_1	S_3	S_3

Arzani et al., 2014; Amiri, 2009a).

Because of unity, most of the effective factors and comprehensive investigation of this method are used for grazing suitable model and confirmed previous results of researchers. Most of the studies around the world pointed out using RS and GIS for every field research are useful because in spite of a lot of data, it has low cost with high accuracy ability (Javadi et al., 2008; Amiri and Arzani, 2013).

It is worth mentioning that forage production according to allowable use factor for each type is different from forage production for each species, so this calculation will have effects on the final model of rangeland suitability for sheep grazing.

Soil erosion model

Always to determine soil sensitive criteria to erosion in grazing suitability in rangeland, three models of PSIAC, MPSIAC and EPM are used. Some studies (Borzolabadi, 1996; Mohtashamnia, 2001; Parviz, 2001; Ebrahimi, 2004; Amiri, 2010) used sub-model PESIAC.

Amiri compared two models EPM and MPESIAC for efficiency in plant type units after determining erosion suitability classes and sediment (Amiri, 2009a). According to limitation of determining factors in EPM model, the estimation of erosion will be higher than real one and this model can be used only for lands and feature to erosion sensitive. In MPSIAC model, with respect to significant effective factors in erosion such as plant cover, this model is preferred to EPM model in suitable model to grazing. Also, MPSIAC model is adapted and real measurements are given with fact in field in comparison with EPM; so, according to these pluses, MPSIAC model has been used for the study. On the other hand, Daneshvar and Bagherzadeh (2012) in Isfehan-Fridan investigated geology by RS and this study gave results that MPESIAC model is a good technique and viable to investigation of field information due to soil erosion.

Water resource model

Research showed that water resource suitability for cattle grazing needs the assessment of two factors such as slope and number of water source and steep slope and suitable distance from water resource (Guenther et al., 2000a). In studies of Borzolabadi (1996) and Mohtashamnia (2001) to determine animal grazing suitability, they carried out three factors such as forage production, water resource and soil sensibility based on FAO (1991a) method. FAO applied three sub-models such as plant cover, slope and precipitation for determination of the final model of grazing capacity and declared that the results by GIS and RS had acceptable accuracy to management of rangeland that our results proof them. The results of the study showed that the quantity (number of permanent water resources), quality and the distance from the water resources did not impose many limitations on the rangelands suitability for grazing livestock. However, the steep slopes along the livestock path to the water resources resulted in the formation of an 'unsuitability' category for livestock. Valentine (2001) reported the importance of the slope factor in reaching the water resources, and declared that by increasing the slope, the ability to graze decreases and increases the livestock demand to expend lots of energy. The quality and quantity of the water resources in the rangeland did not impose any limitations. The outcome of the research indicates the slope as the reducing factor and sometimes limiting factor in the range suitability. Hence, the slope factor is of considerable importance in determining the suitability of the pasture for grazing. As the slope increases, the water retention time on the ground decreases, the rate of penetration decreases, and the amount of water run-off increases. **Cook1954<empty citation>** explained that on slopes of more than 60%, little forage is grazed. Amiri (2009a) and Gavili et al. (2011) defined the slopes with more than 60% as useless for all kinds of livestock while Holechek et al. (1995) reported slopes of more than 60% and Arzani et al. (2006) defined slopes of more than 60% as useless for livestock grazing. On such steep slopes, wild animals would graze better than livestock. Due to the existence of numerous permanent water resources in the Sarab Sefid rangelands, the water resources factor does not impose much limitation on the suitability. However, the slope factor in reaching the water resources in limited areas of the rangeland was a suitability limiting factor. It must be noted that the results reported by Guenther et al. (2000b) were similar to those observed in the present study.

Conclusion

In this research, recent developments of using GIS as a smart tool in supporting the ranchers and stakeholders for monitoring land suitability for livestock feeding purposes are challenged.
Using the results of this research, it can be concluded that although there are sufficient water resources in terms of quantity, they are not properly distributed and if water resources are developed in the entire region, a large area of the region will be highly suitable for livestock grazing.
As FAO argues, different land units have different qualities for specific uses and current research had shown that the entire area did not have the same suitability for livestock grazing due to the different conditions of fodder production, water resources and soil erosion.

Authors contributions
Authors have contributed equally in preparing and writing the manuscript.

Availability of data and materials
The authors declare that the data supporting the findings of this study are available within the paper.

Conflict of interests
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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